Assessment of surface and subsurface water quality of Northern coalfields limited, Singrauli, MP, India based on water quality index method

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Abstract:

The surface and subsurface water are the most crucial natural available resources for the human utilization. The present study has shown the Water quality index (WQI) of surface and subsurface water based on the data of 23 samples capriciously collected at twenty three sampling sites of the entire study area, NCL district, Madhya Pradesh. The important water quality parameters were assessed using nine parameters of water qualitylike pH, dissolved oxygen, Total Dissolved Solids (TDS), electrical conductivity (EC), sulphate, calcium, magnesium, chloride and iron.

The minimum and maximum WQI value of the water samples from the study area varies from 29.8 and 991respectively. The obtained results of WQI shows that 43.5% of water sample comes in the 'good' water category. On the other hand, 13% of water samples come in the 'fairwater to poor water' and remaining 43.5% of water samples fall in 'very poor' to 'Unhealthy for utilization' category. The present study shows that the many surface and subsurface sampling sites water samples are not suitable for direct any utilization. The Surface and subsurface water can be utilized for drinking, domestic, industrial and agricultural purposes after appropriate necessary treatment.

Keywords: Surface and Subsurface water, WQI, NCL, Physico-Chemical Parameters.

INTRODUCTION

The quantity and quality of natural water resources has become serious concern all over the world due to increased pollution level and climate change (John et al., 2014; Todd, A. S. et al., 2012). In the present time, due to rapid growth of huge population and industrialization, severe stress are increasing on the natural water resources and their conservation for the future generation is one of the major challenges for human all over the world. Surface and subsurface water are a most essential resource for a different sectors of economy such as farming, domestic animals production, forestry, hydropower generation, fisheries, different industrial activities and other innovative uses for millions of people (Ghalib, 2017; Tyagi et al., 2013; Yousefi et al., 2018;Yadav and Jamal, 2018).Present time the contamination of water quality of natural water resources in and around the coalmine areas are due to solid and liquid waste discarded in form of overburden, tailing ponds, surface impoundments, acid mine drainage(AMD) discharges from active and inactive mines (Singh et al., 2013, Yadav and Jamal,2018,2018a).Which is liable for contamination of surrounding natural water quality of water resources. Which create very unhealthy circumstances for all living form. Such type of decline threatens the use of water resources, particularly for the domestic water supply and financial growth of nation. However, according to very responsible agencies like, US EPA, UNICEF and WHO, improving the quality of water supply remains a challenge for all over the world. Therefore, many developed and developing countries have implementing water quality monitoring programme and also taking many protection measures (Behmel et al., 2016).WQI is one of the most powerful, efficient, simple and effortlessly comprehensible tools to measure the suitability of surface and subsurface water quality(Bora and Goswami 2017) for different uses like drinking, domestic, industrial, agricultural and first time developed and used by R.K Horton (1965) in United States and also utilized and accepted in many, European and Asian country including, India also. After that WQI has been further used by various renowned researchers (Wu et al., 2018). Although many formulas are accessible to work out the WQI, all of them successfully changemanycomprehensiblechemical and physical water quality parameters into a very simple, single value for community and managers. The results of WQI of surface and groundwater of NCL MP may help the people, NGOS, Government and policymaker's to implementation of engineering and science-based water policies for utilization of water for drinking, irrigating, and industrial purposes in study area.

EXPERIMENTAL

Materials and methods

The present study area Singrauli region is located on the state boundary of Madhya Pradesh and Uttar Pradesh in north India between the latitudes 23˚47'and 24˚12' latitudes and longitudes 81˚48' and 82˚52' covering total area 2200 sq km, about 80 sq km lies in the district, Sonebhadra Uttar Pradesh, although2120sq km areas lies in the Shahdol and Sidhi districts of M.P.. Many industries based on coal and chemicals are situated in study area directly or indirectly more or less liable for degradation of surface and subsurface water quality. GovindBallabh Pant Sagar is one of Asia's largest man-made reservoir having 46,600 hasubmergencearea (Rai et al. 2007).Which fulfil the water demand of Singrauli and the entire eastern part of Uttar Pradesh. Thesolid and liquid waste generated from coal and coal based industries many harmful pollutants incessantly directly or indirectly released in surrounding waterbodies, which pose a severe threat to human, animals, plants and aquatic ecosystem(Yadav and Jamal.2017,2018).

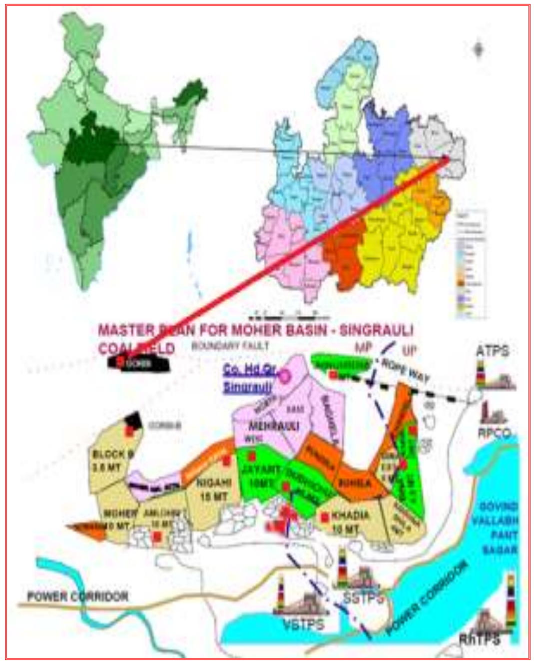

Figure 1 show the sampling location

Water sample collection and laboratory analysis.

Twenty three representative water samples from surface and sub surface water sources were collected from 23 different sampling sites in a pre-acid-washed high quality 5-L plastic gallons. The selected water quality parameters like water temperature (T), pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO),calcium, magnesium, chloride, sulphate and total iron(in mg/L) and show in Table-2.The pH, EC, TDS,DO, were measured and recorded in situ by using a Hanna Multiparameter probe and others selected parameters like sulphate, calcium, magnesium, chloride and iron are measured in the departmental laboratory, IIT BHU, Varanasi India. For the analysis of iron in water sample, 200 ml water samples were directly filtered through 0.45-µm size
whatman filter paper and analyzed by using photo Lab 6100.

Calculation of Water Quality Index (WQI)

The WQI is a mathematical technique developed by American scientist R.K. Horton for ranking the water quality, which shows the common effect of the different water quality parameters on the whole quality of water. It reduced the numerous parameters of water quality in a single, easy and beneficial mathematical value (Yadav and Jamal, 2018; Yadav et al., 2022). WQI is a very valuable tool for citizens, administration, stakeholders and policymakers for showing the complete quality of water in a single arithmetical value in place of numerousparameters of water quality. For the WQIWeighted Arithmetic Index method are used as per recommendations of BIS (BIS: 10500) and (WHO) (Tyagi et al. 2013; Yadav and Jamal, 2018; Baruah and Singh, 2022).

$WQI = W_iQ_i/W_i$ (1)

$W_i = K/S_i$ (2)

Wi= The unit weight for each water quality parameters and suffix i shows the number of parameters.
K= proportionality constant and calculated by the following equation;
Where K =1/ Σ1/Si
Si= shows the standard permissible valve for ith parameter
The value of quality rating or sub index (Qi) for Surface and Subsurface was calculated by using the following equation:
Qi = 100 [(Vi-Vo) / (Vs- Vo)] (3)
Where Qi is the Quality rating for the ith water quality parameters,
Vo=actual idealvalue of parameter in pure water. The ideal value of Vo is taken as zero (0) for all parameters except pH and DissolvedOxygen(taken as 7.0 and 14. 6mg/L respectively).
Vi= is the obtained value of the parameter,
Vs=Standard value recommended by WHO for the i^{th} parameter.
The obtained results of water quality index are again classify into six (6) main Categories shown in Table-1.
Table-1.Water quality index and its corresponding water quality status for different uses (Yadav and Jamal 2018)

S. No	WQI values	Classification of categories	Grades	Possible different Uses
1.	0-25	Excellent	A	Suitable for Drinking, irrigation and for different industrial activities
2.	26-50	Good water	B	Suitable for Domestic, Irrigation and for different industrial activities.
3.	51-75	Fair water	C	Suitable for Irrigation and for different industrial activities
4.	76-100	Poor water	D	Suitable for Irrigation
5.	101-150	Very poor	E	Suitable for limited use for Irrigation
6.	Above 150	Unhealthy for utilization	F	Suitable treatment essential before use

Table 2: Shows the characteristic of water sample and

Table 2: Shows the characteristic of water sample and calculated water quality index

SITES	**pH**	**DO**	**TDS**	**EC**	**SO4-**	**Ca2+**	**Mg2+**	**Cl-**	**Fe2+**	**WQI**
SW1	7.8	6.1	480	240	35	23	5.0	281	0.135	46.69
SW 2	7.7	6.0	460	230	34	22	5.1	254	0.139	49.42
SW3	7.4	6.2	240	120	35	18	4.6	150	0.145	44.32
SW4	7.5	5.9	201	101	51	15	3.3	170	0.145	49.52
SW5	7.2	5.9	209	105	51	14	3.2	165	0.145	48.89
SW6	8.5	6.3	1120	450	540	40	4.9	511	0.541	171.5
SW7	8.4	6.2	1110	446	540	39	4.2	501	0.555	173.57
SW 8	7.4	6.2	211	106	50	15	3.1	171	0.165	55.09
SW 9	8.26	5.7	1614	489	120	41	1.0	1250	0.04	32.96
SW 10	8.4	6.3	201	330	32	51	13	32	0.12	44.14
GW 11	8.01	4.8	1800	900	65	37	8.0	720	0.081	33.12
GW 12	8.1	5.1	1200	600	60	22	13	480	0.071	29.77
GW 13	8.3	5.3	940	470	32	25	12	410	0.081	32.97
GW 14	8.3	5.4	1260	630	60	14	27	2010	1.145	350.74
GW 15	8.2	5.3	1270	635	59	15	28	2011	1.147	351.22
GW 16	8.3	5.4	700	350	15	23	11	410	1.157	344.17
GW 17	8.2	5.3	730	365	15	24	12	405	1.159	356.28
MW 18	6.55	4.8	658	1097	464	29	61	85	0.681	195.31
MW 19	6.51	5.6	359	718	434	121	41	20	0.845	259.00
MW20	7.91	5.1	112	223	310	41	10	6.8	0.166	58.346
MW21	6.55	5.9	496	765	384	39	30	41	0.309	98.47
MW22	5.60	6.1	672	1121	424	58	51	87	3.312	990.85
MW23	6.71	4.1	212	784	316	32	49	57	0.491	153.73
Mean	7.64	5.61	706.7	490.2	179.4	32.9	17.4	444.7	0.555	172.61
SD	0.7709	0.566	483.5	298.7	188.0	22.3	17.3	556.9	0.707	214.3

SW-SURFACE WATER, GW-GROUND WATER, MW- MINE WATER, all parameters in mg/l except ph and electrical conductivity(μS/cm)

RESULTS AND DISCUSSION

Physicochemical characteristics

pH Value

The pH value of water play a very important role to decide water is acidic or alkaline. The pH value of water sample in the study area varies from 5.60 to 8.5 with a average value of 7.64 (Table-2, Fig.-1). The acceptable limit of pH for drinking purposes prescribed by BIS, CPCB and WHO 6.5- 8.5.Some water sample is falls below its limits. The variations of pH level found in the study area due to the geographical circumstance and present of elemental opus in the horde rocks.

Dissolved oxygen (DO)

The dissolved oxygen (DO) play a very crucial role in respiration for underwater life as aquatic creatures .The dissolved oxygen (DO) varied from 4.1 to 6.3 mg/l with a average value of 5.61 mg/l, indicating water sample collected from surface and subsurface water resources is well oxygenated.

Total Dissolved Solids (TDS)

The concentration of TDS in the our study area varies from 112 to 1800 mg/L with a average value of 706.7 mg/L (Table-2) which showed the study area is anthropogenic ally impacted. The availability of (TDS) in water bodies also plays a very important role to decide its appropriateness for varioususes. The higher concentrations of TDS may cause severe healthproblems like, laxative or constipation, kidney and heart diseases (Kumaraaswamy and Pollut res, 1999).

Electrical Conductivity (EC)

The EC (in µS/cm) in water resources depends on the ionic species in term of quantity, concentration and movement rate (Anshumali and Ramanathan 2007).The Electrical Conductivity (EC) of the study area varies from (101-1121 µS/cm) with average value of 490.2 µS/cm .The concentration of EC were falls below the acceptable limit(300-1000 µS/cm) for drinking and irrigation uses, except location MW18 and MW 22 in the study area. Excess values of EC (3000 µS/cm) is not suitable for almost all the crops.This results in cases of decreased agricultural productivity (Yadav and Jamal, 2018).

Calcium (Ca^{2+})

In the study area calcium ion varies from (14-121) mg/L with a average value of 32.9 .Which falls within the allowable limits (75-200) mg/L prescribed by (WHO). The excess quantity of calcium cause several negative health effects.

Magnesium (Mg^{2+})

In the study are a magnesium ion varies from 1-61 mg/L with an average value 17.4 mg/L. which is within the permissible limit (30-

150) mg/L, prescribed by (WHO). The presence of excess quantity of Magnesium in water cause many health effects.

Chloride (Cl^-)

The presence of chloride in surface and subsurface water resources depend on geochemical circumstances of the surrounding area. High amount of Chloride (Cl^-) in water resources Influence the corrosion incident.(Logeshkumaran et al. 2015). The range of chloride varies from 6.8-2011 mg/L with an average of 444.7 mg/L. All values are comes within the prescribed limit of WHO (250-1000mg/L), except location SW9, SW14, SW15.Whichinfluence the soil porosity, permeability and corrosion phenomenon (Logeshkumaran et al. 2015).

Sulphate (SO42-)

The concentration of Sulphate in the study area varies from 15 to 540 mg/l with a average values of 179.4.Which is less than the allowable limit (400 mg/L) set by WHO except location SW6, SW7,MW18, MW19 and MW22. Its attendance in water samples in study areas are due to gypsum and limestone.36The excess accessibility of Sulphate in water impart taste and might contribute to the deterioration of water supply pipes materials.15

Total iron

The iron concentration in water sample range from (0.08-3.312) mg/L with an average values of 0.555mg/L. This is higher than the permissible limits (0.3-1.0) in the studies area at some location. The excess presence of iron in the natural water resources may be liable for many health and environmental problems.

Conclusion

The assessment of surface and subsurface water for drinking purposes is measured based on water WQI technique. WQI reports say that the more than half of the surface and subsurface water sample sites in study area has been polluted as indicated by WQI. Water quality of the area concluded on the basis of WQI which shows 43.5% of water sample comes in the ‘good’ water category.Where13% of water samples comes under ‘fairwater to poor water’ category and remaining 43.5% of water samples comes under ‘very poor’ to ‘Unhealthy category and not suitable for any types of utilization. The maximum water quality index observed (>100 to 990.85) inthe study areas viz, SW6, SW7, GW14, GW15 GW16, GW17, MW22 and MW23, which show the most horrible situation of water. This study strongly suggested appropriate treatment of water before utilization for domestic, industrial and agricultural purposes. To prevent any potential degradation of the natural quality of water resources in the study region due to expanding coal and coal-based enterprises and agricultural activities, this can be accomplished by continuously monitoring surface and subsurface water resources in the study area.

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