

The effect of selected metals on the central metabolic pathways in biology: A review

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Abstract

In South Africa, mining and industrial activity may cause toxic substances including metals to pollute surface and groundwater resources. Furthermore, there is an increased public awareness regarding pesticides, fertilisers, agricultural products and metals that might endanger our indigenous fish populations and aquatic ecosystems. This is mainly because humans use these natural resources as food and water supplies and are therefore also exposed to products polluting these resources. Of particular concern is the exposure of bio-organisms to metal pollution, as it is known that metals act as mutagenic/genotoxic compounds, interfere with xenobiotic metabolic pathways, and may also affect glycolysis, the Krebs cycle, oxidative phosphorylation, protein amino acid metabolism as well as carbohydrate and lipid metabolism. Therefore, in this review, we discuss the two phases of the central metabolic pathways, as well as how metals affect the different enzymes and metabolic processes in these pathways. The focus is particularly on metals most frequently found in groundwater in South Africa and include cadmium (Cd), copper (Cu), aluminium (Al), zinc (Zn), lead (Pb), arsenic (As), iron (Fe), manganese (Mn) and chromium (Cr). We conclude that metals in the environment and polluting our groundwater may have a major impact on human and animal life and that ultimately exposure to these products may be the cause of many diseases due to their effect on the central metabolic pathways.

Keywords: metals, metabolic pathways, groundwater, pollution

Introduction

There has been a general global increase in industrial activity over the past few decades, resulting in a significant application of metals in the various processes, in turn causing a great escalation of metals in the environment. Although some metals are essential to human health and may be found naturally at low concentrations in the body, these may act as toxicants when humans or animals are exposed to high concentrations, which cause wide-ranging toxicological effects in these organisms as the metals tend to accumulate in several tissues. In South Africa, mining and industrial activity may cause toxic substances including metals to pollute surface and groundwater resources. Many South Africans still do not have access to clean potable water and rely on streams, rivers, marshes and other types of wetlands for their daily water supply as one of the most limiting natural resources in South Africa is water (DWAF, 1986).

Approximately 20% (7 million people) of the South African population does not have access to an adequate supply of potable water, and half of the population (21 million) lacks basic sanitation (WRCA, 2003). Underground rocks and soils may contain arsenic, cadmium, chromium, lead, and selenium but these metals are usually not found at levels of concern. However, activities such as mining and construction can release large amounts of metals into nearby groundwater sources, which at high levels pose a health risk according to a report published by the United States Environmental Protection Agency (2006).

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Currently, it is difficult to find any source of water that does not carry fingerprints of human activity (United Nations Environment Programme, 2004). Acid rain and increasing numbers of synthetic organic compounds and metabolised pharmaceuticals are finding their way into surface waters in unlikely places (Huang and Xia, 2001), and identifying them by untargeted chemical analysis is prohibitively expensive. Even after chemical identification the possibility of synergism/additively remains.

Public concerns regarding pesticide, fertiliser, agricultural products and metals in recent years have escalated, particularly following major fish kills in the Mpumalanga and Eastern Cape rivers (Heath and Claassen, 1999). The impact of pollutants on specifically aquatic ecosystems is either acute (due to exposure to immediate lethal dose) or insidious/chronic (due to gradual accumulation of lethal concentrations in body tissues) Heath and Claassen (1999). Unfortunately, humans using these fish resources may therefore also be exposed to 'lethal' concentrations of these pollutants, because it is well-known that fish accumulate metals in tissue and organs when exposed to metal polluted water.

According to the WRC, currently fish are considered to be an extremely reliable component of an aquatic monitoring system, because they integrate the effect of detrimental environmental changes as consumers, which are relatively high in the aquatic food chain. In a South African study it was found that metals accumulate in different fish tissues, e.g. As, Cd, Ni, Co, Mg, Fe, Cu, Pb, were found in the liver; Zn, Al, and Mn were found in the gills; Al and Cr were found in the testes, while Cd and Co were found in the ovaries. The above-mentioned metals are frequently termed heavy metals. However, over the past few