Quality of drinking water in industrially contaminated area in relation to potential risk to humans and animals

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Abstract

Drinking water is polluted by various human activities in many different ways. Some pollutants cause immediate problems but some can be seen only after longer period. Industrial plants release many metals and toxic chemicals to the atmosphere which eventually end in the soil from which they can be leached to ground and surface water, particularly in regions exposed to acidic rains. Buildup of chemicals in organisms and food chain may impair different processes in the body and contribute to cancer.

We carried out chemical and bacterial examination of potable water in 20 wells, 3.5 to 14 m deep, in a village with approximately 500 inhabitants, located in industrially contaminated area affected in the past by intensive mining activities and processing of Fe and Cu ores. The village was not connected to mass drinking water supply.

Chemical examination included parameters indicating pollution of water with animal or human wastes (pH, ammonium, nitrates, chlorides, COD_{Mn}) and some metals (Sb, As, Cr, Cd, Ni, Pb, Hg). Bacteriological examination of water focused on plate counts of total coliforms and *E. coli*.

The results showed no indication of excessive acidification in the area. Out of 20 wells only in 6 none of the chemical parameters was exceeded. The highest acceptable limit for As was exceeded in 2 wells, for As and Ni each in one well, and Fe was within the recommended range in 5 wells.

Bacteriological examination showed that none of the wells was completely safe at all samplings despite the fact that occasionally we detected individual effort to make the water safer by chlorination (presence of free chlorine).

The results indicated contamination of water with human or animal wastes (extensive animal production) and failure to comply with the rules for protection of water sources.

Introduction

Quality of drinking water is a pressing problem in many areas of the world. Various human activities pollute sources of drinking water in many different ways. Some pollutants cause immediate problems but some can be seen only after a longer period of. Contamination of atmosphere with nitrogen and sulphur oxides results in acidic rains and leaching of some metals from soil to water. Animal production and human wastes can contaminate water with pathogenic bacteria, viruses and protozoa and some macronutrients. In advanced countries the sources of drinking water are protected and those intended for mass consumption are frequently checked and, if necessary, treated (Ondrašovič et al., 1997). However, there are still locations where people depend on individual sources of water the quality of which may be questionable and is not protected by regular disinfection.

The aim of the present study was to investigate the quality/pollution of individual water sources in an industrially polluted area with some extensive animal production and determine the safety of water used for drinking and preparation of food.

Material and methods

Our investigations were carried out in the period of one year in a village (about 500 inhabitants) with extensive animal production, located in environmentally polluted region affected negatively by mining activities and processing of complex Fe and Cu ores. We examined water in 20 wells, 3.5 to 14 m deep, of varying capacity.

Chemical investigations included determination of pH, ammonium (NH_4^+), nitrates (NO_3^-), chlorides (Cl^-), and chemical oxygen demand (COD_{Mn}) and some metals. pH was determined by a pH electrode (ORION Research), ammonium by spectrophotometric method with Nessler reagent, nitrates by ion selective electrode (ORION Research), chlorides by argentometric titration and chemical oxygen demand by boiling with potassium permanganate for 10 min. AAS method was used to determine Sb, As, Cr, Cd, Ni, Pb and Hg.

Microbiological examination focused on plate counts of total coliforms and *E.coli* on Endo agar at 37° and 43°C with confirmation by lactose fermentation.

Results and discussion

The results of all examinations were compared with the respective national standard (Statutory order of SR No. 354/2006 of the Civil Code) which sets maximum contaminant levels (MCL) for water intended for human consumption.

The determination of selected metals showed that the respective MCL were exceeded in three wells. Higher concentration of nickel (27 $\mu g.l^{-1}$) was detected in Well 6, of antimony in Well 16 (12 $\mu g.l^{-1}$) and of both antimony and arsenic in well 18 (8.6 and 19.0 $\mu g.l^{-1}$, resp.). Metals are inorganic substances that occur naturally in geological formations. Some are essential for life and are naturally available in our food and water. In addition to them, drinking water may contain metals which cause chronic and acute poisoning. Contamination of water resources by poisonous metals occurs largely through human activity. These activities include industrial processes, such as mining and processing of metal ores, agricultural activities, discarding of wastes in landfills (ALLOWAY, AYRES, 1993).

Arsenic in drinking water causes bladder, lung and skin cancer, and may cause kidney and liver cancer. Arsenic harms the central and peripheral nervous systems as well as heart and blood vessels, and causes serious skin problems. It also may cause birth defects and reproductive problems (NRDC, 2001).

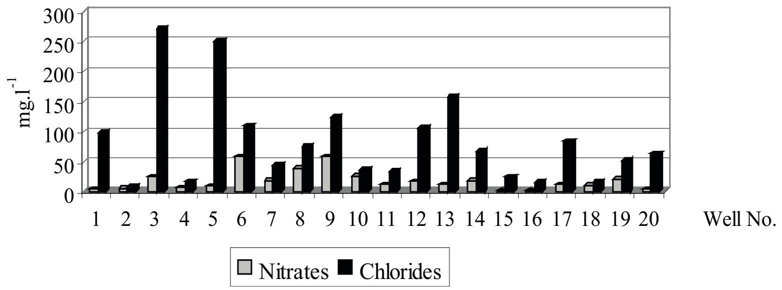
We have become interested in the concentration of antimony in drinking water since 1998, on the basis of WHO recommendation, particularly with respect to its carcinogenic effects. Continuous exposure to antimony may result in lung diseases, heart problems, diarrhoea, vomiting and stomach ulcers (ATSDR, 1992).

Nickel concentrations in groundwater depend on the soil use, pH, and depth of sampling. The average concentration in groundwater in the Netherlands ranges from 7.9 $\mu g.l^{-1}$ (urban areas) to 16.6 $\mu g.l^{-1}$ (rural areas). Acid rain increases the mobility of nickel in the soil and thus might increase nickel concentration in groundwater (ICPS, 1991). In groundwater with a pH below 6.2, Ni concentrations up to 980 $\mu g.l^{-1}$ have been measured (RIVM, 1994). Allergic contact dermatitis is the most prevalent effect of nickel in the general population. Soluble Ni exposure increased risk of cancer.

The remaining chemical examination included pH as indicator of decomposition processes or environmental pollution and potential indicators of contamination of water with animal and human wastes or (ammonium, nitrates, chlorides, COD_{Mn}).

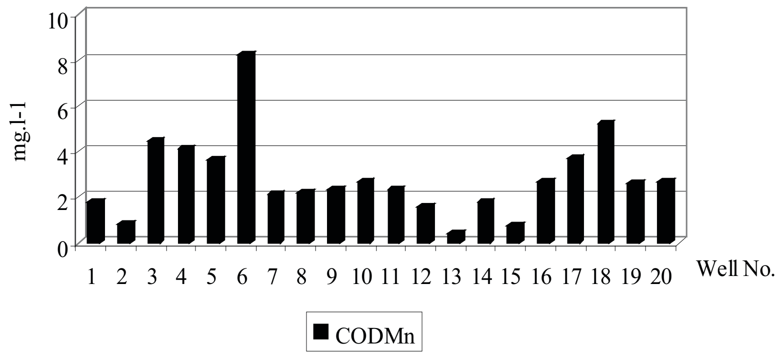
The pH value in the examined wells ranged from 6.03 to 7.68 so there was no indication of excessive acidification in the area. Of all remaining chemical parameters determined in water, the acceptable ammonia level (0.5 mg.l^{-1}) was exceeded only in one well at one sampling, nitrate level (50 mg.l^{-1}) in three wells and chloride level (100 mg.l^{-1}) in 10 wells at least at one sampling (Table 1).

Table 1. Mean concentration of nitrites and chlorides in examined wells



The COD_{Mn} acceptable limit (3 mg.l^{-1}) was exceeded in 6 wells. This parameter which represents the sum of chemically oxidizable organic substances is of hygiene importance especially when water is disinfected with active chlorine and carcinogenic trihalometanes can develop. We also checked the wells for traces of active chlorine and found out that on occasion free chlorine was present probably as a result of an effort to eliminate the risk of transfer of pathogens.

Table 2. Mean values of COD_{Mn}



Out of 20 wells only in 7 none of the examined parameters were exceeded but one of these 7 wells showed increased concentration of antimony.

On the basis of chemical examination Well No. 6 appeared to be most contaminated (levels of 5 chemical parameters were exceeded).Determination of plate counts of selected micro-organisms revealed that total coliforms were present in all wells (in 10 ml volume) and in every one of them *E.coli* were detected at least at one sampling. This indicates that none of the wells could be considered safe from the bacteriological point of view.

The results obtained indicate general contamination of soil and groundwater in the respective area. Although the number of families keeping some farm animals has decreased recently, pigs and cattle were still kept and their manure was applied to gardens and adjoining fields.

Moreover, the rules for protection of individual sources of drinking water (STN 75 5111, 1993) have not been observed which most likely contributed to the unfavourable situation.

Acknowledgement
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STN 75 5115 Water management. Well for individual water supply, 1993

STATUTORY ORDER OF SR No. 354/2006 of the Civil Code on requirements on drinking water and quality control of drinking water.