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Evaluation of water quality index (WQI) for South Sindhudurg district

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Abstract
Groundwater is one of the important water resources because of its wide use for irrigation purpose. Due to urbanization and industrialization, quality of groundwater is rapidly declining. The present study was conducted to evaluate the groundwater quality and its suitability for irrigation purpose for South Sindhudurg district. The study was carried out with groundwater data collected from 2016-17 to 2020-21. The Water Quality Index was ascertained by considering multiple physio-chemical parameters like pH, Electrical Conductivity, Total Dissolved Solids, Total Hardness, Alkalinity, Calcium, Magnesium, Sodium and Potassium. The spatial distribution map of WQI was generated using the Raster Interpolation technique, Inverse Distance Weighted (IDW) in QGIS software. The result shows that the groundwater in the study area is in 'Excellent' category which means it can be used for irrigation purpose.

Keywords: Groundwater, water quality index (WQI), irrigation, spatial distribution, QGIS

Introduction

Water is the foremost requirement for the assistance of life on this earth. Water is essential for nearly all forms of life, and is usually obtained from two sources: surface water, including streams, canals, and freshwater lakes and rivers; and groundwater, such as borehole and well water. (Hasan *et al*. 2017) [8]. As most of the Earth's water is saline, it is not suitable for human consumption as well as human activities like irrigation of crops, fish farming and any other agricultural activities.

All over the world, groundwater is used for domestic and industrial water supply and irrigation. Approximately 230 km^3 of groundwater is used annually, with India being the largest user in the world. Moreover, 60% of the groundwater is used for irrigation, while 85% is used for India's drinking supplies. (CGWB, 2014) [5]. Nowadays groundwater is gaining more importance due to drought problem, rural water supply and low cost of development it requires. The availability and quality of groundwater is being affected by rapid urbanization, particularly in developing countries such as India.

The quality of ground water is equally important as that of quantity. The study of the quality of groundwater has revealed whether or not the water is suitable for agricultural and other uses. Whenever groundwater is used as irrigation water the quality is important for successful crop production. The poor quality of the irrigation water may affect crop yields and soil also. Therefore, water quality analysis is one of the most important aspects in groundwater studies.

For evaluation of the suitability of groundwater quality for irrigation, Water Quality Index (WQI) is a fast and effective tool. A single number is derived from a variety of mathematical operations to transform a large quantity of water quality information, allowing a decision-maker to make an informed decision regarding water quality and its applications. (Al. Maliki *et al*. 2020) [1]. A water quality index (WQI) is easy way to understand the general water quality status of a water source and hence it can be used for both surface and ground water quality assessment. The aim of the study is to evaluate the ground water quality for South Sindhudurg district.

Materials and Methodology

Sindhudurg district is situated in the Konkan region, covering an area of 5207 sq.km. Its boundaries are between 15°37' and 16°40' north latitude and 73°19' and 74°13' east longitude, stretching along the Arabian Sea coast for 720 km. The average annual rainfall of the district ranges from 3500 to 4000 mm, making it a part of the 'Assured and High Rainfall zone'. The climate is generally humid. December is the coldest month with mean daily maximum temperature at 32.7 °C and the mean daily minimum temperature at 18.7 °C.

April is the hottest month. Rrelative humidity during the southwest monsoon is very high (86-90%) and during winter and summer months is above 57%. (CGWB 2014) [5]. The study area includes four talukas of the district are Sawantwadi, Vengurla, Kudal and Dodamarg.

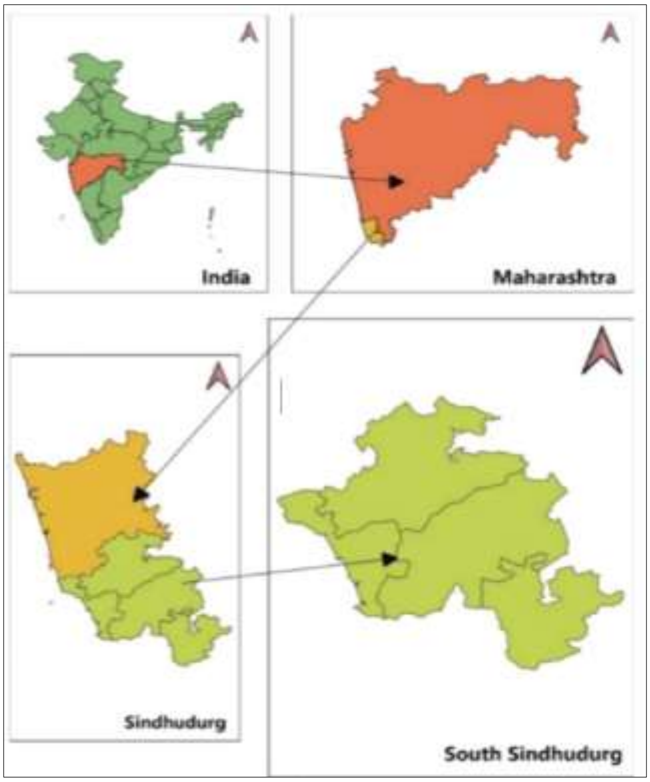

Fig 1: Study area

Methodology

Water Quality Index (WQI)

The water quality index is calculated to simplify the vast amount of ground water quality data into one numerical value generally with no dimension in simple way. Calculating a water quality index is an important technique for distinguishing groundwater quality and assessing its suitability for domestic and agricultural use.

The eleven important parameters are considered for calculation of water quality index. The WQI used in this study has been taken from the recommendation giving the irrigation water quality standards. In the present study weighted arithmetic index method has been used to fix the WQI of the water.

WQI worked out depend on following process-

The recommended standards for the corresponding water quality parameters are inversely proportional to the weighting (Wi) of the various parameters-

Unit weight (Wi) was calculated by using the following formula:

$$Wi = k/Si \quad (1)$$

Where,
k = proportionality constant,
Si = Standards desirable value of parameter.

Sub index (Qi) is a measure that expresses the relative value of a parameter in a situation where the water is polluted, taking into account the concentration of the parameter relative to its allowable standard value. It is calculated using the following equation:

Sub index (Qi) was calculated by using,

$$Qi = 100[(Vi – Vo) / (Si – Vo)] \quad (2)$$

Where,
Vi = Concentrate of parameter in analysed water,
Si = Standards desirable value of parameter,
Vo = Ideal value from standard table (pH = 7 and 0 for all parameters)

WQI was calculated by using following formula,

$$WQI = \Sigma WiQi / \Sigma Wi \quad (3)$$

(Deepika and Singh, 2015) [7].

Table 1. Classification of water quality based on weighted arithmetic WQI method

WQI	Status
0 – 25.0	Excellent
25.1 – 50.0	Good
50.1 – 75.0	Poor
75.1 – 100	Very Poor
> 100	Unsuitable

(Horton, 1965) [9]

The spatial distribution of all groundwater quality parameters is shown in a GIS map and the WQI was prepared using the Inverse Distance Weighted (IDW) technique. The pH, EC, TDS, Al, Cl, Total hardness, SO_4, Ca, Na, K parameters have been used to calculate WQI in the study area.

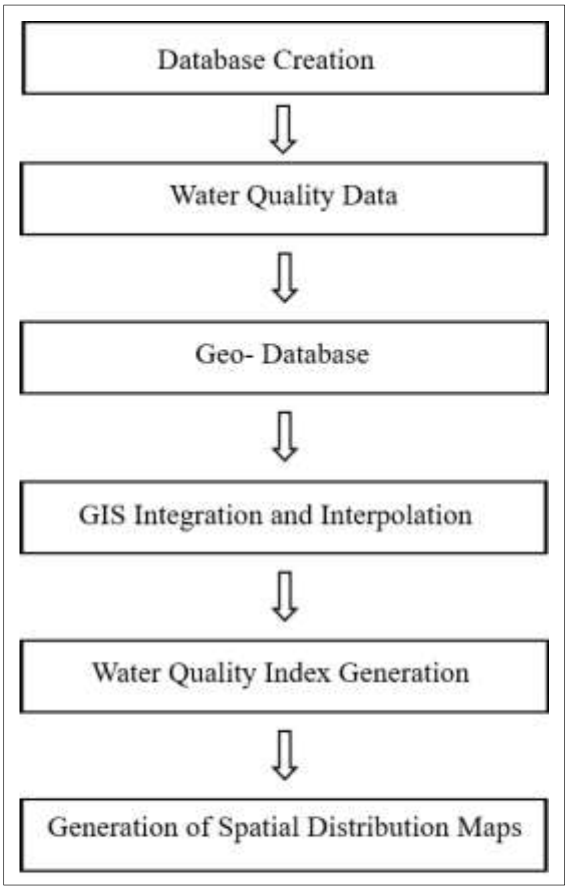

Fig 1: Flow chart of generation of WQI map

The degree to which the soluble salts in the irrigation water can harm soil properties and affect crop yield must be assessed in order to evaluate the quality of the water. To evaluate the quality of irrigation water, this standard has been used.

Table 2: Standard values for water quality parameters for irrigational use

Parameter	Standards Value
pH	6.5-8.5
Electrical Conductivity	2250
TDS	1500
Alkalinity	100
Chloride	600
Sulphate	1000
Calcium	0-400
Magnesium	0-60
Sodium	0-200
Potassium	0-10
Total Hardness	300

(Chaudhary and Satheesh kumar, 2018)

Result and Discussion

The relative weight (Wi) of each physicochemical parameter and the proportionality constant k are calculated in order to calculate the WQI index and evaluate the water quality as shown in Table 3.

Table 3: Water quality parameters, their standards, and assigned weights

Parameter	Standard, Si	1/Si	K	Wi
pH	8.5	0.117647	3.862125	0.454368
EC	2250	0.000444	3.862125	0.001716
TDS	1500	0.000667	3.862125	0.002575
Alkalinity	100	0.01	3.862125	0.038621
Cl	600	0.001667	3.862125	0.006437
SO_4	1000	0.001	3.862125	0.003862
Total Hardness	300	0.003333	3.862125	0.012874
Ca	400	0.0025	3.862125	0.009655
Mg	60	0.016667	3.862125	0.064369
Na	200	0.005	3.862125	0.019311
K	10	0.1	3.862125	0.386212
	Total	0.258925		1

Water quality index maps

Water quality index map (2016-17)

The whole area categorized into 5 Classes such as Excellent, Good, Poor, very poor and Unsuitable. Maximum 81.41 % (2026.13 km^2) area falls under excellent class which represent the groundwater has no limitations to use and is suitable for irrigation. 0.18 % (4.49 km^2) area comes under unsuitable class.

Water quality index map (2017-18)

Out of 2488.75 km^2, 81.83 percent (2036.49 km^2) area comes under excellent category, 17.86 percent (444.44 km^2) under good, 0.31 percent (7.78 km^2) under poor category and 0.001 percent (0.03km^2) under very poor category.

Water quality index map (2018-19)

For year 2018-19, the 53.26 percent (1325.54 km^2), 46.60 percent (1159.72km^2) and 0.14 percent (3.49 km^2), area was found to be under excellent, good and poor class, respectively.

Water quality index map (2019-20)

The studied area is divided into five classes based on the suitability of groundwater for irrigation. 69.90 percent (1739.71 km^2) groundwater falls under excellent class and 29.27 percent (728.54 km^2) under good class. 0.03 percent (0.86 km^2) groundwater falls under unsuitable area.

Water quality index map (2020-21)

Out of total 2488.75 km^2 area, 74.63 percent (1857.27km^2) area comes under excellent category, 25.01 percent (622.51 km^2) under good, 0.30 percent (7.51 km^2) under poor category, 0.04 percent (1.06 km^2) under very poor category and 0.02 percent (0.40 km^2) under unsuitable category.

Similar results were observed in Bhange *et al.* 2016 [4] and Bhange *et al.* 2018 [3] which was also carried out for the Konkan region.

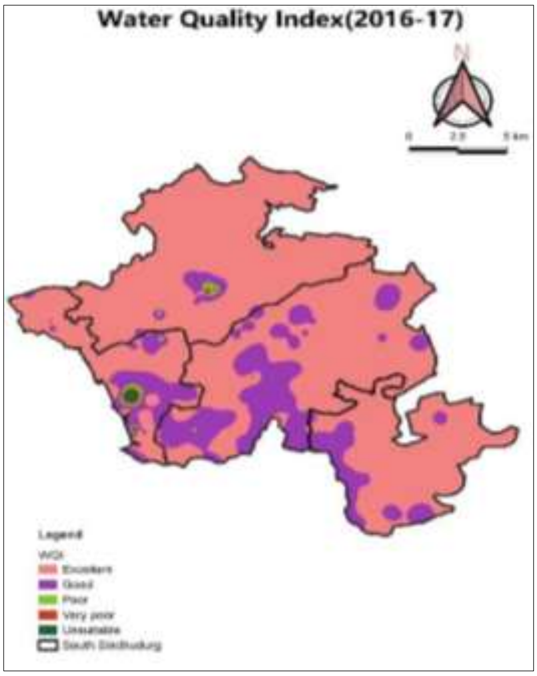

Fig 2. Spatial distribution of WQI (2016-17**)**

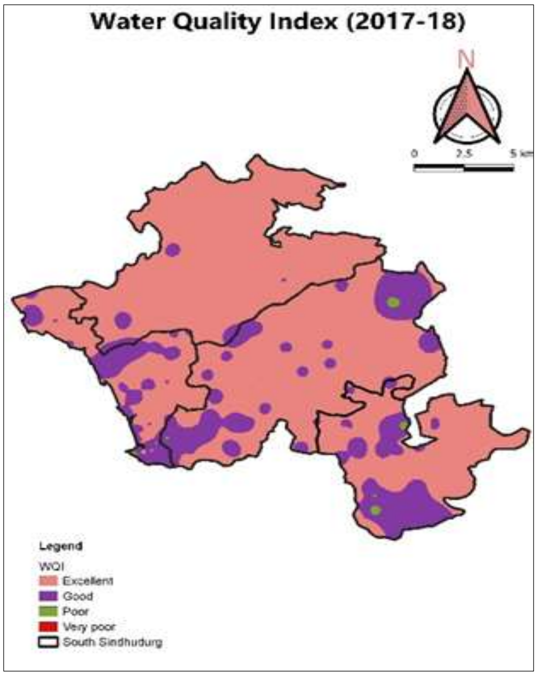

Fig 3: Spatial distribution of WQI (2017-18)

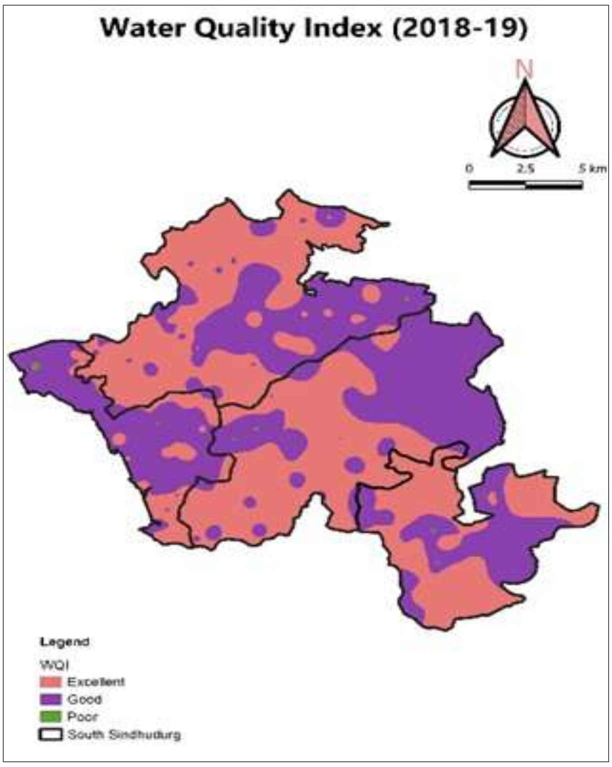

Fig 4: Spatial distribution of WQI (2018-19)

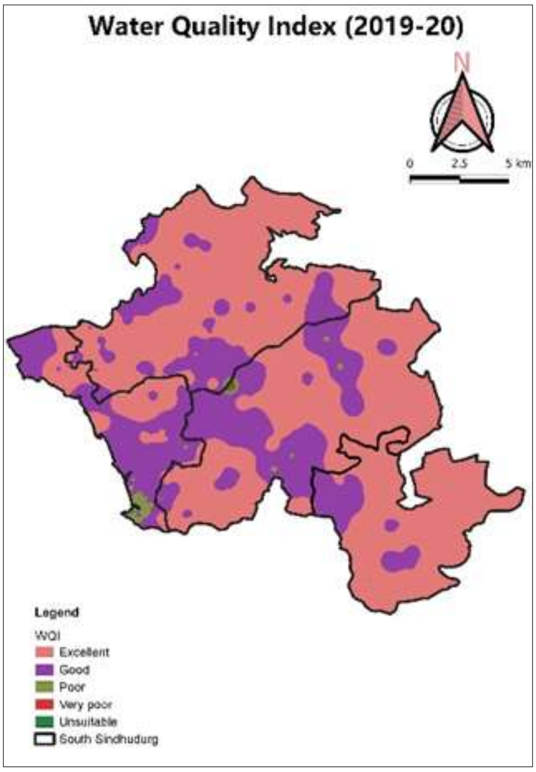

Fig 5: Spatial distribution of WQI (2019-20)

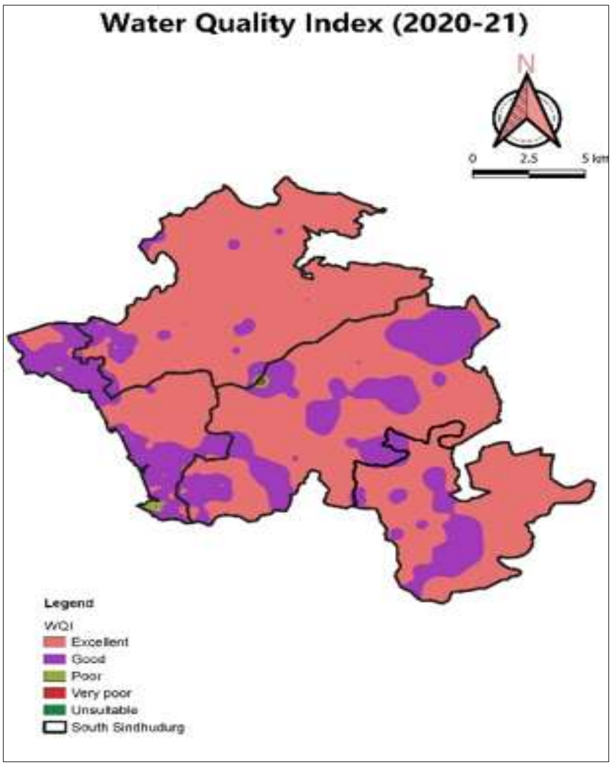

Fig 6: Spatial distribution of WQI (2020-21)

Table 4: Water quality index categorized classes and its area

S. N	Year	Class	Area (km^2)	Area (%)
1	2016-17	Excellent	2026.13	81.41
		Good	443.76	17.83
		Poor	10.99	0.44
		Very poor	3.38	0.14
		Unsuitable	4.49	0.18
2	2017-18	Excellent	2036.49	81.83
		Good	444.44	17.86
		Poor	7.78	0.31
		Very poor	0.03	0.001
3	2018-19	Excellent	1325.54	53.26
		Good	1159.72	46.60
		Poor	3.49	0.14
4	2019-20	Excellent	1739.71	69.90
		Good	728.54	29.27
		Poor	18.44	0.74
		Very poor	1.20	0.05
		Unsuitable	0.86	0.03
5	2020-21	Excellent	1857.27	74.63
		Good	622.51	25.01
		Poor	7.51	0.30
		Very poor	1.06	0.04
		Unsuitable	0.40	0.02

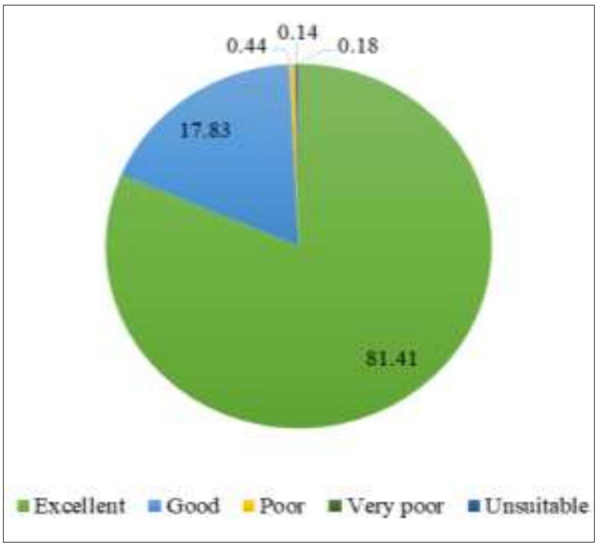

Fig 7: Pi chart for suitable percent area of WQI (2016-17)

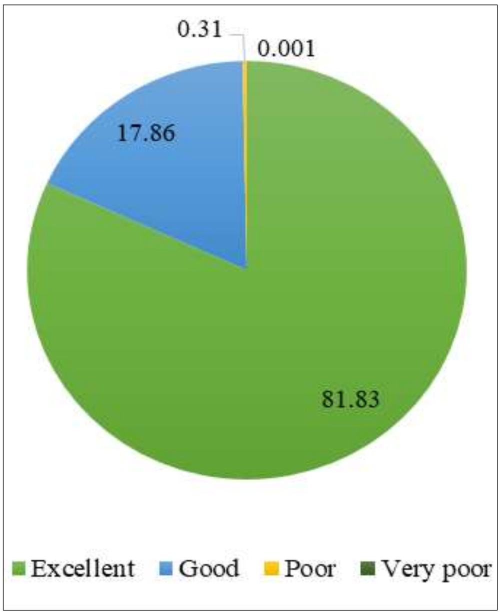

Fig 8: Pi chart for suitable percent area of WQI (2017-18)

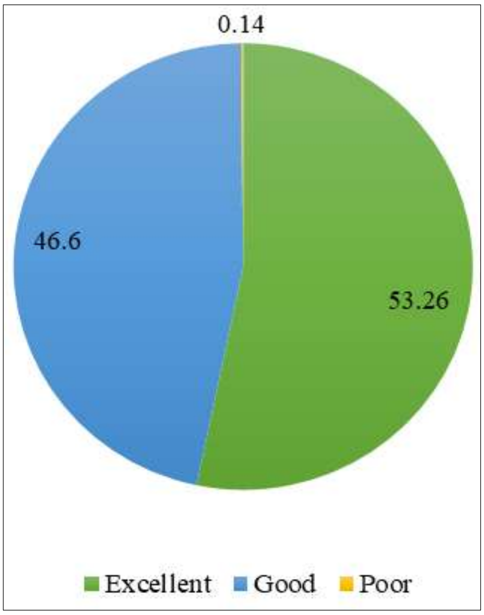

Fig 9: Pi chart for suitable percent area of WQI (2018-19)

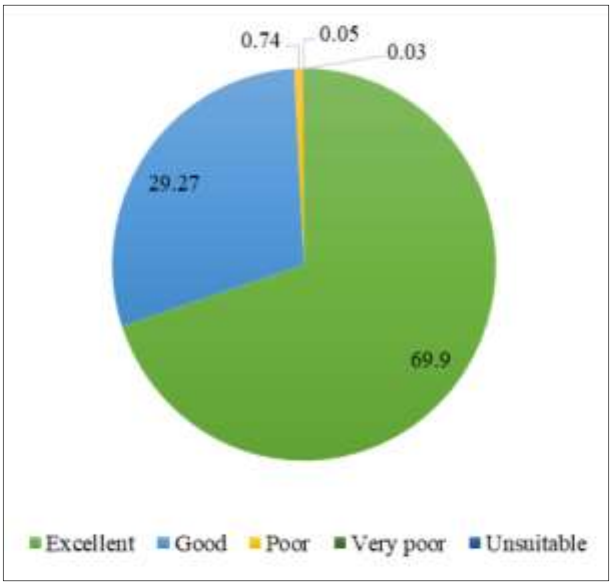

Fig 10: Pi chart for suitable percent area of WQI (2019-20)

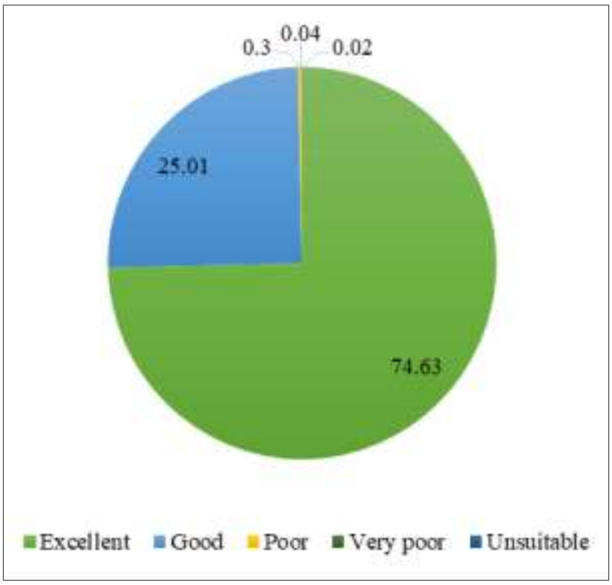

Fig 11: Pi chart for suitable percent area of WQI (2020-21)

Conclusions

For the present study, groundwater quality was analyzed for 4 tehsils of South Sindhudurg district. For assessment of WQI, different groundwater quality parameters were analyzed for five years data. Water Quality Index (WQI) maps were prepared from spatial distribution map of Groundwater quality parameters like pH, EC, TH, TDS and more. From five years, WQI maps we can conclude that maximum area 81.41 percent (2016-17), 81.83 percent (2017-18), 53.26 percent (2018-19), 69.90 percent (2019-20) and 74.63 percent (2020-21) came under excellent category. It shows that groundwater can be used directly without any limitations for irrigation purpose in the study area. Also, The QGIS software was found to be suitable for predicting the water quality necessary for irrigation. It can be even used with limited data conditions. Hence, The Water Quality Index (WQI) technique is useful tool for evaluating the overall quality of water used for irrigation.

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