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GROUND WATER POLLUTION DUE TO INDUSTRIAL EFFLUENTS IN LUDHIANA, INDIA

Y.P. KAKAR and N.C. BHATNAGAR
Central Ground Water Board, Chandigarh, India.

ABSTRACT

Rapid industrialisation of Ludhiana area and gross neglect of pollution abatement measures by industrial units has resulted in ground water pollution at several places due to toxic constituents present in the industrial effluents. Monitoring of sources of contamination has revealed that point, line and diffuse pollution is taking place. Untreated effluents from industrial units connected with manufacture of bicycles and ancillary parts, electroplating, steel and foundaries etc. are discharged near the factories. These effluents percolate into soil near the source or travel through unlined channels to shallow pits where seepage into soil and vadose zone takes place which eventually contaminates ground water.

The area under investigation is underlain by Indo-Gangetic alluvium of considerable thickness of Quarternary age and comprises unconsolidated sand, silt, clay, kankar and their intermixture in varying proportions. Storage capacity for potential pollutants may exist in the soil and vadose zone and some of pollutants may be attentuated by processes like dilution, filteration, sorption, precipitation, redox reactions. However, attentuation capacity is not unlimited as evidenced by analytical results. Copper and zinc have reached the saturated zone which shows that soil and vadose zone in respect of these elements have become saturated and further pollution is possible in future.

Present study reveals that very high concentrations of hexavalent chromium and cyanide have been found in ground water at shallow depths. High concentrations of Cr^{+6} which are linked with ulcers, dermatitis and effect nasal mucosa, larnyx and may cause lung carcinoma, have been observed to the extent of over 12 mg/l in ground water. Cyanide, which can be lethal due to inhibition of cellar respiration, has been recorded between 1.5 to 2.0 mg/l at several places. Such high concentrations of toxic constituents indicate necessity for immediate

pollution abatement measures to prevent further damage to ground water resources.

INTRODUCTION

Due to rapid industrialisation of Ludhiana area and very little attention paid to treatment of industrial effluents, serious ground water pollution has taken place. As a result of rapid industrial growth, demand for water and consequently generation of waste water has increased many folds. Industrial units in their endeavour to cut down costs and increase profits have neglected pollution abatement measures. It has resulted in induction of toxic constituents present in effluents to ground water reservoirs by direct infilteration or precipitation recharge.

Effluents from industrial units are commonly discharged in the rear or front of factories from where these travel in unlined channels to low lying depressions. The soil cover is mostly less than two meters in areas where pollution has taken place and underlain by thick beds of sand with high permeability with the result that seepage occurs resulting in degradation of ground water quality.

DISCRIPTION OF THE AREA AND SUB-SURFACE GEOLOGY

The area under study covers approximately 188 square km including area around Ludhiana City (Fig.1) with a projected population of 0.694 million for 1981. Ludhiana is the major industrial town of Punjab State and there has been many fold increase in setting of industrial units connected with manufacture of transport equipment (mostly bicycles), machinery and machine tools, basic alloy industries, metal products, founderies, electrical machinery, hoisery etc.

The area is underlain by Indo-Gangetic alluvium of Quaternary age. It is comprised of unconsolidated sands, pebbles, clay, kankar and their admixtures in varying proportions. The top soil varies in thickness from 1.82 to 3.05 metres. Below the top soil, beds of sand, clay and kankar have been observed. Ground water occurs occupying the pore spaces of the unconsolidated alluvial deposits in the zone of saturation. There are several clay bands varying in thickness mostly from 1.50 to 6.10 metres. The depth to water in the area ranges from 2.86 to 12.42 metres below the land surface.

EXPERIMENTAL

Samples were collected in polyethylene bottles, treated at the time of collection and analysed according to standard procedures outlined in literature (Standard Methods 1975, Brown et.al.1970, Handa 1976). Trace elements were determined by Atomic Absorption Spectrophotometer and cyanide by Specific ion electrode. Cr^{+6} has been determined by spectrophotometric method. Eighteen samples (15 ground water and 3 industrial effluents) were collected in 1977 and 65 samples (54 ground water and 11 industrial effluents) were collected in 1978 from the areaa under study (Fig. 2).

PROCESS OF POLLUTION

The process of pollution of ground water is controlled by several factors like nature and concentration of effluents, soil and sub-soil characteristics, time factor, porosity, permeability, hydraulic gradient, storage capacity of aquifers etc. The following considerations are significant during pollution of ground water from effluents :

(i) Reactions in the top soil and vadose zone : Some of processes like biological degradation, filteration, sorption, oxidation and reduction, precipation, buffering etc. take place in the top soil and vadose zone. These reactions are affected by microstratigraphy, pore velocities, hydrodynamic dispersion and hydrochemical factors. As a result of these reactions several trace elements may be removed or added depending on the characteristics of effluents and nature of strata through which infilteration takes place.

(ii) Effect of soil moisture deficiency: Storage capacity and moisture characteristics of vadose zone are important factors in controlling percolation of polluted waters. In areas where moisture deficiency is there due to lack of recharge, considerable amount of pollutant may remain in the soil and vadose zone.

(iii) Laminar flow of pollutants : Unlike non-laminar and at times turbulent flow of polluted surface waters, the flow of ground water through strata is laminar. According to Walker (1973), recharge water with pollutants appears to maintain a bulb like mass as it moves downward to the lower part of surficial aquifers, then horizontally through the aquifer material to some nearby discharge point. McKee and Wolf (1963) have observed that a small ribbon of polluted water injected into ground water flow will move in a well defined streamline with a minimum of lateral or vertical diffussion and in many cases vertical diffusion is inhibited by horizontal clay lenses or extensive aquicludes. These findings indicate that dilution of polluted water by native ground water during movement of pollutants from recharge to discharge areas can take place only to a limited extent.

(iv) Specific gravity,viscosity effects: The specific gravity and viscosity of effluents are usually different from natural ground water and difference in these characteristics may play an important part to prevent diffusion of effluents with ground water.

(v) Slow movement of effluents : The flow of ground water and polluting constituents that it may contain is very slow as compared with flow on land surface. Underground flow may be only a few feet per year through sandstone and other finer grain deposits and a few feet per day through sand and gravel or creviced limestone. A s a result of slow movement of effluents, it may take considerable time for polluting materials to move away from the source of pollution and degradation in water quality may remain undetected. However, when pollution effects are evidenced, rectification cannot be achieved by stopping the pollution from source as process of purification by leaching takes more time than initial period of pollution.

DISCUSSION

(i) General chemical quality : The ground water in the area has low to medium mineralisation with specific conductance range of 373 to 1717 micromhos/cm. Concentrations of major constituents in different ranges of specific conductance indicate that during low mineralisation water is predominatly of mixed Ca-Mg, HCO_3 type. With increase of mineralisation, there is increase of sodium, chloride and sulphate ions. pH of ground water at most of the places is between 7 to 8. In case of samples polluted by acidic effluents, pH was observed to be between 6 to 7. Distribution of major ions is in conformity with general characteristics of ground water of areas with alluvial formations.

(ii) Hexavalent chromium : Chromium occurs in aqueous systems as both trivalent (Cr^{+3}) and hexavalent (Cr^{+6}) forms and Cr^{+3} forms highly insoluble hydroxide. Cr^{+6} is a common component of polluted waters from industrial pollution and metal plating operations. The major sources of waste chromium are chromic acid bath and renise water processes. The principal toxic effects of chromium on human body are exerted on skin, nasal mucous membrane, larnyx, lung carcinoma, lesions of kidneys (Browning 1961). There are eruptions and ulceration of skin, irritation of the conjuctive and respiratory passages and continuous exposure to chromates may cause cancer of lungs (Dubois & Geiling 1959). Due to cumulative nature of chromium in human body, it could be found in blood and urine of persons exposed to high levels of chromium years after cessation of exposure.

In Ludhiana area, Cr^{+6} was detected in 30 samples out of 54 in 1978 and 8 samples out of 15 in 1977. The number of samples in which Cr^{+6} levels exceeded 0.05 mg/l(limit prescribed by U.S.Public Health) was

6 in 1978 and 7 in 1977. Hexavalent chromium concentrations as high as 12.90, 12.10, 11.00, 3.50 mg/l have been observed in ground water near bicycle factories. These factories discharge among other effluents chromate wastes without proper treatment. As a result of seepage, these effluents move to water table which is 8 to 10 metres in the areas where these factories are located.

High concentrations of Cr^{+6} in ground water are not confined to shallow levels only. While in most of the cases ground water with high Cr^{+6} concentration has been tapped from depth levels ranging from 16.77 to 27.44 metres, Cr^{+6} level of 12.10 mg/l has been found in ground water in a well at the depth of 60.97 metres. It shows that ground water at deeper levels has also been adversly affected by effluents.

For wells in which Cr^{+6} has been detected but level is below 0.95 mg/l, there are chances for increase of concentration in future. It is probable that effluents have not reached these points in full intensity or complex formation, sorption has taken place during traverse period. Percolation of acidic effluents can cause migration of chromium and thereby increase its levels in ground water.

There is increase in Cr^{+6} levels in ground water at several places with passege of time. Cr^{+6} concentrations have increased from 3.75 to 11.00 and from 6.80 to 12.10 mg/l in two wells in about one year. In other cases near bicycle factories where no chromium was earlier detected, Cr^{+6} has been observed in ground water. Only in one case where Cr^{+6} was present earlier has not been detected again, which may be due to complex formation, sorption etc.

(iii) Cyanide : Electroplating wastes are the major source of cyanide in industrial effluents. Cyanide concentrations arise from cyanide vats, dips, drip from the articles and rinse operations and contain high levels of cyanide. High toxicity of cyanide to human body is well known. Cyanide reacts with Fe^{+3} of cytochrome oxidase to form Cytochrome-oxidase-CN complex and with that of methemoglobin to form cyanomethemoglobin. Cytochrome oxidase is particularly reactive with cyanide and when the two substances combine, cellular respiration is inhibited. The minimum lethal oral dose is between 0.7 to 3.5 mgr.per kilo body weight (Polson & Tattersal 1969).

In the area under study, cyanide has been detected in 33 ground water samples out of 54. At 10 places, cyanide levels are more than 0.05 mg/l, (the limit prescribed by W.H.O. 1971). At five sampling points, cyanide levels are between 0.04 to 0.05 mg/l and are quite close to maximum permissible limit. Cyanide concentration ranging between 0.05 to 0.98 mg/l have been observed in ground water from industrial area where industries connected with manufacture of ancilliaries are concentrated and electroplating of different metals is carried out. Cyanide levels in 5 samples of ground water collected in 1977 were observed between 1.60 to 2.00 mg/l near discharge points of bicycle industry effluents.

High levels of cyanide to the extent of 63 and 26 mg/l have been observed in the industrial effluents of bicycle industries. As pH of industrial effluents goes on changing depending on the shop from which discharge is made, it is probable that low cyanide values of other effluents may be due to decomposition of cyanide at intermediate stage by acidity of some of effluents. Similarly for ground water, decrease in cyanide levels as compared with previous concentrations may be due to decomposition of cyanide, complex formation etc.

(iv) Other trace elements: Apart from chromium and cyanide, other trace elements determined in ground water at some places and effluents are: Cu, Zn, Co , Mo, Cd, Tl, Sr, Li, Cs and Ag. Concentrations of these trace elements are mostly within limits where standards for domestic supplies have been prescribed. As the area has been affected by pollution, these values can serve background concentrations to monitor pollution of these constituents for subsequent studies.

Copper and zinc ions present in effluents are held by soil during percolation. Presence of these ions at some places in ground water indicates that soil zone has become saturated in respect of these ions and further increase in concentrations of these constituents may take place in future.

POTENTIAL RISK OF POLLUTION

High concentrations of hexavalent chromium and cyanide in ground water as discussed are mostly near areas where bicycle factories and industries engaged in manufacture of ancilliary parts undergoing electroplating are located. At some places a few kilometers away from factories, these constituents have been detected which shows that there is potential danger of pollution of ground water in areas away from factories.

Studies carried out to find the direction of ground water movement reveal that in the highly polluted ground water areas, the general flow direction is towards north-west i.e. towards pumping depression. It indicates that polluted ground water is moving towards the main part of the city where the density of population is maximum. There is thus danger of ground water reservoir being polluted by toxic constituents present in industrial effluents unless ameliorative measures are taken.

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FIG. 1

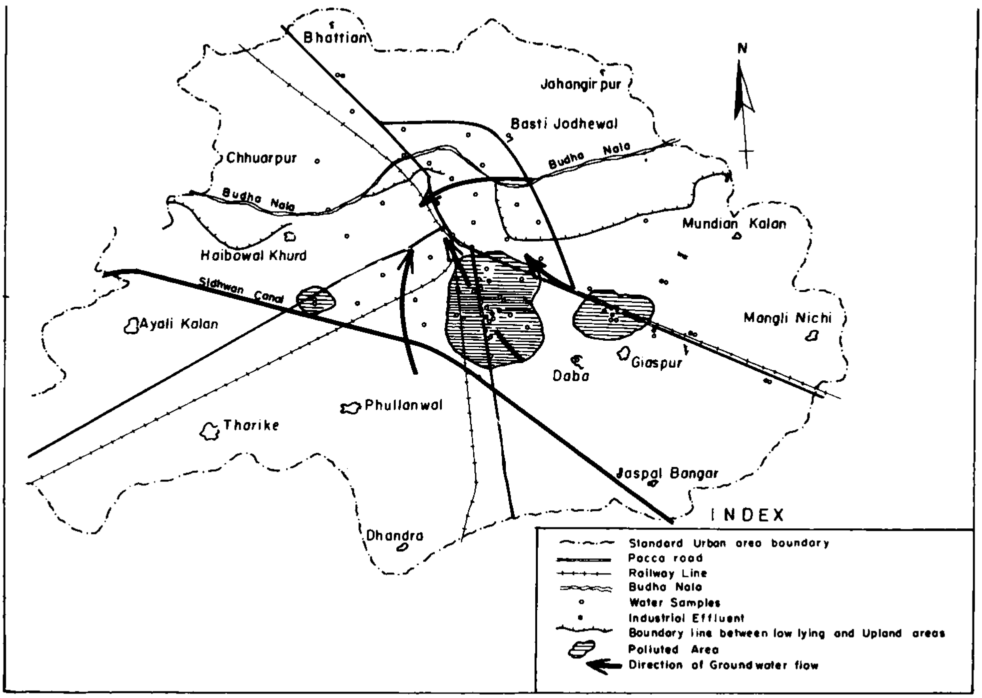
Bhattian
Jahangir pur
Basti Jodhewal
Budha Nala
Chhuarpur
Budha Nala
Mundian Kalan
Haibowal Khurd
Sidhwan Canal
Mangli Nichi
Ayali Kalan
Daba
Giaspur
Phullanwal
Thorike
Jaspal Bangar
Dhandra
N
INDEX
Standard Urban area boundary
Pacca road
Railway Line
Budha Nala
Water Samples
Industrial Effluent
Boundary line between low lying and Upland areas
Polluted Area
Direction of Groundwater flow

FIG 2.