
CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

According to the Environmental Data Report of the United Nations Environmental Programme (UNEP, 1993) there is an increasing awareness that the health of populations are at risk from pollution hazards, but also that the interactions between pollution and health are not well understood. It is estimated that the quantity of hazardous waste generated on a global scale is in the order of $350 - 500 \times 10^6$ tons per annum (UNEP, 1993). According to Fyfe (1998), the population of the world is expected to double in the next fifty years to reach a total of 10 - 12 billion. The greatest increase in population is expected in the 'developing' nations while the majority of these people is expected to live in urban environments (Fyfe, 1998). This will increase the amount and concentrations of waste produced to values in excess of current global estimates. These wastes include domestic, industrial and mining related effluent that must be disposed of or isolated in an environmentally responsible manner. Problems associated with this are evident from the numerous publications and conferences devoted to the subject of environmental contamination.

A need to provide housing and services exists in South Africa. Engineering and environmental geologists are involved with identifying safe sites for housing from a geotechnical and geochemical point of view (Van Rooy, 1996). The land requirement is often greatest in and around cities where redevelopment of previously contaminated industrial or mining land may occur. The British Institute for Civil Engineers (ICE) defines contaminated land as "Land that contains substances which, when present in sufficient quantities or concentrations, are likely to cause harm, directly or indirectly, to man, to the environment, or on occasion to other targets" (Harris & Herbert, 1994). When redevelopment occurs, care should be taken that the new home owners are not exposed to toxic or carcinogenic substances present on the site but not identified during the geotechnical investigation. For this reason, many countries, especially those in the European Union, have instigated soil pollution threshold values for soils (e.g. Interdepartmental

Committee on the Redevelopment of Contaminated Land, 1987). These concentration guidelines can be used to assess whether a site is polluted, before development of an area is allowed.

Mining is one of the activities of man that can have a severe effect on the environment. Nriagu (1996), examined the history of global metal pollution using evidence obtained from peat deposits and arctic ice sections, and showed that metal pollution had started in Roman times where uncontrolled mining and smelting of Pb, Cu, Zn, Hg, Sn and Zn occurred for the first time in an intensive manner. Since then, increased pollution occurred at a rate comparable to the degree of industrialization of the world. By 1990, the global emissions of Cu, Pb and Zn have reached 500, 3500 and 2800 thousand metric tons, respectively (Figure 1.1).

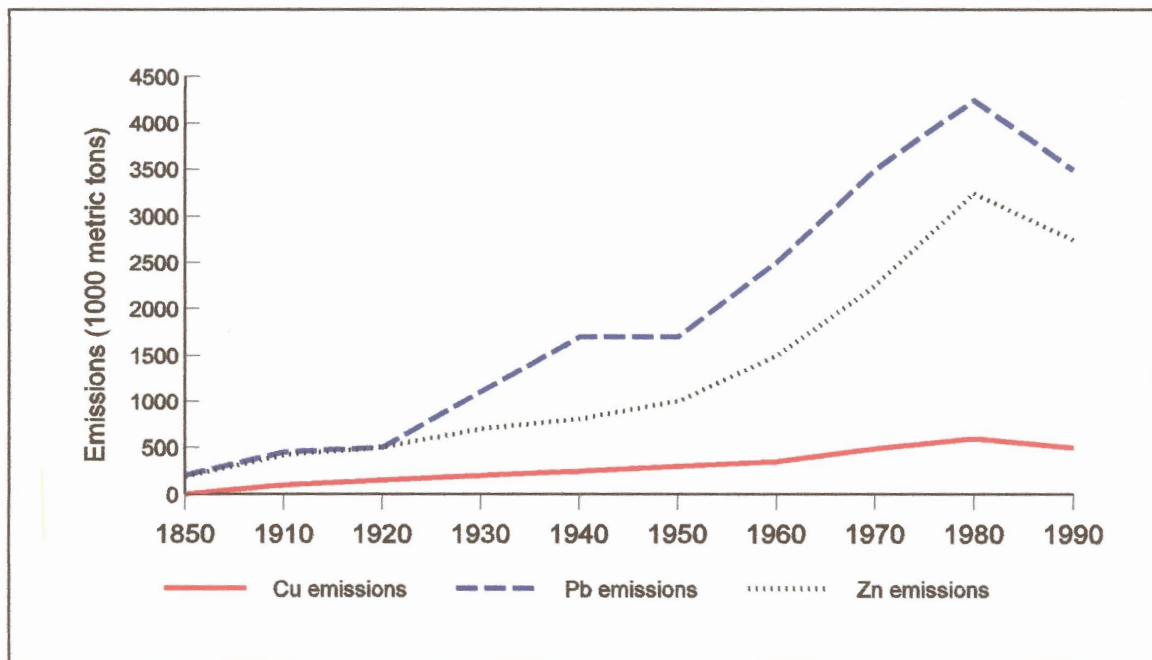


Figure 1.1 Recent historical changes in anthropogenic emissions of Cu, Pb and Zn to the atmosphere, after Nriagu (1996).

In 1998, South Africa produced approximately 533,6 million tons of waste, of which 87,7 per cent was from mining (Lourens, 1999). South Africa has vast economic exploitable mineral reserves with an extensive mining establishment. A literature survey conducted by Rösner, Boer,

Reyneke, Aucamp and Vermaak (1998), shows that gold mining activities in the Gauteng Province are polluting the surrounding environment through an increase in acidity, salinization and heavy metal content of soils, sediments and groundwater bodies. The greatest threat posed by mining in the Gauteng Province is the uncontrolled release of acid mine drainage (AMD). According to Gray (1997), acid mine drainage affects the geo-environment and especially aquatic systems in various ways. Soil systems are affected by increased acidity, with a corresponding lowering of soil pH. The natural soil pH buffering system of soils is depleted and salinization of soils increases. An increase in soluble metals occurs with a corresponding increase in metal mobility.

Mining activities are responsible for an increase in certain trace elements in soils, sediments and groundwater reserves that occur within the influence sphere of the mine. Although trace elements such as I, Co, Mo and others are essential to human health, these micro-nutrients can be toxic when present in excessive concentrations. Non essential exogenous metals, for example Hg, are toxic at virtually all concentrations (Crouse, Pories, Bray & Mauger, 1983). It remains difficult to make an objective assessment of the effects of metal pollution on human health and to recommend remediation goals at contaminated sites (Fyfe, 1998). The reason for this is that toxicological predictions of how end receptor groups (e.g. humans, animals, plants or aquatic ecosystems) will be affected by contaminated land, are difficult due to the complexity of physical and chemical interactions that dictate the movement of toxins and carcinogens through the food chain to the end receptor group. The real, and often fatal, danger of trace elements on human health has however been described by case histories e.g. Hg poisoning of the fishing village of Minamata in Japan (Ellis, 1989).

Hatheway (1998) states that the engineering geological profession occupies a niche market in the sense that it can generate predictable site specific data that describes the geology, geohydrology and geotechnical nature of a site. The engineering geologist is therefore the natural candidate of professional field-orientated persons to become more involved in, or conduct, site specific risk assessment investigations where soil and groundwater contamination is involved. This view is

supported by Van Rooy (1996), who states that engineering geologists in South Africa should assist in evaluating the effects of waste disposal, and any other polluting practice, and to monitor pollution levels in soils, air and groundwater.

It is against this background that a research project was initiated with the aim to investigate the degree of soil pollution occurring at an abandoned gold mine in the North West Province of South Africa.

1.2 RESEARCH AREA

The research was conducted at the abandoned Machavie gold mine, west of Potchefstroom. Gold from the Black Reef Formation of the Transvaal Supergroup was mined, while the mine was operational until the 1940's. During the life of the mine, five tailings dams were produced. After closure, the tailings were reworked by wind and water erosion to the extent that large areas downslope from the tailings dams are now covered with a layer of tailings, generally less than 0,20 m thick, but up to 1,50 m thick in some places.

1.3 OBJECTIVES OF RESEARCH AND LAYOUT OF DISSERTATION

1.3.1 Objectives of the research

The primary aim of the research, which investigates the degree of soil pollution occurring at an abandoned gold mine, is to contribute towards the understanding of how trace element pollutants behave in soils. To achieve this aim, it was necessary to satisfy the following secondary aims:

- (i) the distribution of total element concentrations of As, Co, Cr, Cu, Ni, Pb, and Zn in the tailings as well as in the soils affected by reworked gold mine tailings, and
- (ii) the mobility of As, Co, Cr, Cu, Ni, Pb and Zn in the tailings and the affected soils as well as the influences of selected soil properties on the mobility of the trace elements.

Machavie gold mine presents an ideal research locality as the mine is situated far from any industrial or urban activities that could add to the contamination load of the area. Pollution occurring in the study area is therefore only attributed to the abandoned mine.

1.3.2 Layout of dissertation

Chapter 2 is a literature survey of pollution by trace elements and of acid mine drainage from gold mine tailings dams. In Chapter 3 a general description of the geomorphology, climate, vegetation cover, geology and pedology of the study area is presented. Chapter 4 describes the site specific geology, pedology and geotechnical properties of the study area in detail. In Chapter 5 the total trace element concentrations in the gold mine tailings and the affected soils are investigated while in Chapter 6, the NH_4NO_3 extractable trace element concentrations in the tailings and affected soils are investigated. Discussion of the results and conclusions are contained in Chapter 7.