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An Assessment of the Underground Roadway Water Quality for Irrigation Use around the Barapukuria Coal Mining Industry, Dinajpur, Bangladesh

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ABSTRACT

The study area Barapukuria Coal Mine is situated in the Parbatipur Upazilla, Dinajpur District, and north-west part of Bangladesh. The area is criss-crossed by a number of streams under three rivers namely the Khorkhori, the Jamuna (local name) and the Ghirnai. Most of the streams are locally originated which are filled by rain water. From long period, the local people used various sources of water for agricultural purposes before the development of Barapukuria Coal Mine, on the other hand presently using a large quantity of mine discharged water for agricultural purposes especially for irrigation. As it is well known that currently the influences of underground coal mining activities has become a leading issue in the changes of water resources and their uses around the mining area. While the mining area thoroughly bounded by the irrigated land where underground water is the main sources of irrigation use. In the case of Barapukuria Coal Mine, a huge volume of water is pumping regularly from the underground tunnel roadway to surface. Thus it is a matter of question regarding its quality for irrigation and other uses. From this view point, this study monitored and assessed the quality of inflow water in the roadway for different years for irrigation purpose. The investigation shows that the roadway water is suitable for irrigation purposes where the overall quality of water is dominantly controlled by the rock weathering and evaporation natural processes in the area. In fact, the suitability of roadway water for irrigation was evaluated based on SSP, Salinity Hazard, Sodium Percent, Sodium Adsorption Ratio, Residual Sodium Carbonate, US salinity diagram, Wilcox's diagram, Kelly's ratio, Permeability Index, Magnesium Hardness, Total Hardness and so on. On the whole, the concentration of such parameters, major cations, anions, trace elements (e.g. As, Cd, Zn, Cr, Cl, Al, Mn), and others elements (e.g. TSS, DO, DOB, Oil and Grease, C. Count, T. Coliform, F. Coliform etc.) did not exceed the permissible limit for irrigation purposes hence suitable for irrigation uses. Conversely, the slight Mg hazard with moderately hard to hard tendencies of water bodies suggests a restriction for frequent utilization of this water for irrigation. Thus this study strongly recommends for continuing the ongoing monitoring program with necessary precautionary measures for maintaining the quality of roadway water in the underground tunnel of the mine.

Key words: Barapukuria coal mine, Underground tunnel roadway, Inflow water quality, Irrigation use.

1. INTRODUCTION

The Barapukuria Coal Mine (BCM) is situated in the Parbotipur Upazila, Dinajpur District, which lies between the latitudes 23°31′45″ and 23°33′05″N, and the longitudes 88°57′48″ and 88°58′53″E [1] shown in Fig. 1. As for the exploration report, the hydrogeological condition around the mine is much complicated as a result the mine industry endured various problems to develop new roadway and safely take out coal from underground. During the development work of coal mine in 1996, a severe water inrush accident occurred consequently thoroughly inundated the underground roadway. In this case, this waterlogged condition has been resolved using forced pumping activities and this water drained into the nearby agricultural field. As we know, the drainage from mine is well recognized as a cause of landscape disturbance as being highly impactful to water resources and, as a cause of social and economic problems [2,3,4&5]. On the other hand, the discharged huge volume of water from the water bearing formation affects groundwater elevations equally which may be more distinct as underground mines are more deeper and of larger aerial extension than the open cut mines.

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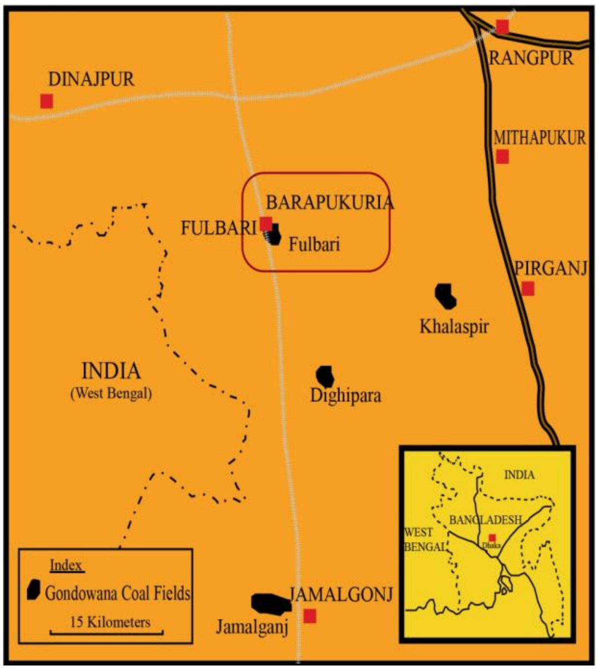

Fig. 1 The location map of the BCM field, Dinajpur, Bangladesh.

The lowering of groundwater level can occur over miles due to major mining operations [2&6]. However, mining affects water resources, both surface and groundwater, at various stages of the life cycle of the mine and even after its closure. The mining process itself, mineral processing operations, mine dewatering, seepage of contaminated lactates, flooding of mine workings, and discharge of untreated water are some important processes with related mine water problems [7&8]. Especially, the coal mine roadway water containing various hazardous materials may be dangerous to the surrounding environment. Contaminants released from the coal can pollute the water, soil and air, and can affect human health. For that reason, the areas where hazardous wastes are accumulated must be examined to avoid pollution. From long period, the local people used various sources of water for agricultural purposes before the development of BCM. But at present they are using huge amount of coal mine discharge water for their agricultural purposes especially for irrigation. Thus, from these points of view, it is very much essential to understand the total discharge rate of water from the aquifer to underground roadway, their quality, drainage system and utilization. In the study area, a group of researchers carrying out different research works from the early period of mine operation to present, but yet not a single research considered on the monitoring of the discharge rate of water, their quality and likewise their relation to lowering the water level around the mine. Under this situation, the prime objectives of the present studies are to ascertain the intensity of discharge water from the year 2001 to 2011, their quality for irrigation use around the area. Finally, discuss and compare the present results, and recommends the necessary steps for the present and future safety of underground tunnel, mining industry, surrounding environments and others.

2. MATERIALS AND METHODS

In order to understand and assess the inflow water quality in the roadway and the contemporary situation of water level around the BCM Industry, this study carried out intensive field inspections for collecting different relevant data such as the monitored groundwater samples from different location of the tunnel of the mining industry and their laboratory analysis. Moreover, field investigation was also carried out to observe the management system of mine drainage water and their utilization around the area. During field investigation, groundwater quality monitored data for a year as 2013 and water samples have been collected from Deep belt entry (Dupi Tila), Tract belt entry (Gondwana), Coal bearing water (Tract Gate), 430m Main Sump, Inrush Point, 1101, 1104, 1105, 1109, 1111, 1116, 1203, 1204 and 1210 faces, Outside boundary drain water, and Production level coal phase of the mine, and instantly measured some physical parameters such as Electrical Conductance (EC), Total Dissolved Solid (TDS), pH and Temperature. During field work, pH has been measured with a portable pH meter (HANNA pocket pH meter). The EC meter (HANNA HI 7039pS meter) was used to measure the EC, Temperature and TDS. The major cations like calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and anions like bicarbonate (HCO_3), carbonate (CO_3), chloride (Cl), nitrate (NO_3) and sulfate (SO_4) with some minor elements As, Cd, Zn, Cr, Cl, Al, Mn and other parameters, chemical analyses were carried out using appropriate certified and acceptable international procedures outlined in the standard methods for the Examination of Water and Wastewater [9]. The results were evaluated in accordance with the overall quality and irrigation standards given by the WHO & US salinity diagram and others for the classification of irrigation water [10].

The Permeability Index (PI) values have been calculated to know the suitability of water for irrigation use around the mining area while the soil permeability is affected by the long term use of irrigation water as it is influenced by Na, Ca, Mg and HCO_3 content of the soil [7]. Based on the PI values, Doneen (1964); Raghunath (1987) and WHO (1989) provide a classification to assess the suitability of groundwater for irrigation 11,12&13]. The PI is defined as Equation 1:

$$PI = \frac{(Na + \sqrt{HCO_3}) \times 100}{(Ca + Mg + Na)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where all concentrations are in meq/L.

3. DATA ANALYSIS AND RESULTS

3.1 Evaluation of Inflow Water for Its Possible Irrigation Utilizations

To understand the quality of water, a considerable number of water samples for a year of 2013 has been collected from various points of the underground tunnel such as Deep belt entry (Dupi Tila), Tract belt entry (Gondwana), Coal bearing water (Tract Gate), 430m Main Sump, Inrush Point, 1101, 1104, 1105, 1109, 1111, 1116, 1203, 1204, 1210 faces, Outside Boundary Drain Water and Production Level Coal Phase. These water samples have been analyzed in the laboratory, and results are plotted in the diagram (Table 1) for explaining the variations of water quality parameters of samples. From data analysis, some test parameters have been mentioned as Table 1 to Table 3 for underground roadway water. The outcome from data analysis gives significant values for determining water quality and compared these different quality parameters like physical and chemical parameters of tunnel roadway water with the standard acceptable limit recommended by WHO (2011) and EQS (1991), which confirms that the concentration of all parameters are within acceptable limit[14 & 15] and not much divergence occurred in the tunnel. Moreover the minor elements such as As, Cd, Zn, Cr, Cl, Al, Mn, and others, such as TSS, DO, DOB, Oil and Grease, C. Count, T. Coliform, F. Coliform etc. are also in the tolerable limits and can be used for different purposes with minor treatment. Meanwhile, the mining industry locates thoroughly in the plain land where the land use is dominated by agriculture workings and main crop is rice. The most of the lands within the mining area are cultivated in a natural way along with crops are harvested in two to three times in a year.

Table 1: Physicochemical characters of underground roadway water for the year 2013

Test Parameter & Units	1101 Coal Phase	1206 Coal Belt Gate (3-L)
pH	6.82	8.27
EC, µS/cm	156.80	151.60
Turbidity, NTU	90	153
Total Alkalinity, mg/L (as $CaCO_3$)	128	133
TH, mg/L (as $CaCO_3$)	45	70
CO_3, mg/L	7.20	11
HCO_3, mg/l	180.15	210.45
Fe (III), mg/L	0.60	0.40
Ca (II), mg/L	30	40
Mg (II), mg/L	15	30
Na (I), mg/L	7.7	5.40
K (I), mg/L	3.10	2.80
As (III), mg/L	0.012	0.011
TDS, mg/L	116	115
SO_4, mg/L	1.33	1.70
PO_4, mg/L	1.20	1
SiO_2, mg/L	35.50	36
NO_3, mg/L	0.18	0.12
Cl, mg/L	5.32	5.96
NH_3, mg/L	NF	0.44
Cd (II), mg/L	0.05	0.028
Zn (II), mg/L	0.21	0.24
Cr (III), mg/L	0.09	0.017

Table 2: Physicochemical characters of underground roadway water, 2013 year.

Test Parameter & Units	1210 Coal Phase	1106 Coal Phase Belt Gate (3-R)
pH	8.03	7.33
EC, µS/cm	91.20	174.30
Turbidity, NTU	28	34
Total Alkalinity, mg/L (as $CaCO_3$)	113	125
TH, mg/L (as $CaCO_3$)	80	71
CO_3, mg/L	9	6
HCO_3, mg/l	145.65	177.3
Fe (III), mg/L	0.45	0.34
Ca (II), mg/L	55	45

Mg (II), mg/L	25	26
Na (I), mg/L	6.20	7.20
K (I), mg/L	2.80	3.30
As (III), mg/L	0.012	0.013
TDS, mg/L	83	127
SO_4, mg/L	1.30	1.23
PO_4, mg/L	1.20	1.10
SiO_2, mg/L	35	35.4
NO_3, mg/L	0.13	0.17
Cl, mg/L	6.39	6.03
NH_3, mg/L	0.25	0.17
Cd (II), mg/L	0.030	0.026
Zn (II), mg/L	0.26	0.24
Cr (III), mg/L	0.012	0.015

Table 3: Physicochemical characters of underground roadway water of a year (2013)

Test Parameter & Units	1203 Coal Phase (2-L)	1206 R/W Track Gate (2-R)	Mother Rock (R/W)
pH	7.75	7.63	7.71
EC, µS/cm	352	323	403
Turbidity, NTU	90	198	27
Total Alkalinity, mg/L (as $CaCO_3$)	134	111	145
TH, mg/L (as $CaCO_3$)	55	46	59.50
CO_3, mg/L	6	21	26
HCO_3, mg/l	135.8	225.35	255.3
Fe (III), mg/L	0.52	0.47	0.39
Ca (II), mg/L	35	29	38.5
Mg (II), mg/L	20	17	21
Na (I), mg/L	4.10	3.50	5.50
K (I), mg/L	2.13	1.90	2.70
As (III), mg/L	0.014	0.012	0.015
TDS, mg/L	256	241	301
SO_4, mg/L	1.40	1.50	1.31
PO_4, mg/L	1.50	1.40	1.54
SiO_2, mg/L	42.50	53	45
NO_3, mg/L	0.15	0.19	0.18
Cl, mg/L	5.04	5.68	5.54
NH_3, mg/L	0.13	0.18	0.14
Cd (II), mg/L	0.024	0.035	0.032
Zn (II), mg/L	0.27	0.28	0.23
Cr (III), mg/L	0.017	0.016	0.014

Especially in the case of irrigation, the farmers are mostly dependent on the underground water, but currently they faced the problem to properly irrigate their land because of land subsidence, availability of underground water and so on. In this situation, the mine authority can supply this huge inflow water to a local farmer for irrigation and other uses. But before supplying this inflow water to the inhabitants, the authority might have to maintain the proper quality of water. Thus, considering this enormous quantity of inflow water in the underground tunnel and demand of water in the area, this research principally assesses the quality of water for irrigation. The quality of water for irrigation use normally evaluates by some essential issues such as EC, Sodium Absorption Ratio, Soluble Sodium Percentage, Sodium Percentage, Magnesium Hazard, Residual Sodium Carbonate, Permeability Index and United States Department of Agriculture classification. Along with the above indicators, some additional indices have been calculated to categorize the groundwater for irrigation like Kelly's Ratio and TH [16]. In general, when the concentrations of Ca and/or HCO_3 are a substantial form in the water, which are considered to be employed for irrigation consequently a variable fraction of this constituent will precipitate in the soil as $CaCO_3$ following this reaction as 2 [17].

$$Ca^{2+} + 2HCO_3^- = CaCO_3 + H_2O + CO_3 \text{ ----------- } (2)$$

As it is well known that salinization is the major cause of loss of production, which also severely limits the choice of crops, adversely affect crop germination and yields, and can cause soils to be difficult to work [18]. In fact, it is essential that all evaluations about irrigation water quality allied to the assessment of the soils to be irrigated [2&19]. In the present studies, the important hydro-chemical properties of underground tunnel water utilized to determine its suitability for irrigation and as a whole the inflow water in most cases was found to be suitable for irrigation shown in Table 4.

Table 4: Suitability of groundwater for irrigation based on different classification scheme

Classification Scheme	Categories	Ranges	No. of samples	Percent of samples
EC	Permissible	<1,500	7	100%
	Not permissible	1500-3000	0	Nil

	Hazardous	>3000	0	Nil
Salinity Hazard EC (µS) (Raghunath 1987)	Excellent	<250	4	57.14%
	Good	250-750	3	42.86%
	Medium	750-2250	0	Nil
	Bad	2250-4000	0	Nil
	Very Bad	>4000	0	Nil
Na% (Wilcox 1955)	Excellent	<20	7	100%
	Good	20-40	0	Nil
	Permissible	40-60	0	Nil
	Doubtful	60-80	0	Nil
	Unsuitable	>80	0	Nil
Na% (Eaton 1950)	Safe	<60	7	100%
	Unsafe	>60	0	Nil
SSP (Shah and Mistry 2013)	Good	<50	7	100%
	Bad	>50	0	Nil
SAR (Richards 1954)	Excellent	<10	7	100%
	Good	10–18	0	Nil
	Doubtful	18–26	0	Nil
	Unsuitable	>26	0	Nil
RSC (Richards 1954)	Good	<1.25	5	71.43%
	Medium	1.25-2.5	2	28.57%
	Bad	> 2.5	0	Nil
PI (Doneen 1964)	Class-I	>75	0	Nil
	Class-II	25-75	7	100%
	Class-III	<25	0	Nil
KR (Kelly 1940)	Good	<1.0	7	100%
	Unsuitable	>1.0	0	Nil
MH (Szabolcs and Darab 1964)	Suitable	<50	6	85.71%
	Harmful &Unsuitable	>50	1	14.29%
TH (Sawyer et al. 2003)	Soft	<75	0	Nil
	Moderately Hard	75-150	2	28.57%
	Hard	150-300	5	71.43%
	Very hard	>300	0	Nil

3.2 PI Status of Water for Irrigation Use

In this research, the calculated PI values have been plotted in Fig. 2. In the case of class I and II, waters are grouped as well for irrigation with 75% or more of maximum permeability, whereas class III is unsuitable with 25% of maximum permeability [20].

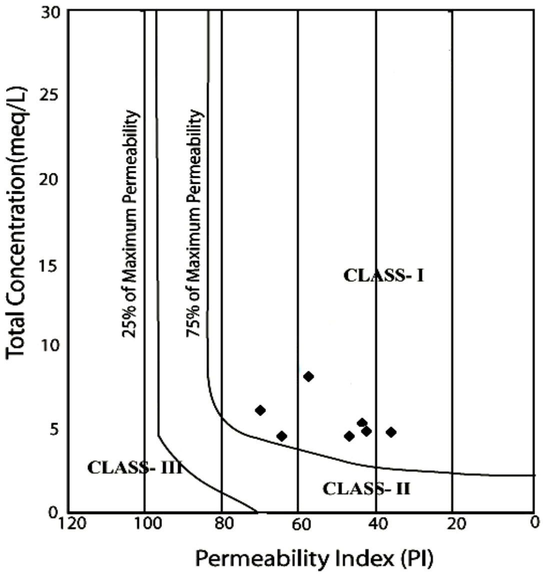

Fig. 2 Classification of irrigation water based on PI (After Ramesh and Elango 2011).

In the present research, the PI values vary from 35.81 to 69.25% (Table 4) which thoroughly belong to the class II reflects the inflow water is suitable for irrigation and quality is medium to excellent.

4. CONCLUSIONS

This study monitored and assessed the volume of inflow water in the roadways of underground tunnel with their quality for irrigation use around the BCM. In other cases of this water quality for irrigation, the results of chemical analyses for the major ions of water samples for different years collected from different points of the roadways of the mine are presented. The quality investigation is carried out with the evaluation of major, minor and other components such as pH, Ca, Mg, Na, K, HCO_3, CO_3, Cl, NO_3, SO_4, specific conductance, alkalinity and hardness, TDS and dissolved oxygen, and the minor elements such as As, Cd, Zn, Cr, Cl, Al, Mn and, others are TSS, DOB, Oil and Grease, C. Count, T. Coliform, F. Coliform etc., respectively, which indicates a sign of good quality of water as per WHO and EQS standards. On the basis of these results certain parameters such as TH, PI, SSP, SAR, Na%, potential salinity, RSC, KR, magnesium ratio, index of base exchange and GR were computed for irrigation purpose only, which implied that all the parameters are varied from good to excellent category hence suitable for irrigation. At the end, this study suggests that the present roadway water quality status must be maintained by taking a strict precautionary measure with the ongoing monitoring of inflow water quantity and quality of the mine.

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NOMENCLATURE

BCM : Barapukuria Coal Mine
EC : Electrical Conductance
PI : : Permeability Index, meq/L
TDS : Total Dissolved Solid
WHO : World Health Organization

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