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Evaluation of Heavy Metals Contamination due to Overburden Leachate in Groundwater of Coal Mining Area

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Abstract: Groundwater contamination with heavy metals released from mining activities is a worldwide environmental problem. The leachate generated from mine waste Overburden dumps may have the potential to pollute the surrounding water resources. This study conducted to evaluate the heavy metal concentrations in the groundwater of coal mining area. Groundwater samples analyzed based on their heavy metal concentrations such as Co, Cu, Ni, Fe, Mn, Zn and Pb. Subsequently, statistical methods employed to identify the controlling factors affecting the heavy metal constituents of the groundwater. Finally, the results were compared with the Drinking Water Quality Standard of the World Health Organization (WHO), India Standard for Drinking Water Specification (IS: 10500) and United States Environmental Protection Act (USEPA). The results of the present study indicate that, the concentration of Mn and Fe showed their presence in groundwater samples above the desirable limit recommended for the drinking water Quality Standards. Concentrations of other metals in most cases e found well within the threshold values. Concentration of Mn in the groundwater samples varied from 0.669 to 0.812 mg/L whereas concentration of Fe varied from 0.606 to 0.792 mg/L.

Key words: Coalmine waste, groundwater, heavy metals, leachate, overburden

INTRODUCTION

Mining waste is the high-volume material that originates from the processes of excavation, dressing and further physical and chemical processing of wide range of metalliferous and non-metalliferous minerals by opencast and deep shaft methods. It comprises overburden, run-of-mine rock as well as discard, slurry and tailings from the preparation/beneficiation or extraction plants assessment of heavy metals contamination in soils using data on the total content of the individual heavy metals[1]. The most significant impact of a mining project is its effects on water quality and availability of water resources within the study area. Key questions are whether surface and ground water supplies will remain fit for human consumption, and whether the quality of surface waters in the project area will remain adequate to support native aquatic life and terrestrial wildlife[2]. The leach ate generated from mine waste dumps may have the potential to pollute the surrounding water sources and contamination of soil also. The most serious problem is groundwater contamination[3]. The adverse impact on the surrounding atmosphere due to leach ate is depending on the characteristics of that leach ate. So it becomes very important to assess the characteristics of the leach ate generated as well as the relationship between the characteristics of leach ate and its impact on water quality of the surrounding sources. Contamination of the underlying aquifer beneath a mining area is usually of great concern even when a prevention plan has been implemented.

Water from abandoned mines may contain significant concentrations of heavy metals and total dissolved solids, may have elevated temperatures, and altered pH, depending on the nature of the ore body and local geochemical conditions. These waters may become acidic over time when exposed to oxygen and, if present, pyrites or other sulfide minerals. The acidic water may also solubilize metals contained in the mine and mined materials, creating high concentrations of metals in solution. These acidic metal-laden waters may contaminate down-gradient ground-water and surface water resources. Neutral and alkaline mine waters may also contain metals in excess of water quality standards and be of significant concern to human health and the environment[4]. Heavy metals and other contaminants release from mining sites, especially from mine waste dumps or tailing ponds[5, 6]. So, the monitoring wells should be established around the nearby areas in order to monitor the groundwater pollutions. However, such monitoring is quite expensive and time consuming. Various mathematical simulation models have been developed for the assessment of groundwater vulnerability to groundwater contamination, water resources management and design of monitoring well systems. The majority of mine wastes are in the form of OB materials, waste rock and tailing from the ore treatment process as solid waste and workshop effluent, mine water and runoff water as liquid effluents. Large volume of these can present typical problems on their disposal in regards to pollution hazards, land sterilization and quality of water resources[7]. In the process of mining huge amounts of water discharged on surface to facilitate the mining operation. The discharged water often contains high load of TSS, TDS, hardness and heavy metals, which contaminate the surface and ground water[8].

MATERIALS AND METHODS

Sample collection: To assess the ground water quality of the Jharia coalfield, a systematic sampling carried out as per standard sampling methods[9]. For over burden leach ate study coalmine waste overburden samples collected from representative sampling locations and samples combined to make a composite sample. In an effort to study the extent of the groundwater contamination, the sampling locations for groundwater collection chosen approximately highly residential areas near the mine site. The samples were collected in thoroughly cleaned polypropylene containers that were rinsed with 8M HNO_3 followed by repeated washing with double distilled water. Again, the sampling bottles rinsed with a portion of sample. After collection of samples, each container labeled and relevant details were recorded for each sample.

Leach ates extraction: For the extraction of overburden leach ate, collected OB dumps analyzed by lysimeter test methods with standard protocol. This test is often called a dynamic test as the leaching solution is under continuous flux and may be more representative of field conditions. It involves the placement of OB material in a lysimeter in compacted manner and then the addition of leaching solution to the material to produce leach ate. Leaching solution used here was distilled water.

Methods of Analysis for Trace/Heavy Elements: Overburden leach ates and groundwater samples were analyzed for heavy metal such as Co, Cu, Ni, Fe, Mn, Zn and Pb. Atomic Absorption Spectrophotometer (Model, GBC - Avanta) did the trace/heavy elements analysis. For analysis of trace/heavy elements, the collected samples were filtered with Whatmann Filter Paper (Grade-42) and preserved by adjusting the $pH<2$ with the help of 6 N Nitric acid. 1000 ml of the water sample was concentrated by evaporation and the final volume was made to 50 ml, filtered and preserved for analysis.

Correlation study: Correlation carried out to understand the relationship between the various parameters and to test the significance. It was considered to be not significant when the value of the probability of significance (p) was greater than 0.05. All these statistical analyses estimated performed using SPSS statistical (Version 7.5 Windows XP, SPSS and Chicago, IL, USA). These methods act as an accurate tool to fully integrate a better explanation of the origin of groundwater contamination.

Water Quality Assessment: Finally, the studied variables were compared with the maximum permissible limits for drinking water Quality Standard of the World Health Organization (WHO)[10], India Standard for Drinking Water Specification (IS: 10500)[11] and United States Environmental Protection Act (USEPA)[12].

RESULTS AND DISCUSSION

Heavy metals concentration in overburden leach ate: The heavy metals concentration of the leach ate samples collected from the over burden dump has been presented in Fig-1. The result of overburden leach ate showed that the higher concentration of Mn and Fe. The concentration of Mn varied from 1.125 to 1.326 mg/L, whereas concentration of Fe was varied from 0.956 to 1.052 mg/L (Fig. 1). The concentration of Cu varied from 0.105 to 0.121 mg/L and the concentration of Cu varied from 0.086 to 0.095 mg/L. The similar results was also noticed by[7] that the level of Fe, Cu, Ni and Mn were found more in the leach ate water than that of top water. This leaching behavior of these metals affects the ground water quality because no precautions at the initial level have been taken to protect the ground water zone beneath the overburden dumps at the experimental site. It may also contaminate the ground water sources in nearby areas.

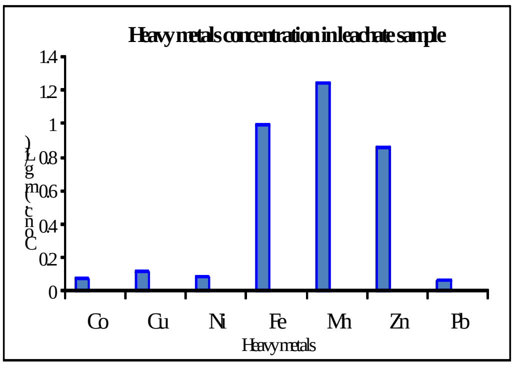

Fig. 1: Heavy metals concentration in overburden leach ate

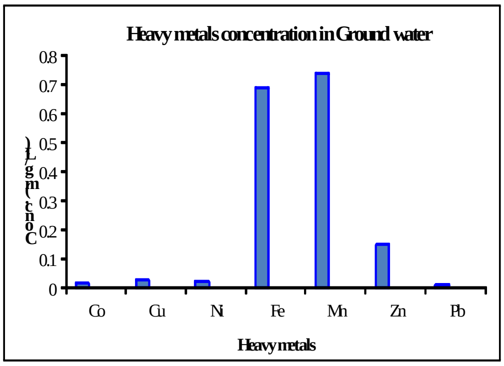

Fig. 2: Heavy metals concentration in groundwater

Table- 1: Pearson Correlation matrix of heavy metals concentration in overburden leach ate

	Co	Cu	Ni	Fe	Mn	Zn	Pb
Co	1	.856	.981**	-.427	-.432	-.354	-.410
Cu		1	.868	-.709	-.008	-.688	-.369
Ni			1	-.431	-.468	-.357	-.566
Fe				1	-.553	.992**	.243
Mn					1	-.637	.444
Zn						1	.164
Pb							1

****. Correlation is significant at the 0.01 level (2-tailed).**

Table- 2: Heavy metals concentration in groundwater with standard values

Heavy metals	**Unit**	**Range**	**Avg. value ± SD**	**IS:10500** (2009)	**WHO** (2011)	**USEPA** (2002)
Co	mg/L	0.015-0.025	0.0202±0.00336	NM	NM	0.01
Cu	mg/L	0.019-0.036	0.0282±0.00555	0.05	2.0	1.3
Ni	mg/L	0.018-0.031	0.0223±0.0038	NM	0.07	NM
Fe	mg/L	0.606-0.792	0.6935±0.0625	0.3	NM	0.3
Mn	mg/L	0.669-0.812	0.7405±0.04638	0.1	0.4	0.05
Zn	mg/L	0.123-0.192	0.153±0.02044	5.0	3.0	5.0
Pb	mg/L	0.007-0.018	0.0125±0.00696	0.05	0.01	0.015

***NM = Not mentioned**

Sources: IS: 10500, India Standard for Drinking Water Specification. 2009.; WHO (World Health Organization). 2011; USEPA (United States Environmental Protection Act). 2002.

Table- 3: Pearson Correlation matrix of heavy metals concentration in groundwater

	Co	Cu	Ni	Fe	Mn	Zn	Pb
Co	1	.718*	.386	-.299	-.023	.160	.028
Cu		1	.228	-.072	-.189	-.005	-.006
Ni			1	.427	.276	-.217	.514
Fe				1	.435	-.562	.556
Mn					1	-.051	.906**
Zn						1	-.057
Pb							1

*** Correlation is significant at the 0.05 level (2-tailed);**
****. Correlation is significant at the 0.01 level (2-tailed).**

The concentration of Co, Cu and Zn was found to be below permissible limit in groundwater samples. The metals Pb and Ni are characterized as toxic one for drinking water. The concentration of these metals was also found to be below permissible limit and below detection limit in groundwater samples. This likely indicates that these metals may be absorbed by the soil strata or by the organic matter in soil.

Leach ate water were characterized from three types of opencast mine overburden dumps and found higher level of Fe, Cu, Ni and Mn in the leach ate water than that of top water and also noticed leaching of Cu, Ni and Mn in the lower column of water of the same dump[13]. This leaching behavior of these metals affects the ground water quality. Presence of Fe in water can lead to change of color of groundwater. The higher concentration of Mn indicates that, the Mn ion may be abundant as dissolved ions. The sources of Mn occurrence could be from the weathering process[14]

CONCLUSIONS

The results of the present investigations clearly showed that the higher concentration levels of Mn and Fe were found in overburden leach ate samples. In the present study the concentration of Mn and Fe also observed in groundwater samples above the desirable limit level recommended for the drinking water quality standards. Concentrations of other metals in most cases were found well within the threshold values. The higher concentration of Mn indicates that, the Mn ion may be abundant as dissolved ions. Therefore, it can be concluded that leach ate has significant impact on groundwater quality near the mining area. Although, the concentrations of few contaminants do not exceed drinking water standard even then the ground water quality represent a significant threat to public health. Some remedial measures are also recommended to stop further groundwater contamination.

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