WAWQI-Based Water Quality Assessment in Villages Near Namchik-Namphuk Coal Field, Changlang District, Arunachal Pradesh, India

Abstract: This study is concerned with the assessment of water quality in 5 villages in and around the Namchik Namphuk Coal field under Kharsang Circle in Changlang District of Arunachal Pradesh. A total of 11 water samples were collected, and standard laboratory assessments were conducted to determine various physicochemical properties, viz. Turbidity, pH, hardness, alkalinity, total dissolved solids, chloride (Cl), sulphate ($SO4^{2-}$) fluoride (F), nitrate (NO_3^-), iron (Fe), arsenic (As), lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), nickel (Ni), dissolved oxygen (DO) and Oil and grease. Based on the results, and considering the standard limits for drinking water suggested by the Bureau of Indian Standards (BIS), the water quality index has been worked out using the Weighted Arithmetic Water Quality Index Method. It has been found that only 1 sample can be considered as excellent, 2 samples were good, 1 sample each in the poor and very poor categories, while 6 samples were found to be unsuitable for drinking. The findings highlight that the availability of quality drinking water in these villages is a major issue.

Keywords: Changlang District, Coal Field, Namchik-Namphuk, Water quality, Water quality index, WAWQI

Introduction

Water is a precious and very limited resource. Though a large part of the globe is covered with water, only a small fraction of it is readily available for human consumption. Fresh, consumable water is again not equally distributed; there are areas with an abundance of it, and there are also water-stressed areas. According to WHO/UNICEF (2019), about 2.2 billion people lack access to safely managed drinking water, and about 2 million children under 5 years of age die annually due to diarrheal diseases because of poor sanitation and water quality.

Water can be polluted by an array of pollutants that can be broadly classified under organic, inorganic compounds, and particulate materials (Geissen et al., 2015). These pollutants may come in contact with water directly (e.g. sewage and oil spills) or indirectly (e.g. pesticides and nutrients used in agriculture) (Singh et al., 2020), and these pollutants could be of natural origin as well as anthropogenic. The quality of water is also influenced by the mineralogy of the rocks in the area. For instance, alkalinity is largely influenced by the mineralogy of the rocks; limestone and CaCO3 add to the alkalinity of water, while rocks such as granite lack alkalinity (Addy et al., 2004). The present paper attempts to evaluate the quality of drinking water in five villages surrounding the Namchik-Namphuk coal field under Kharsang Circle, incorporating the Weighted arithmetic Water Quality Index (WAWQI), considering various physicochemical properties of the water; turbidity, pH, total hardness (as CaCO3 mg/L) TDS, total alkalinity, Cl, $SO4^{2-}$, F, NO_3^-, Fe, As, Pb, Cr, Zn, Cd, Ni, dissolved oxygen and Oil and grease as the determinants for its quality.

The WAWQI is a very widely used mathematical tool to determine and summarise the overall quality of water based on various physicochemical and biological parameters. It is one of the several methods used for the determination of water quality with water quality indices (WQI). The WAWQI method assesses water quality based on the most widely used water quality variables (Tyagi et al., 2013). The WAWQI integrates several water quality parameters into a single mathematical equation (Sarwar et al., 2020). The concept of WQI was initially introduced by Horton in 1965, and later, various attempts have been made by various scholars to understand the water quality. The WAWQI method is a modified version of Horton's method, put forward in 1970 by Brown et al. (Kumar et al., 2024). WAWQI is very popular among scholars due to its simplicity and the ability to integrate multiple water quality parameters, each weighted according to its relative importance in influencing the overall quality of water (Akhtar et al., 2021; Farouq, 2018; Talukdar, 2022).

Materials and Methods

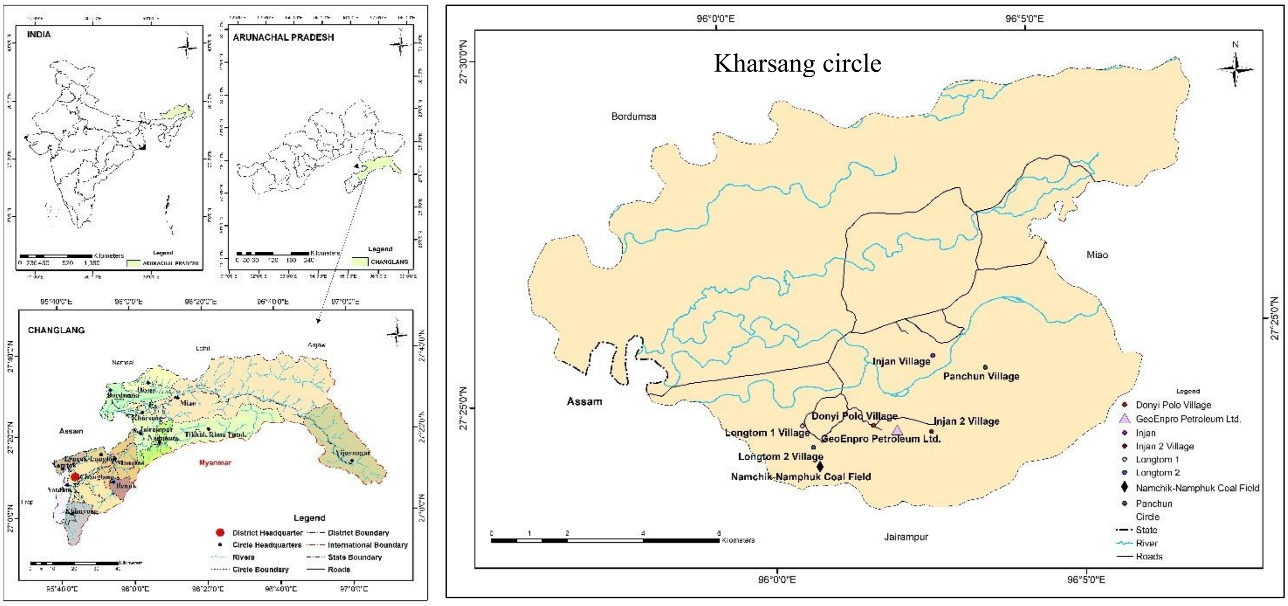
Study area

Five villages, namely Panchun, Donyi-Polo, Longtom I, Longtom II, and Injan under Kharsang Circle in Changlang District, Arunachal Pradesh, have been considered for the present study. These villages are situated near the Namchik-Namphuk coal fields, and they are inhabited by the tribal community of the Tangsas. According to census 2011, these villages have a total population of about 1876 and about 383 households.

The Kharsang circle lies between 27° 24' 56" N latitude and 95° 59' 55" E longitude with a total area of about 579 square km. This area primarily consists of a flat terrain with moderate hills in the southern part, which belong to the Naga-Patkai range. This mountain range, part of the larger Arakan Yoma chain, trends ENE-WSW and curves near the Mishmi Thrust, reaching heights of up to 2780 meters. It comprises tertiary sequences from Assam and southeastern Arunachal Pradesh. The elevation in the area generally ranges between 100 to 200 meters. The terrain mostly features level to gentle slopes to moderately steep slopes (Geological Survey of India, 2010). Numerous streams and rivers traverse the region, with the Namphuk River being the most significant.

The study area primarily comprises five distinct geological formations: Girujan clay, Sorbhog, Hauli, Jairampur, and Tipam Sandstone. These formations originated during the Miocene to Holocene period. The geomorphology of the area consists of low-dissected structural hills and valleys, moderately dissected structural hills and valleys, older floodplains, younger alluvial plains, piedmont alluvial plains, rivers, and lakes. In terms of lithology, the area is mainly comprised of 5 distinctive groups: Mottled clay with subordinate sandstone; Oxidised sand, silt with pebbles of shale, and gneiss; Oxidised to feebly oxidised sand, silt, and clay; Sandstone, clay, shale, and fossil wood; Silt and clay sequence with carbonised wood (Ngemu, 2021). The area experiences a monsoon-influenced humid-subtropical type of climate and is famous for its natural resources, viz—coal and petroleum. The availability of these natural resources has benefited the local communities in terms of job and income opportunities. On the other hand, the negative effects of mining operations and allied activities cannot be ignored. Degradation of soil and water quality, deforestation, and other environmental issues are linked to the availability and exploitation of these resources.

Figure 1 Study Area



Source: Generated using ArcGIS 10.3 based on the administrative and political map of Arunachal Pradesh, Census of India, 2011.

Database and analysis

A total of 11 water samples were collected from the study area in airtight containers. Each sample was labeled and the coordinates were recorded for future reference. The samples are all collected from wells, which are the primary source of potable water in the concerned villages. The data regarding the quality of water in terms of various physicochemical properties namely Turbidity (NTU), pH, Total Dissolved Solid, Total Hardness as CaCO3(mg/L), Total Alkalinity, Chloride, Sulphate, Fluoride, Nitrate, Iron, Arsenic, Lead, Chromium, Zinc, Cadmium, DO, OIL and Grease, and Nickel have been obtained through laboratory analysis of water samples at the State Water Quality Testing Laboratory Itanagar and Environmental Research and Evaluation Centre (EREC) Guwahati. Detailed information on various parameters of the water samples is provided in Table 1. The acceptable limits for different parameters in drinking water, as per the Bureau of Indian Standards (BIS) IS 10500: 2012, were used to calculate WAWQI. Along with the collection of water samples, 114 households were interviewed from the villages for their experiences and views on the water quality and associated issues.

Assessment of water quality index using WAWQI

WAWQI is one of the widely used tools for calculating Water Quality Indices (WQI), which summarises the overall quality of water based on various physicochemical and biological parameters.

It is calculated as $WQI = \sum Q_i W_i / \sum W_i$

The individual parameters' quality rating scale (Qi) is calculated as:

$$Qi = 100 [(Vi-Vo/Si-Vo)]$$

Where, Vi = The estimated concentration of the ith parameter in the water sample under analysis. Vo = Ideal value of this parameter in pure water, which is 0 (except pH (7.0) and Dissolved Oxygen (DO) (14.6 mg/l). Si = Recommended standard value of ith parameter. The unit weight or (Wi) for every individual parameter is calculated as: Wi = K/Si, where, K = Proportionally constant or can be calculated as $K = 1/(\sum(I/Si)$ (Brown et al., 1972). The quality of water is then determined based on the rating scheme provided below:

Table 1 Water quality rating based on the WAWQI method (Brown et al., 1972)

WQI Value	Water Quality Rating	Grade
0 - 25	Excellent	A
26 - 50	Good	B
51 - 75	Poor	C
76 -100	Very poor	D
Above 100	Unsuitable for drinking	E

Table 2 Physicochemical properties of water samples as compared to acceptable limits set by BIS 2012

Sample	Turbidity (NTU)	pH	Total Hardness as $CaCO_3$	TDS	Total Alkalinity	Cl	$SO4^{2-}$	F	NO_3^-	Fe	As	Pb	Cr	Zn	Cd	Ni	DO	OIL & Grease
			(mg/L)															
BIS 2012	**5**	**8.5**	**600**	**2000**	**600**	**1000**	**400**	**1.5**	**45**	**0.3**	**0.05**	**0.01**	**0.05**	**15**	**0.003**	**0.02**	**6**	**0.5**
K15	3	7.1	185	208	132	28.6	1.23	0.03	1.19	0.07	0	0.02	0	0	0.01	0.04	8.7	0.086
K2	5	6.05	156	184	127	19.5	1.36	0.09	0.23	0.08	0.01	0.03	0	0	0	0.06	8.1	0.09
K6	11	6	70	89.2	66	6.9	0.53	0.05	0.25	0.1	0.01	0.02	0.08	0	0	0.01	7.9	0.13
K5	4	6.1	57	74.7	62	4.8	0.35	0.02	0.12	0.02	0.01	0.004	0.02	0	0.001	0	7.8	0.12
K14	12	6.14	61	53	68	4.4	0.56	0.11	0.52	0.03	0	0.02	0.01	0	0.01	0	7.8	0.09
K9	8	6.06	253	351	134	53.4	2.71	0.15	1.38	0.09	0.01	0.03	0.01	0	0.02	0	8.4	0.07
K8	4	6.15	59	81.9	68	12.5	0.54	0.09	0.27	0.04	0.02	0.001	0.01	0	0.02	0	8.1	0.2
K11	7	6.6	148	234	124	26	1.39	0.06	0.84	0.06	0	0.02	0.01	0	0.02	0	7.4	0.08
K17	1.12	6.74	5	7.6	5	1.2	0.43	0.11	0.37	0.05	0.01	0	0	0	0.01	0	8.8	0.08
K20	1.65	6.78	10	11.2	4	1.7	0.41	0.09	0.42	0.03	0.02	0.02	0	0	0	0.03	8.7	0.1
K22	0.96	6.34	45	55.7	23	3.9	0.53	0.04	1.19	0.01	0	0.01	0	0	0	0	8.6	0.07
							Descriptive statistics											
Maximum	12	7.1	253	351	134	53.4	2.71	0.15	1.38	0.1	0.02	0.03	0.08	0	0.02	0.06	8.8	0.2
Minimum	0.96	6	5	7.6	4	1.2	0.35	0.02	0.12	0.01	0	0	0	0	0	0	7.4	0.07
Mean	5.25	6.37	95.36	122.75	73.91	14.81	0.91	0.07	0.62	0.05	0.008	0.016	0.013	0	0.008	0.01	8.20	0.10
SD	3.82	0.37	78.70	107.55	49.81	16.06	0.71	0.04	0.45	0.03	0.008	0.011	0.023	0	0.009	0.02	0.46	0.04

Note. NTU= Nephelometric Turbidity Unit, TDS= Total dissolved solids, DO= Dissolved oxygen, BIS= Bureau of Indian Standard, SD= Standard deviation
Source: Field survey; State water quality testing laboratory, Itanagar and EREC Guwahati.

UNDER PEER REVIEW

Table 3 Calculation of WAWQI based on the parameters and readings for different parameters found in Table 2

Parameters		Turbidity (NTU)	pH	Total Hardness as CaCO3	TDS	Total Alkalinity	Cl	SO42-	F	NO3-	Fe	As	Pb	Cr	Zn	Cd	Ni	DO	OIL & Grease		
	Vi	0.00	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.6	0.00		
	Vs	5	8.5	600	2000	600	1000	400	1.5	45	0.3	0.05	0.01	0.05	15	0.003	0.02	6	0.5		
	Vo	**Observed values (Table 2) were used for the calculation of the individual parameter sample**																			
	Wi	0.2	0.117	0.001	0.0005	0.002	0.001	0.002	0.666	0.022	3.333	20	100	20	0.066	333.3	50	0.166	2		
Sample	**Qi**	**Quality rating for each parameter and sample calculated from Table 2**																		**WQI value**	**WQI Rating**
K15		60	6.7	30.8	10.4	22	2.9	0.3	2	2.6	23.3	0	200	0	0	333.3	200	68	17.2	**266.5**	**UD**
K2		100	-63.3	26.0	9.2	21.2	2.0	0.3	6.0	0.5	26.7	20	300	0	0	0	300	61.3	18	**86.96**	**VP**
K6		220	-66.6	11.7	4.5	11	0.7	0.1	3.3	0.6	33.3	20	200	160	0	0	50	63.2	26	**49.65**	**Good**
K5		80	-60	9.5	3.7	10.3	0.5	0.1	1.3	0.3	6.7	20	40	40	0	33.3	0	64.1	24	**30.95**	**Good**
K14		240	-57.3	10.2	2.7	11.3	0.4	0.1	7.3	1.2	10	0	200	20	0	333.3	0	64.1	18	**248.4**	**UD**
K9		160	-62.6	42.2	17.6	22.3	5.3	0.7	10	3.1	30	20	300	20	0	666.7	0	58.4	14	**477.8**	**UD**
K8		80	-56.6	9.8	4.1	11.3	1.3	0.1	6	0.6	13.3	40	10	20	0	666.7	0	61.3	40	**423.8**	**UD**
K11		140	-26.6	24.7	11.7	20.7	2.6	0.3	4	1.9	20	0	200	20	0	666.7	0	83.7	16	**458.1**	**UD**
K17		22.4	-17.3	0.8	0.4	0.8	0.1	0.1	7.3	0.8	16.7	20	0	0	0	333.3	0	67.4	16	**210.6**	**UD**
K20		33	-14.6	1.7	0.6	0.7	0.2	0.1	6	0.9	10	40	200	0	0	0	150	68.6	20	**53.6**	**Poor**
K22		19.2	-29.3	7.5	2.8	3.8	0.4	0.1	2.7	2.6	3.3	0	100	0	0	0	0	69.7	14	**18.10**	**Excellent**

Note. Vi= ideal value, Vs =standard value (acceptable values as per BIS, IS 10500: 2012), Vo= Observed value in samples, Wi= unit weight, Qi= Quality rating, UD= Unfit for drinking, VP= Very poor.

Adapted from "Use of Weighted Arithmetic Water Quality Index (WAWQI) to Determine the Suitability of Groundwater of Chaugachcha and Manirampur Upazila, Jashore, Bangladesh" by Sarwar, S., Ahmmed, I., Mustari, S., & Shaibur, M. R. (2020). *Environmental and Biological Research*, *2*(2), 37-48.

Results and discussion

The findings show that the average hardness, TDS, alkalinity, Cl, $SO4^{2-}$, F, NO_3^-, Fe, As, Cr, Zn, Ni, and Oil and grease in the samples are under the acceptable limits prescribed by BIS, IS 10500: 2012. On the other hand, the average turbidity, Pb and Cd are found to be slightly higher than the acceptable limit. The average pH is significantly below the acceptable limit, indicating acidification.

Total hardness, TDS, alkalinity, Cl, $SO4^{2-}$, F, NO_3^-, Fe, As, Zn, and Oil and grease are under the acceptable limit in each sample. The maximum, minimum, and average values for total hardness are 253, 5, and 95.36 mg/L, respectively. For TDS, 351, 7.6 and 122.75 mg/L. For alkalinity, 134, 4 and 73.91 mg/L. For Cl, 53.4, 1.2 and 14.81 mg/L. For $SO4^{2-}$, 2.71, 0.35 and 0.91 mg/L. For F, 0.15, 0.02 and 0.07 mg/L. For NO_3^-, 1.38, 0.12 and 0.62 mg/L. For Fe, 0.1, 0.01 and 0.05 mg/L. For As, 0.02, 0 and 0.008 mg/L. For Zn, 0 mg/L and Oil and grease, 0.2, 0.07 and 0.10 mg/L.

In terms of turbidity, four samples have been found to exceed the acceptable limit of 5 NTU prescribed by BIS. The maximum, minimum and average values for turbidity are 12, 0.96 and 5.25 NTU. For Pb, seven samples out of eleven were found to exceed the acceptable limit of 0.01 mg/L. The maximum, minimum and average values for Pb are 0.03, 0 and 0.016 mg/L. In terms of Cr, only one sample has been found to exceed the acceptable limit, while the average (0.013 mg/L) is under the acceptable limit. The maximum, minimum and average values for Cr are 0.08, 0, and 0.015 mg/l. For Cd, five samples out of eleven were found to exceed the acceptable limit. The maximum, minimum and average values for Cd are 0.02, 0 and 0.008 mg/L. For Ni, three samples out of eleven were found to exceed the BIS acceptable limit. The maximum, minimum, and average values for Ni are 0.06, 0, and 0.01 mg/L, respectively. In terms of dissolved oxygen, all samples show a concentration well above the minimum concentration suggested by the Central Pollution Control Board (CPCB), 6mg/L. The maximum, minimum and average values are 8.8, 7.4 and 8.20 mg/L, respectively. The average pH level in the water samples was found to be lower than the BIS's lower limit or the minimum value (6.5-8.5). Seven out of eleven (about 63.6%) samples have a pH value of less than 6.5, suggesting a serious degree of acidification often seen in areas affected by coal mining and resultant pollution.

The villagers complained of unpleasant taste, odour, staining of clothes, and skin irritation problems with the usage of the water. The wells are the sole source of potable water in the villages, and it has been found that many wells in the villages have been abandoned because the water quality is so unusable. The villagers are compelled to carry water manually from distant wells with comparatively better-quality water for their consumption. Health issues such as Diarrhea, Cholera, Typhoid, and other Gastro-intestinal problems are closely associated with poor quality of water (Mohsin et al., 2013; Gundry et al., 2004). Water-related health issues, such as typhoid and other stomach ailments, such as gastritis, are common in the concerned villages. The most common health concerns are related to gastrointestinal issues, which are followed by respiratory ailments, including chest pain, severe cough, and sinusitis.

Out of a sample population of 114 households, it has been found that about 70% of the households practice water filtration and boiling before consumption. On the other hand, about 30% of the sample population does not use any filtration or boiling methods and consumes water from wells directly. This makes them prone to waterborne diseases. Of the sampled population, about 69% reported experiencing issues with water, primarily concerning quality concerns such as taste, iron content, and the availability of fresh water. Furthermore, about 44% of respondents strongly attribute water problems to mining and allied activities in the region.

The pollution of water resources has an impact on agriculture as well. The acidic nature of water laden with coal debris and red-brown precipitate materials has affected agricultural land, making the soil acidic. The soils affected by acid mine drainage had a very low pH level of 3, suggesting their acidification. The effect of acid mine drainage has also been seen on tea plantations and fisheries in Panchun village. During the field study, it was discovered that about 6.7 hectares and 7.6 hectares of wet paddy cultivation plots at Longtom 2 and Panchun village, respectively, had been affected, leading to the failure of crops and the abandonment of agricultural land.

Conclusion

The villages lie in proximity to the Namchik-Namphuk coalfield, and it is evident that mining and related activities, such as the production of coke coal and brick kilns and resultant pollutants in the form of fly ashes, acid mine drainage, and its seepage, are contributing factors to the poor quality of water in the area. Many scholars have studied the influence of coal mining on water quality (Tiwari, 2001; Swer and Singh, 2004; Sangita et al., 2010; Nephalama and Muzerengi, 2016), all of which suggest that coal mining and related activities have a high potential of degrading the water quality in their peripheral areas.

Assessment of the water quality of wells in the area using WAWQI has brought out the fact that there are already concerning signs of water contamination. The native villagers also opine that the quality of water is degrading, and access to clean consumable water is a challenge for the villagers, especially the poor. There are also health concerns, as the survey suggests a prevalence of water-related health issues in the village and a lack of filtration practice for drinking water.

The deterioration of water affects agriculture as well, in terms of acidification of soil and crop failures. There is an urgent need to address the issues of unscientific and illegal mining and allied activities, such as coke coal production in the area, to prevent further deterioration of the water quality. Proper disposal and treatment of mining effluents must be prioritised. There must be a provision for regular testing of water quality and health assessment. Though the magnitude of this issue in terms of negative impact on human health and the environment may seem small now, it might be magnified by manifolds if timely interventions are not made.

There is no lack of evidence for the potential threats that mining industries pose to water resources and the resultant effects on human health and the environment. All the stakeholders and the administration need to at least provide a proper supply of drinking water to the villages. Though some pipelines and tube wells are laid under some government schemes, their functionality is questionable. Villagers are at the mercy of the water supply from the oil drilling company GeoEnpro Petroleum Limited; otherwise, they struggle to fetch water from wells with better quality water for their daily consumption.

Conflict of interest

The authors declare that there is no conflict of interest.

References

Addy, K., Green, L. and Herron, E., 2004. pH and Alkalinity. *University of Rhode Island, Kingston*. https://web.uri.edu/wp-content/uploads/sites/1667/pHalkalinityFINAL.pdf

Akhtar, N., Ishak, M. I. S., Ahmad, M. I., Umar, K., Md Yusuff, M. S., Anees, M. T., ... & Ali Almanasir, Y. K. (2021). Modification of the water quality index (WQI) process for simple calculation using the multi-criteria decision-making (MCDM) method: a review. *Water*, *13*(7), 905. https://doi.org/10.3390/w13070905

Brown, R.M., McClelland, N.I., Deininger, R.A. and O'Connor, M.F., 1972. A water quality index—crashing the psychological barrier. In *Indicators of Environmental Quality: Proceedings of a symposium held during the AAAS meeting in Philadelphia, Pennsylvania, December 26–31, 1971* (pp. 173-182). Springer US. https://doi.org/10.1007/978-1-4684-2856-8_15

Bureau of Indian Standards. (2012). Drinking water — Specification (IS 10500:2012) (2nd rev.). https://law.resource.org/pub/in/bis/S06/is.10500.2012.pdf

Farouq, A. U. (2018). Comparative Water Quality Indices of Hand-Dug Wells Near Septic Tanks In Effurun, Delta State, Nigeria. *IOSR Journal of Environmental Science*, *12*(5),82-86. https://www.academia.edu/download/56816371/K1205018286.pdf

Gundry, S., Wright, J. and Conroy, R., 2004. A systematic review of the health outcomes related to household water quality in developing countries. *Journal of water and health*, *2*(1), pp.1-13. https://doi.org/10.2166/wh.2004.0001

Geissen, V., Mol, H., Klumpp, E., Umlauf, G., Nadal, M., van der Ploeg, M., van de Zee, S.E. and Ritsema, C.J., 2015. Emerging pollutants in the environment: a challenge for water resource management. *International soil and water conservation research*, *3*(1), pp.57-65. https://doi.org/10.1016/j.iswcr.2015.03.002

Geological Survey of India. (2010). Geology and mineral resources of Arunachal Pradesh (Miscellaneous Publication No. 30, Pt. 4, Vol. 2 (i)). https://prod-qt-images.s3.amazonaws.com/indiawaterportal/import/sites/default/files/iwp2/Report_Arunachal_Pradesh_State_Geology_and_Mineral_Maps_Geological_Survey_of_India.pdf

Kumar, R., Rajput, J., & Saxena, A. K. (2024). Assessment of water quality of Tighra Reservoir using weighted arithmetic water quality index (WA-WQI). *Int. J. Innov. Sci. Res. Technol. (IJISRT)*, *9*, 1086-1092. https://doi.org/10.38124/ijisrt/IJISRT24MAY1308

Mohsin, M., Safdar, S., Asghar, F. and Jamal, F., 2013. Assessment of drinking water quality and its impact on residents health in Bahawalpur city. *International Journal of Humanities and Social Science*, *3*(15), pp.114-128. https://www.academia.edu/download/100309150/14.pdf

Nephalama, A. and Muzerengi, C., 2016. Assessment of the influence of coal mining on groundwater quality: Case of Masisi Village in the Limpopo Province of South Africa. *Proceedings of the Freiberg/Germany, Mining Meets Water—Conflicts Solutions, Leipzig, Germany*, pp.11-15. https://imwa.info/docs/imwa_2016/IMWA2016_Nephalama_159.pdf

Ngemu, P. (2021). COAL MINING AT KHARSANG AND ITS ENVIRONMENTAL IMPACTS, CHANGLANG DISTRICT, ARUNACHAL PRADESH [Unpublished master's thesis]. Rajiv Gandhi University.

1 in 3 people globally do not have access to safe drinking water, 2019, accessed 13 June 2021, <https://www.who.int/news/item/18-06-2019-1-in-3-people-globally-do-not-have-access-to-safe-drinking-water-unicef-who>.

Sangita, G. U., Prasad, B., & Prasad, B. (2010). Studies on environmental impact of acid mine drainage generation and its treatment: an appraisal. *IJEP*, *30*(11), 953-967. https://doi.org/10.1201/9781351011259-4

Sarwar, S., Ahmmed, I., Mustari, S., & Shaibur, M. R. (2020). Use of weighted arithmetic water quality index (WAWQI) to determine the suitability of groundwater of Chaugachcha and Manirampur Upazila, Jashore, Bangladesh. *Biolog. Res*, *2*(2), 22-30.

Swer, S. and Singh, O.P., 2004, March. Status of water quality in coal mining areas of Meghalaya, India. In *Proceedings of the national seminar on environmental engineering with special emphasis on mining environment* (pp. 19-20). https://dspace.nehu.ac.in/bitstreams/d1274435-db91-47fe-b948-6c51265e015d/download

Singh, J., Yadav, P., Pal, A.K. and Mishra, V., 2020. Water pollutants: Origin and status. *Sensors in water pollutants monitoring: Role of material*, pp.5-20. https://doi.org/10.1007/978-981-15-0671-0_2

Talukdar, S. (2022). Seasonal variation of water quality index at raw water collection point of Saidabad water treatment plant and its impact on plant operations. https://doi.org/10.71097/ijsat.v16.i2.5861

Tiwary, R.K., 2001. Environmental impact of coal mining on water regime and its management. *Water, Air, and Soil Pollution*, *132*, pp.185-199. https://doi.org/10.1023/a:1012083519667

Tyagi, S., Sharma, B., Singh, P. and Dobhal, R., 2013. Water quality assessment in terms of water quality index. *American Journal of water resources*, *1*(3), pp.34-38. https://doi.org/10.12691/ajwr-1-3-3

Water for health enshrined as a human right 2002, accessed 12 June 2021, <https://www.who.int/news/item/27-11-2002-water-for-health-enshrined-as-a-human-right>.