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PIG Based Water Quality Assessment in West Suvarnamukhi River Basin, Karnataka, India

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Abstract

Groundwater quality depends on the quality of precipitation, recharging water, surface water and sub-surface geochemical processes. Changes in the constituents of the recharging water and human intervention cause changes in groundwater quality. Water pollution affects both water quality and human health. Hence it is essential for continuous monitoring of the quality of groundwater so that pollution can be minimized. The computed values of Pollution Index of Groundwater (PIG) for West Suvarnamukhi River Basin varies from 0.67 to 2.02. The Insignificant pollution zone covers an area of 78.6%, 14.4% by Low pollution, 5.5% by Moderate and about 1.47% of High pollution zone. Spatial variation map has been prepared using GIS. The variation map depicts that most of the study area accounts for Insignificant pollution zone (78.6%). Spatial distribution map reveals that the higher values of Ow in moderate and highly polluted zones is mainly due to geogenic, anthropogenic factors and also it is compounded due to agricultural activity. The results obtained from the study indicates that groundwater is suitable for both drinking and domestic purpose in general, except in few cases.

Keywords: Water Quality , PIG, Spatial Variation, Geogenic, Anthropogenic, Agro inputs.

Introduction

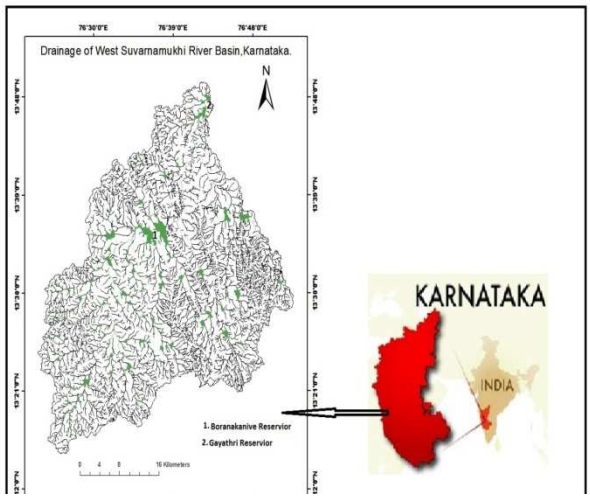
Groundwater is an important source for domestic, agricultural and industrial use. Economic growth, increased population and other developmental activities have resulted in demand for water resource. This is also a cause for degradation of its quality. Changes in topography and drainage system directly affect both quantity and quality of the groundwater. For the past few decades water pollution has become a major problem in many developing countries including India. The groundwater pollution is due to either natural or anthropogenic activities. Groundwater quality depends on the quality of recharging precipitation, recharging water, surface water and sub-surface geochemical processes. Water pollution affects both water quality and human health. Due to this fact, it becomes essential for continuous monitoring of the quality of groundwater so that pollution can be minimized.

Water quality is influenced by natural and anthropogenic effects including local climate, geology and agricultural practices. The quality is a function of the physical, chemical and biological parameters and could be subjective, which depends on the intended use. There are different ways for assessing water quality. One of the technique for demarcating groundwater quality and its suitability for domestic purposes is Pollution Index of Groundwater (*PIG*). It is a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption (Brown,1972). It serves in understanding of water quality by integrating complex data and generating a

score that describes water quality status (Mishra and Naik, 2011). In this context an attempt has been made to quantify the pollution for the present study area.

Study Area

The West Suvarnamukhi river is a major tributary of Vedavati river, flowing in Tumkur and Chitradurga districts of Karnataka. The river basin lies between Lat.13^0 15' to 13^0 55' N and Long. 76^0 20' to 76^0 55' E (Map 1). The areal extent of the basin is 1745 sq. kms. The highest elevation in the basin is 1071m. noticed at Venkajjigudda to the east of Chikkanayakanahalli and a minimum elevation of 673m. is seen near Javagondanahalli. Other prominent topographic features within the basin are Chikkanayakanahalli Schist belt and Javagondanahalli belt. The major part of the basin lies in Tumkur district and a small northern portion of the basin is in Chitradurga district. The NH- 4 passes through the northern end of the basin near Javagondanahalli. Bangalore-Shimoga State Highway passes close to the Southern boundary of the basin. No



Map: 1Study Area

railway line passes through the basin. The nearest airport is Bangalore, which is 135 Kms.

Methodology

In West Suvarnamukhi river basin 152 groundwater samples were collected from various locations. The samples were analyzed for pH, EC, major cations *viz.*,Calcium, Magnessium, Sodium, Potassium and anions *viz.*, Sulpate, Chloride, Nitrate and Bicarbonate by adopting standard analytical procedures. The analyzed data has been used in the computations. The standards for drinking purposes as recommended by WHO and BIS have been considered for the calculation of *PIG* (Davis and Dewiest 1966 and Holden 1970).

There are different steps for computing *PIG* which includes assigning a weight to each chemical parameter according to its relative importance in the overall quality. *PIG* is a mathematical equation used to transform large number of water quality data into a single number. It is simplest method to know about quality and possible use of the water body.

Computation of Pollution Index of Groundwater (*PIG*)

PIG is a technique of rating which provides the composite influence of individual water quality parameters on overall quality of water for human consumption (Horten,1965). *PIG* is a mathematical tool to integrate the complex water quality data into a numerical score that describes the overall water quality status. The computation of *PIG* involves the following steps.

Relative Weight (*Rw*)

Each Chemical parameter is assigned a weightage by keeping its impact on human health into consideration. The range of numerical magnitude of Relative weight ranges from 1 to 5 (Table - 1). For instance the parameters like pH, F, NO_3, SO_4 are assigned the *Rw* 5 and Na, Cl as 4 and Ca, Mg as 2 respectively. The lower values of *Rw* indicates lesser impact of respective chemical parameters on health and higher values have more impact over human health.

Computation of Weight Parameter (*Wp*)

Weight parameter is the ratio of *Rw* of every water quality measure to the sum of all relative weights. Weight parameter enables to know about the relative share of each water quality measure on overall water quality. The *Wp* is given by the equation;

$$Wp = \frac{\mathrm{Rw}}{\sum \mathrm{Rw}}$$

Status of Concentration (*Sc*)

Status of concentration is the ratio of concentration of each water quality measure of every water sample (C) to its respective drinking water quality standards (Ds). The *Sc* of each water quality measure is computed by the equation;

$$Sc = \frac{\mathrm{C}}{Ds}$$

Const. (mg/l.)	Relative Weight	Weighted Parameter	BIS
Ca	2	0.052	75
Mg	2	0.052	30
Na	4	0.105	200
K	1	0.026	10
Cl	4	0.105	250
SO_4	5	0.131	150
NO_3	5	0.131	45
F	5	0.131	1.20
HCO_3	3	0.026	300
EC (ms/cm)	2	0.052	1400
pH	5	0.131	7.5

Table - 1: Weightage scheme

Overall Water Quality (*Ow*)

The overall water quality is computed by taking the product of each water quality measure with its corresponding status of concentration. *Ow* reflects overall water quality and also enables to understand the nature of weight parameter with respect to concentration of each water quality measure. *Ow* is calculated by;

$$Ow = Wp * \mathrm{Sc}$$

Pollution Index of Groundwater (*PIG*)

PIG is calculated by the addition of all the values of *Ow* contributed by all the water quality measures of each water sample. *PIG* is given by;

$$PIG = \sum Ow$$

PIG Classification

The classification of *PIG* is based on water quality standard for drinking purpose. *PIG* classification could also be used in the assessment of groundwater contamination. When both the values of quality of particular water sample and concentration of water quality measure are same then their impact on health could be insignificant. With an account of this, when the *PIG* value is less than 1.0, it could be considered as a non-pollution index and when *PIG* exceeds more than 1.0, then it may be the contribution from a contaminant into an aquifer thus polluting.

PIG	Quality Status
0 - 1	Insignificant Pollution
1 - 1.5	Low Pollution
1.5 - 2	Moderate Pollution
> 2	High Pollution

PIG based Pollution Zones

Result and Discussion

Const. (mg/l.)	Max	Min	Mean	S.D	Coef. of var.
Ca	314	8	81.3	61.1	75.15
Mg	196	3	43.5	30.3	69.65
Na	690	20	135.6	102	75.22
K	90	0	12	14.6	121.6
Cl	840	20	176.6	151.1	85.56
SO_4	583	7	86.8	86.1	99.53
NO_3	237	1	56	45.8	81.78
F	2.2	0.5	0.8	0.4	50
HCO_3	911	83	372.1	154.7	41.57
EC (ms/cm)	6400	400	1394	826.3	59.27
pH	8.9	7	7.6	0.4	5.26

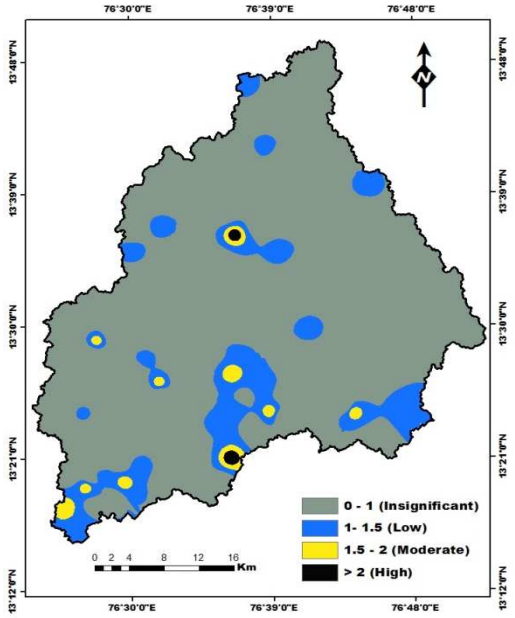
Table - 2: Composition of groundwater

The study area has pH varying from 7 to 8.9 with an average of 7.6. The desirable limit of pH for drinking water is 7 to 8.5. EC of the groundwater varies from 400 to 6400 microsiemens/cm at 25^{o}C with an average of 1394. The Calcium value in the study area ranges from 8 mg/l to 314 mg/l with an average of 81 mg/l. The Magnesium value ranges from 3 mg/l to 196 mg/l with an average of 43 mg/l. The average Sodium content for the study area is 135 mg/l, ranging from 20 mg/l to 690 mg/l. Potassium concentration is found varying from traces to 90 mg/l, with an average of 12 mg/l in groundwater. The Sulphate concentration varies from 7 mg/l to 583 mg/l. with an average of 86 mg/l. Chloride concentration in the study area ranges from 20 mg/l to 840 mg/l with an average of 176 mg/l. Nitrate concentration varies from 1 mg/l to 237 mg/l with an average of 56 mg/l. Fluoride concentration ranges from 0.5 mg/l to 2.2 mg/l. with an average of 0.8 mg/l. Statistical parameter of the analytical results of groundwater is given in Table – 2 below.

PIG values are computed for water quality measures in West Suvarnamukhi River Basin. In the study basin the *PIG* values varies between 0.674 to 2.033. According to the *PIG* classification, about 78.6% of the total groundwater samples represents insignificant pollution zone in the study area.14.4% as Low pollution, 5.5% as Moderate and about 1.47% as High pollution zone. The relative contribution of concentration of water quality measure of each water sample is taken into consideration, if *Ow* is more than 0.1(which is the 10% of the value of 1.0 of *PIG*). This gives a clear picture on impact of pollution on groundwater system.

Spatial variation map has been prepared using GIS. The variation map (Map-2) depicts that Insignificant pollution zone by 78.6% is covering the study area. Low pollution zone is spread randomly throughout the basin and few pockets of moderately polluted zones are observed in southern portion of the basin.

Map:2 Spatial distribution of pollution zones



However a few pockets of high pollution zone are observed in central and southern portion of the basin i.e., in and around Huliyar and Jayachamarajapura.

Generally *PIG* value of Insignificant zone ranges from 0 to 1. However in the present investigation overall *PIG* value of Insignificant zone is 0.64. But in Insignificant zone only NO_3 (0.10) and pH (0.13) have *Ow* equal/more than 0.1. The remaining chemical parameters *Viz.*, Ca (0.04), Mg (0.05), Na (0.05), K (0.02), SO_4 (0.05), Cl (0.05), HCO_3 (0.09) EC (0.04) and F (0.02) which are less than 0.1 are natural contributors under normal condition. The variation of NO_3 from 1 to 273 (Table-2) is mainly due to agro inputs and to some extent lithology also. But in case of pH ranging from 7 to 8.9 is mainly due to HCO_3.

Ow value of Low pollution zone ranges from 1 to 1.5 and overall *PIG* value is 1.42. The water quality parameters *Viz.*, Ca (0.10), Mg (0.12), Na (0.13), SO_4 (0.16), NO_3 (0.28), Cl (0.16), HCO_3 (0.14) and pH (0.13) which are 0.1 and above (Table-3). But K (0.06), EC (0.09) and F (0.01) are the parameters having less than 0.1. The above said parameters except K, EC and F were in insignificant pollution zone. The high value *Ow* in case of Na, SO_4, NO_3 and Cl

is due to both geogenic and anthropogenic sources.

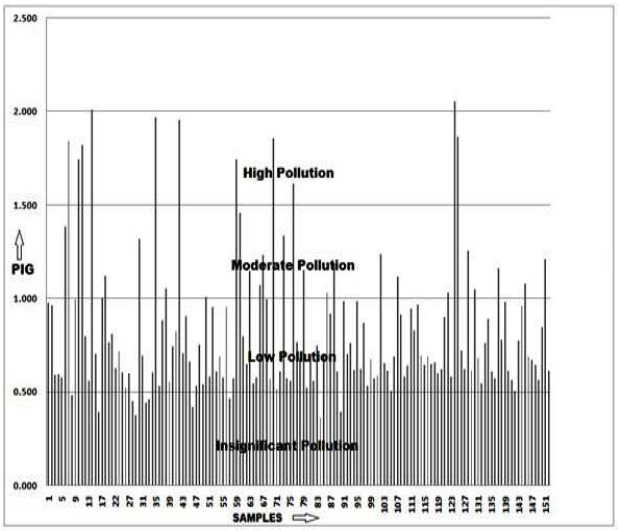


Fig.1: *PIG* values and Pollution Intensity

polluted zone has an average *Ow* value of 1.8.

In Moderate pollution zone *Ow* ranges from 1.5 to 2. The groundwater in the Moderately But the chemical parameters *Viz.*, Ca (0.11), Mg (0.17), Na (0.18), SO_4 (0.24), NO_3 (0.35), Cl (0.21), HCO_3 (0.16), EC (0.12) and pH (0.13) which are greater than 0.1. However K (0.07) and F (0.01) are the only two parameters which have *Ow* less than 0.1. The reason for the chemical parameters having *Ow* more than 0.1 is due to geogenic as well as anthropogenic factors along with the agro inputs. The groundwater samples from High pollution zone have a *Ow* value greater than 2.0 but the average *Ow* value in this zone for the study area is 2.02. The chemical parameters *Viz.*, Ca (0.20), Mg (0.15), Na (0.11), SO_4 (0.50), NO_3 (0.47), Cl (0.19), EC (0.15) and pH (0.13) which have *Ow* greater than 0.1. But parameters *Viz.*, K (0.03), HCO_3 (0.08) and F (0.001) are the three parameters where *Ow* is less than 0.1. Hence the chemical parameters with *Ow* greater than 0.1 in High pollution zone is attributed to geogenic, anthropogenic origin and chemical fertilizers in agricultural activity.

Conclusion

The computed values of *PIG* for West Suvarnamukhi River Basin varies from 0.67 to 2.02. However 78.6% of total groundwater samples lies in Insignificant pollution zone, 14.4% in Low pollution, 5.5% in Moderate and 1.47% in High pollution zone. Spatial variation map is prepared in GIS. The variation map depicts that most of the study area accounts for Insignificant pollution zone (78.6%). Low pollution zone is spread randomly throughout the basin and few pockets of moderately polluted zones are observed in southern portion of the basin. A few pockets of high pollution zone are seen in central and southern portion of the basin. Spatial distribution map reveals that the higher values of *Ow* in the moderate and highly polluted zones is mainly due to geogenic and anthropogenic factors. Even the agro inputs are a source for some of the anomalies seen and explained. Hence it can be concluded that groundwater in the basin is suitable for both drinking and domestic purpose based of pollution index of groundwater.

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PIG	Ca		Mg		Na		K		SO4		NO3		Cl		HCO3		EC		pH		F	
	mg/l	Ow	mg/l	Ow	mg/l	Ow	mg/l	Ow	mg/l	Ow	mg/l	Ow	mg/l	Ow	mg/l	Ow	ms/cm	Ow		Ow	mg/l	Ow
Insignificant Pollution Zone																						
0.645	67	0.040	28	0.05	108	0.05	9.52	0.02	62	0.05	36	0.10	117	0.05	338	0.09	1056	0.04	7.51	0.13	0.8	0.02
Low Pollution Zone																						
1.424	152	0.101	72	0.12	269	0.13	26	0.06	193	0.16	97	0.28	404	0.16	570	0.14	2860	0.09	7.53	0.13	0.75	0.01
Moderate Pollution Zone																						
1.802	173	0.115	107	0.17	362	0.18	30	0.07	279	0.24	123	0.35	535	0.21	631	0.16	3793	0.12	7.60	0.13	0.71	0.01
High Pollution zone																						
2. 02	314	0.209	92	0.15	234	0.11	14	0.03	583	0.50	159	0.47	468	0.19	317	0.08	3400	0.15	7.50	0.13	0.25	0.009

*** The values are avg. of that pollution zone**

Table – 3. Classification of Pollution Zones based on PIG values.