

Groundwater quality assessment using Water quality index in Mendki and Surrounding Area of Bhramapuri Taluka of Chandrapur District, Maharashtra, India

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ABSTRACT: Water Quality Index is a tool not only to identify the status of the present water quality scenario with respect to priority of parameter against weight value but also to assess the allocation wise suitability towards quality of water. The present work is aimed at assessing groundwater quality using the water quality index (WQI) for the groundwater of Mendki and surrounding Area of Bhramapuri Taluka of Chandrapur District, Maharashtra, India. This has been determined by collecting 72 groundwater samples and subjecting the samples to a comprehensive physicochemical analysis for Major cations and anions as pH, TDS, Ca²⁺, Mg²⁺, Na⁺, K⁺, HCO₃⁻, Cl⁻, SO₄⁻, NO₃⁻ and F ions. For calculating the WQI, the following 9 parameters have been considered: total dissolved solids, total hardness, total alkalinity, calcium, magnesium, chloride, nitrate, sulphate, and fluorides. The high value of WQI has been found to be mainly from the higher values of nitrate, total dissolved solids, hardness, and bicarbonate in the groundwater. The nitrate appeared as a major problem of safe drinking water in this region. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination.

KEYWORDS: Water quality index (WQI), groundwater quality assessment, Chandrapur.

I. INTRODUCTION

Water is one of the most vital resources. It is essential to sustain life. Life, prosperity, and civilization rotate around water in the whole world. The availability of a water supply adequate in terms of both quantity and quality is essential to human existence. Early people recognized the importance of water from a quantity point of view (K. Sundara Kumar, 2015). Based on the fundamental quality, water is used in different purposes viz. domestic, agriculture, power and industry. Throughout the world groundwater pollution has become one of the most serious problems. Water pollution threatens human health, economic development and social success (Milovanovic 2007; Wakode et al. 2014; Tiwari et al. 2015). Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. Therefore, it becomes very important to regularly monitor the quality of groundwater and means to protect it (C. R. Ramakrishnaiah, C. Sadashivaiah and G. Ranganna 2009).

Water quality index is one of the most effective tools to understanding the overall water quality scenario of the area. A water index based on some very significant parameters can provide simple indication of water quality. In general, water quality and its suitability for drinking purpose can be examined by determining its quality index (Yogesh S. Patel, Dr. G.P.Vadodaria, 2015). Water Quality Index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water. It is calculated from the point of view of human consumption (Mufid-al-hadithi., 2012). In this regard, WQI assumes an important position in the water quality management. It is simple and easy to understand for decision makers about quality and possible uses of any water bodies (Ambiga K. et al., 2013). The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public (Abdul-Aziz Y. T. Al-Saffawi, Waffaa E. Al sinjari, Yasser A.J. AL-Tae, 2018).

The main objective of the present work is to discuss the suitability of groundwater for human consumption based on computed water quality index values. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities. Poor quality of

water adversely affected the plant growth and human health (Wilcox, 1984; Thorne and Peterson, 1954; US Salinity Laboratory Staff, 1954; Hen 1991).

II. STUDY AREA AND GEOLOGY

The proposed study area is about 287.35 sq.km. comes under survey of India toposheet 55P/15 and 55P/14 bounded by longitude 79°51'16.92"E and latitude 20°27' 51.62"N (figure 1). The climate here is generally hot and dry, whereas in the rainy season it is humid and the rainfall is quite heavy. The temperature in summer is more than 45 °C and in winter drops down to 10 °C. Geologically major part of study area is covered by unclassified gneisses of Archaean age. The granitic gneisses are represented by a number of basic and few of ultrabasic intrusive in the granitic rocks are seen. Mafic intrusion and mafic enclaves present within the granitic gneisses represent by meta basic rock amphibolites unconformably overlain by sedimentary rocks of Vindhyan Supergroup and overlain by thin cover of Gondwana Supergroup. Gondwanas are represented by yellow coloured sandstones of Kamthi Formation. Alluvium consisting of sand, silt and clays is covered along the river sections. (after DRM, CGWB, 1995).

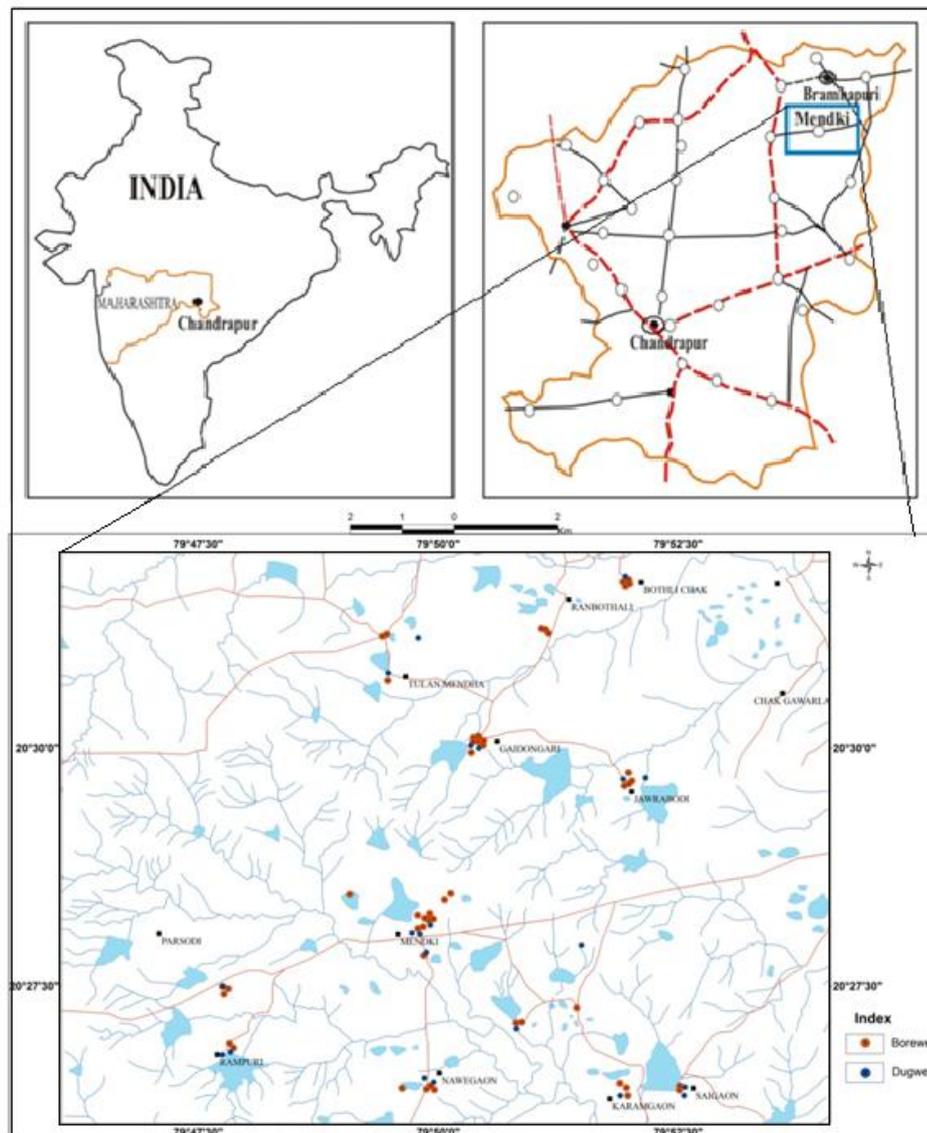


Fig. 1 Location map of study area

III. MATERIALS AND METHODS

A total of seventy two representative groundwater samples were collected (figure 1) from bore wells and dug wells have been collected during post-monsoon season of 2014. The sampling bottles were rinsed thoroughly with



distilled de-ionized water. Sample bottles were also rinsed with actual water samples. pH and electrical conductivity of the water samples were measured in situ using portable water analysis kit. The cations and anions were analyzed using standard methods (APHA 2005). HCO₃, Cl, Ca and TH were analyzed using titration. Na and K were determined by using flame photometer, SO₄, NO₃ and F was determined by digital spectrophotometer. TDS was obtained by the addition of all the cation and anion. The analytical precision of the ions measurement is determined by calculating the absolute error in ionic balance, which is found in all samples within a standard limit of +5 % (Domenico and Schwartz, 1998). Water quality index is calculated from the point of view of suitability of groundwater for human consumption. All the values are presented in milligrams per liter (mg/L) except the conductivity (µS/cm).

IV. RESULTS AND DISCUSSION

DRINKING GROUNDWATER QUALITY:

The chemical analyses of the groundwater and the percent compliance with the Bureau of Indian standards (BIS) and World Health Organization (WHO) are summarized in Table 1. The pH value of groundwater in the study area ranges from 6.9 to 8.5 (mean 7.55), indicating an alkaline nature of most of the groundwater samples. The pH values of all the collected groundwater samples are within the safe limit as prescribed by BIS (2012). Though pH has no direct effect on human health, but it shows close relations with some other chemical constituents of water (Pitt et al. 1999). TDS indicate the salinity behaviors of groundwater and in the study area it varies between 197 and 2,899 mg/l with an average value of 1257.2 mg/l. According to BIS (2012), the maximum permissible limit of TDS in groundwater is 2,000 mg/l and about 12.5% groundwater samples above the permissible limit (Table 1). Hardness is very important property of water from its domestic application point of view. The permissible limit of total hardness is 600 mg/l about 44.44% of groundwater samples above permissible limit according to BIS (2012) (Table 1). Total hardness (TH) in the study area ranges from 86 to 1576 mg/l with an average of 631.47 mg/l. Based on TH, Dufor and Becker (1964) classified water as 0–60, soft; 61–120, moderately hard; 121–180, hard and >180 very hard water. About 95.83% of samples belongs to very hard type and rest to hard type water.

The Na⁺ concentration in groundwater ranges from 45 to 471 mg/l with a mean of 213.6 mg/l. About 48.6% of groundwater samples have Na⁺ concentration above the permissible limit suggested by WHO (2011) (Table 1). Ca²⁺ and Mg²⁺ concentration varies in the range of 16 to 276 (average 72.76) and 17 to 279 mg/l (average 108.8), respectively. Ca²⁺ and Mg²⁺ values of all the collected samples are within the safe limit except one as prescribed by WHO(2011) and BIS (2012) (Table 1). The Cl⁻ concentration varies from 60 to 767 mg/l (average 297.03mg/l) in groundwater of study area. The permissible limit of Cl⁻ in potable water is 250 mg/l, which may be further relaxed up to 1,000 mg/l for Indian conditions (BIS 2012). Cl⁻ values of all the collected samples are within the safe limit. In the study area HCO₃⁻ ranges between 216 and 656 mg/l(average 406.33mg/l) and according to BIS (2012) about 2.77% of groundwater samples are above the permissible limit. SO₄²⁻ is a naturally occurring ion in almost all kinds of water bodies and plays an important role in total hardness of water. At higher concentration, SO₄²⁻ may cause gastro-intestinal irritation particularly when Mg²⁺ and Na⁺ are also present in drinking water resources. It varies from 32 to 320 mg/l and all the collected groundwater samples are within the safe limit (Table 1).

Table 1 Groundwater quality of shallow groundwater samples of study area

Sr. No	Parameters	BIS (2012)		WHO (2011)	
		PL	%of Samples above PL	PL	%of Samples above PL
1	pH	8.5	--	--	--
2	TDS	2000	12.5	1000	52.77
3	TH	600	44.44	500	56.94
4	Ca	200	1.38	200	1.38
5	Mg	100	48.61	150	1.83
6	Na	100	83.33	200	48.61
7	K	12	55.55	12	55.55
8	HCO3	600	2.77	--	--
9	Cl	1000	--	600	8.33
10	SO4	400	--	400	--
11	NO3	45	81.94	50	80.55
12	F	1.5	5.55	1.5	5.55

DL desirable limit. PL permissible limit – not suggested by WHO and/or BIS.



In pure water, NO₃⁻ is rarely present. The NO₃⁻ concentration varies from 1 to 310 mg/l(average 124.35 mg/l) in groundwater. About 81.94% of groundwater samples from have NO₃⁻ concentration above the tolerance limit of 45 mg/l (BIS 2012) (Table 1). NO₃⁻ was higher along highly agricultural areas may be due to leaching from plant nutrient and nitrate fertilizers (Freeze and Cherry 1979; Madison and Brunett 1984). The high concentration of fluoride is generally due to rocks containing fluoride minerals (Wenzel and Blum 1992; Bardsen et al. 1996). The concentration of fluoride in groundwater of the study area varies from 0.3 to 1.8 mg/l with a mean value of 0.96 mg/l. Fluoride is considered as an essential element though health problems may arise from either deficiency or excess amount (Gopal and Gosh 1985). More than 1.5mg/l shows dental fluorosis.

WATER QUALITY INDEX (WQI):

Water quality index (WQI) was used for evaluating the Composite influence of individual water quality parameter on the overall quality of water (Mitra et al. 2006; Yadav et al. 2015). It indicates a single number like a grade that expresses the overall water quality at a certain area and time based on several water quality parameters. Water quality index is calculated in three steps as explained below. For computing WQI of Groundwater, three steps are followed (Ramakrishnaiah et al., 2009).

In the first step, each of the 9 parameters has been assigned a weight (*Wi*) according to its relative importance in the overall quality of water for drinking purposes (Table 2).The maximum weight of 5 has been assigned to the parameter which is of major importance in water quality assessment.

In the second step, the relative weight (*Wi*) is computed from the following equation as it plays an insignificant role in the water quality assessment.

$$W_i = w_i / \sum_{i=1}^n w_i \dots (1)$$

Where the *Wi* is the relative weight, *wi* is the weight of each parameter and *n* is the number of parameters. Calculated relative weight *Wi* values of each parameter are given in Table 2.

In the third step, a quality rating scale (*qi*) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS (2012) and the result is multiplied by 100:

$$q_i = (C_i / S_i) \times 100 \dots(2)$$

Where, *qi* is the quality rating, *Ci* is the concentration of each chemical parameter in each water sample in mg/l, and *Si* is the Indian drinking water standard (BIS 2012) for each chemical parameter in mg/L.

For computing the WQI, the *Si* is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$$S_{Li} = W_i \cdot q_i \dots(3)$$

$$WQI = \sum_{i=1}^n S_{Li} \dots (4)$$

Table 2 Relative weight of chemical parameters

Parameter	BIS DL (Si)	Weight (wi)	Relative Weight (Wi)
TDS in mg/l	500	5	0.147
TA as CaCO ₃ in mg/l	200	2	0.059
TH as CaCO ₃ in mg/l	300	3	0.088
Ca in mg/l	75	3	0.088
Mg in mg/l	30	3	0.088
Cl in mg/l	250	4	0.118
SO4 in mg /l	200	4	0.118
NO3 in mg/l	45	5	0.147
F in mg/l	1	5	0.147
$\sum w_i=34$			

Where, *Si* is the sub index of *i*th parameter; *qi* is the rating based on concentration of *i*th parameter, and *n* is the number of parameters. The computed WQI values have been divided into five classes: (<50-excellent) to (>300-Unsuitable water) (Sahu and Sikdar 2008; Singh et al. 2016) is given in Table 3.

Table 3 Water Quality Classification based on WQI value

WQI	TYPE	No. of Sample	% Of samples
<50	EXCELLENT	1	1%
50-100	GOOD	11	16%
100-200	POOR	33	46%
200-300	VERY POOR	19	27%
>300	UNSUITABLE	7	10%

The results shows (Fig.2 and Table.3) that only 1% shows the ‘Excellent’ category, whereas 16% of the groundwater samples come under ‘Good’ water category; 46% of the samples belong to ‘Poor’ category; groundwater samples with 27% come under ‘Very Poor’ category and 10% have been registered under the ‘Unsuitable’ category. The average WQI for the post monsoon season belongs to ‘Poor’ category.

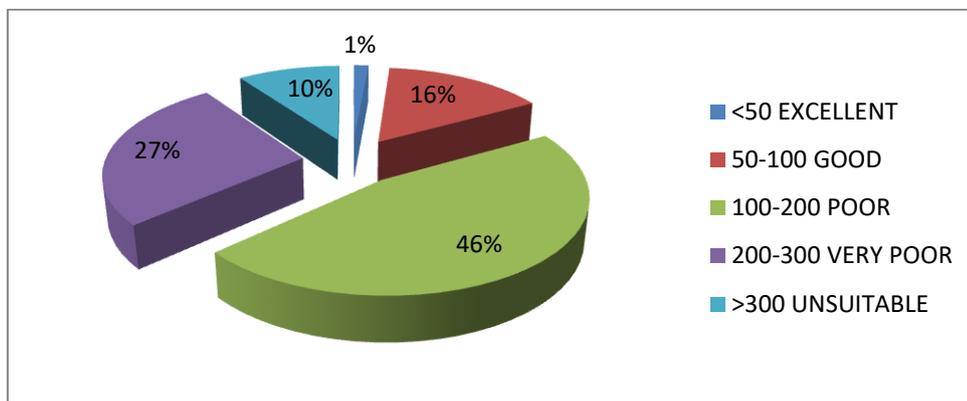


Fig.2. Pie graph showing water quality based on WQI

IRRIGATION GROUNDWATER QUALITY:

Electrical conductivity and Na⁺ play a vital role in suitability of water for irrigation. Higher EC in water creates a saline soil. Higher salt content in irrigation water causes an increase osmotic pressure in soil. The salts, besides affecting the growth of plants directly, also affect the soil structure, permeability and aeration, which indirectly affect plant growth (Subba Rao, 2006). The US Salinity Laboratory’s diagram (US Salinity Laboratory Staff, 1954) is used widely for rating the irrigation waters, where SAR is plotted against EC. The total concentrations of soluble salts in irrigation water can be classified into low (C1), medium (C2), high (C3) and very high (C4) salinity zones. The zones (C1–C4) have the value of EC less than 250, 250– 750, 750–2,250 μS/cm and more than 2,250 μS/cm respectively. The analytical data plotted on the US salinity diagram, (Fig. 3) illustrates that 45.83% of the groundwater samples fall in the field of C3-S1, indicating water of high salinity low sodium type, which can be used for irrigation in almost all types of soils with little danger of exchangeable sodium (US Salinity Laboratory Staff, 1954). About 27.77% samples fall under C4S2 showing very high salinity with medium sodium concentration; here soils constitute higher cation exchange capacity especially under low leaching conditions. About 6.94% of the groundwater samples fall in the field of C2-S1, indicating medium salinity–low sodium type. About 6.94% of the groundwater samples fall in the field of C3-S2, indicating high salinity–medium sodium type. This type of water can be used for irrigation with salt tolerant and semi tolerant crops under favorable drainage conditions.

The sodium absorption ratios (SAR): It is an important parameter for determining the suitability of irrigation water because is responsible for the sodium hazards. The SAR is computed, using the formula as (Hem, 1991):

$$SAR = Na^+ / \sqrt{(Ca^{2+} + Mg^{2+})/2}$$

The SAR values of all the groundwater samples from the study area are less than 10, and are classified as excellent for irrigation (table 4).

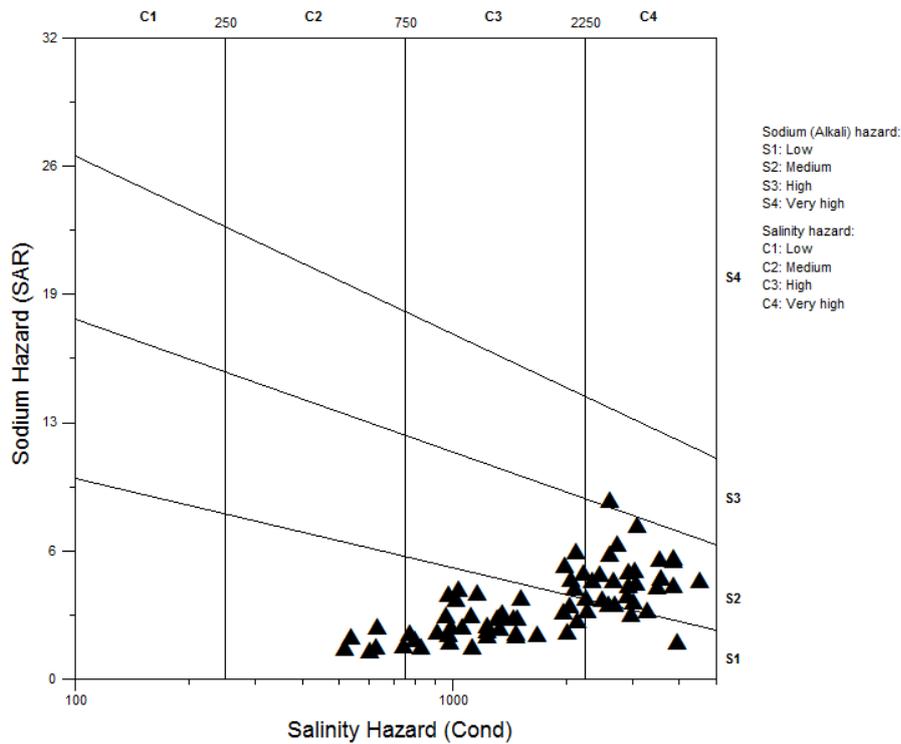


Fig. 3 Suitability of groundwater for irrigation in USDA diagram

Table 4 Classification of groundwater quality based on suitability of water for irrigation purposes.

Parameters	Range	Water Class	No. of samples (%)
SAR	<10	Excellent	72(100%)
	10 to 18	Good	...
	18 to 26	Doubtful	...
	>26	Unsuitable	...
RSC	<1.25	Good	70(97.22%)
	1.25-2.50	Doubtful	2(2.78%)
	>2.50	Unsuitable	0
Kelley's Ratio	<1	Suitable	61 (84.72%)
	01--2	Marginal	11 (15.27 %)
	>2	Unsuitable	0

Residual Sodium Carbonate (RSC): An excess sodium bicarbonate and carbonate influence the physical properties of soil by dissolution of organic matter in soil that leaves a black stain on its surface on drying. (Kumar et al., 2007a and b). This excess of sodium is called RSC and determined by the formula Ragunath (1987):

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

Where, all ionic concentrations are expressed in meq/l. Classification followed by Ragunath (1987) (table.4) shows that 97.22% the groundwater samples of the study area falls under good water class showing its suitability for irrigation.

Kelley's ratio is another classification used for irrigation purposes. The waters with low KI (<1) are suitable for irrigation while those with greater ratio are unsuitable (Sundaray et al., 2009). KI is calculated by the formula (Kelly, 1940).; where ions are expressed in meq/l.

$$KI = Na / (Ca + Mg)$$

The KR values show 84.72% groundwater samples falls under suitable water class. Whereas, 15.27% of samples show the 'Marginal Suitability' for the irrigational utility (table 4).

V. CONCLUSIONS

Groundwater samples analyzed in the study area are alkaline in nature. It has been found that lithology and anthropogenic activities played an important role in influencing chemistry of the groundwater. The results showed that the groundwater are hard (95.83%) and highly mineralized. Calcium and bicarbonate are the dominant cation and anion. The results revealed that groundwater samples were within permissible limits as prescribed by International (WHO) and National standards (BIS), for drinking and irrigation purposes. However, if possible, chlorination or boiling of water is necessary to avoid health implications. According to Davis and Dewiest's classification, 37% of groundwater samples are permissible for drinking and 52% are useful for agricultural purposes. About 81.94% of the groundwater samples have NO_3^- concentration above the tolerance limit of 45 mg/l and not suitable for drinking indicating anthropogenic activities. The WQI calculated exhibit poor quality in greater percentage when compared with the effective ionic leaching, over exploitation, and anthropogenic activities from discharge of effluents from agricultural, and domestic uses. The results of WQI show that 16% of the groundwater samples come under 'Good' category; 46% of the samples belong to 'Poor' category; 27% come under 'Very Poor' category and 10% have been registered under the 'Unsuitable' category. The value of SAR, RSC and TH shows its suitability of groundwater for irrigational purposes. Water quality in the study area is slowly reaching alarming stage so that proper planning is essential in this venture to preserve the fragile ecosystem.

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