Health Aspects of Nitrate in Drinking-water and Possible Means of Denitrification (Literature Review)

Abstract

Drinking-water containing nitrate in excess of 10 mg/l (as N) can cause a (sometimes fatal) blood disorder called methemoglobinemia in infants under the age of six months, especially under three months. Nitrate per se is not toxic, but is the precursor to nitrite which is produced through microbial reduction of nitrate in the intestine or in food preparations, and which causes methemoglobinemia. Children exposed to excessive nitrate in drinking-water can have slightly retarded bodily growth and slower reflexes. Cancer experts warn against prolonged use of high nitrate water by humans since it seems possible that under certain conditions, for example bladder infections, nitrate can be instrumental in the formation of carcinogenic nitrosamines within the human body. Vitamin C is considered to be an effective preventive agent or antidote against the health effects of nitrate or nitrite. Public water supplies should not, therefore, contain more than 10 mg/l nitrate (as N).

Of all the known treatment processes, ion exchange seems to be the most effective and economical for the removal of nitrate from drinking-water in South and South West Africa, where in the case of the latter excessive concentrations of nitrate often occur in groundwater. Solar distillation appears to be suitable for small-scale production of potable water.

Introduction

Groundwaters in certain parts of South Africa and South West Africa (SWA) contain high levels of nitrate and are considered to be unsuitable for human consumption for this reason alone.

Infants are susceptible to nitrate poisoning, which can be fatal if untreated. Since 1945, approximately 2 000 cases of infant methemoglobinemia associated with high nitrate concentrations in drinking-water have been reported in world literature (ISCWQT, 1974). Although some infants were affected by water containing less than 10 mg/l nitrate (as N*), the majority were taken ill after drinking water containing more than 20 mg/l (Shuval and Gruener, 1972). About 10 per cent of these cases were fatal (ISCWQT, 1974). It is estimated that the cases reported represent only 10 per cent of those observed (Winton et al., 1971). Despite this, these figures indicate that the disease is relatively rare.

Consumption of nitrate has no apparent short-term effects on adults. Tredoux (1975) noted that, in some parts of SWA, adults drink water with concentrations of 200 mg/l nitrate and higher, with no apparent ill effects.

This paper deals with the known effects of nitrate on human health, and the need and methods for denitrification of groundwater.

Effects of Nitrate in Drinking-water on Human Health

Methemoglobinemia

The consumption of inorganic nitrates and nitrites by infants, for example in the form of dried milk mixed with water containing nitrate, during the first six months of life (particularly the first three months) may cause methemoglobinemia, resulting in cyanosis, which can lead to suffocation (ISCWQT, 1974).

Physiology

Methemoglobinemia is a condition resulting from the conversion of hemoglobin (Hb), the oxygen carrier of mammalian blood, to methemoglobin (Met Hb), which is unable to transport oxygen (White et al., 1968). The Hb molecule consists of four subunits, each of which is made up of a peptide chain (globin) and a heme group (with a ferrous, Fe^{2+}, ion at the center). Each subunit can reversibly bind and transport an oxygen molecule:

\[
\text{Hb} + \text{O}_2 \rightarrow \text{HbO}_2
\]

Several chemicals such as nitrites, perchlorates, sulphonamides and others (Shuval and Gruener, 1977) can cause conversion of Hb to Met Hb, in which the iron is in the ferric (Fe^{3+}) state, rendering the molecule unable to bind oxygen. The exact mechanism of this conversion is still unknown. Schematically:

\[
\text{Hb} + \text{NO}_2^- \rightarrow \text{Met Hb}
\]

\[
\text{Met Hb} + \text{O}_2 \rightarrow \text{HbO}_2
\]

Nitrate, unlike nitrite, does not convert hemoglobin but can, under certain conditions, be reduced to nitrite by intestinal microflora, with subsequent formation of methemoglobin. Nitrate per se is non-toxic and is readily absorbed and excreted by the human body (Klotter, 1969; ISCWQT, 1974). Nitrate is thus only indirectly toxic in that it is the precursor to nitrite.