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Research Article

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One-Way ANOVA, Tukey HSD, Scheffe, Bonferroni and Holm Multiple comparison tests for Physico-chemical Parameters in Four Water Bodies of Davangere District, Karnataka

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Abstract: Surface water samples were collected for physico-chemical analysis during 2016-17 from four water bodies (Hadadi lake, Gonivada lake, Lokikere lake and Shagalealla) of Davanagere district , Karnataka. The main objectives of this study is to analyse various parameters such as pH, EC, turbidity, total alkalinity, total dissolved solids, chloride, total hardness, calcium, sodium, sulphate ,nitrogen and potassium. One-way ANOVA, Tukey HSD test with Scheffe, Bonferroni and Holm multiple comparison for the water quality parameters were carried out. pH of all the four water bodies are alkaline in nature with the total hardness included under hard to very hard category. Most of the water quality parameters are highest in Shagalehalla due to the agricultural runoff from the surrounding areas and human anthropogenic activities. One Way ANOVA for physical parameters depicted "F statistic value of 52.1265 with a "P" value of 1.112. Similarly, for chemical parameters "F"value and "P" values are 29.3941 and 5.6732 respectively. The p-value consequent to the F-statistic of one-way ANOVA is lower than 0.05 level and Tukey's HSD test to each of the six pairs of water quality parameters them exhibits statistically significant difference, We Compared the outcome against drinking water quality standards as per WHO and BIS, and it is observed that water samples from these water bodies are potable for human consumption after proper treatment due to moderate levels of pollution as per the physico-chemical data. It is concluded that the physico-chemical characteristics of the water indicates that the water bodies are moderately eutrophic in nature and there is an urgent need of preventive measures.

Keywords: Water quality, Hadadi lake, Lokikere lake, Gonivada lake, Shagalehalla,One Way-ANOVA,Tukey HSD test.

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1. INTRODUCTION

Water is an elixir of life and is an essential need of all the living creatures. It is a significant commodity accessible in extremely constrained amounts to man and other living beings. Lentic water bodies may have been regular water sources abused by man at various opportunities to address various issues or may have been made for a huge number of various reason[1] .Physico-chemical factors are created based on scientific data about the impacts of pollutants on a particular use of water[2-3]. The environmental impact of chemical compounds can be viewed as an aggravation in the biological system as far as an expansion in convergence of ions or organic compounds beyond their natural level in plants and animals[4-5]. Water bodies are the fundamental needs for inland fisheries and comprehension of fish faunal assorted variety which is a significant viewpoint for its improvement and the sustainable administration. Wetlands in India support rich variety of fish species, which encourages the business capability of the fisheries[6-7].Spontaneous urbanization, rapid industrialization and indiscriminate use of synthetic chemicals in agriculture are causing serious and varied contamination in aquatic environments leading deterioration of quality and depletion of aquatic life[15]. Environmental pollution is a global problem in now a days. Therefore, the conservation of the fresh water environment and its monitoring is very much necessary[16]. Water quality parameters in aquatic bodies arises from a enormous number of physical, chemical and biological relations. The lentic and lotic water bodies are continuously subjected to a dynamic change with respect to their geological and geo-chemical nature. This dynamic balance in the aquatic system is distressed by human being activities that result in pollution which in turn results in fish kill, bad taste, unpleasant odors and abandoned growth of aquatic flora and fauna. Quality of water is now a great concern for environmentalist as well as the common peoples globally. The decision of the world Health Organization 29th session in May 1976 emphasizes that water for the consumers should be free from pathogenic microbes and toxic substances. Now a days, India faces problems of floods, droughts and high pollution of fresh water resources [17-19]. Water is practically a universal solvent and dissolves some of everything it comes in contact with. The quality requirement of surface water depends upon its various uses. The chemical quality of the water is a factor which is of paramount importance in its utilization for irrigation, drinking and industrial purposes. Many researchers like Rajashekhar *et al*[20], MawhoobNoman Alkadasi*et al*[21], Shivashankar and Venkataramana[22], Thirumala and Kiran[23] and Mane & Madlapure[24] have studied the physico-chemical variables in the lentic and lotic water bodies of India. However, BasavarajaSimpi*et al*[25] analysed the water quality using physico-chemical parameters in Hosahalli tank of Shimoga District, Karnataka, India. Their study depicted all the parameters were within the permissible limits. Their results indicated that the tank is unpolluted and can be used for domestic, irrigation and fish culture. No work has been carried out with regard to comparative study in four water bodies of Davangere district of Karnataka. Hence, the present study is carried out with the following objectives**.**
The main objectives of the study is to know the,

- Comparative study of physico-chemical parameters in four water bodies of Davangere district, Karnataka.
- One-Way ANOVA, Tukey HSD test with Scheffe, Bonferroni and Holm Multiple comparison for Physico-chemical parameters of water bodies.

2. MATERIALS AND METHODS

2.1 *Study Area*

Davanagere district situated on the Deccan Plateau. The district is bounded by Shivamogga, Haveri, Chikamagalur and Ballaridistricts. The southern and western parts are irrigated by the waters of the Bhadra dam.Davanagere is at the centre of Karnataka and located at 14°28' N latitude, 75°59' longitude and 602.5 Metres (1,977 ft) MSL. (NIC;en.wikipedia.org/wiki/).

Fig 1: Hadadi lake covered by Aquatic plants

Fig 2: Different views of Lokikere lake covered by Aquatic vegetation

Fig 3: View of Gonivada lake and ShagaleHalla

2.2 *Experimental*

Four water bodies (Figure 1-3) viz., Hadadi lake ,Gonivada lake, Lokikere lake and ShagaleHalla were selected for the present study during 2016-17.All the chemicals used for analysis were of analytical grade. The electrical conductivity was measured with the help of a conductivity meter. pH was determined with the help of a digital pH meter. Dissolved oxygen was measured with Winkler's method. The remaining water quality parameters were measured as per the standard methods of APHA[8] and Trivedy and Goel[9].

3. STATISTICAL ANALYSIS

One-way ANOVA with post-hoc Tukey HSD Test with Scheffé, Bonferroni and Holm multiple comparison for physico-chemical parameters were calculated as per statistical software of astatsa.com.

4. RESULTS AND DISCUSSION

Table 1 depicts the range of water quality in four water bodies of Davanagere district, Karnataka. Figure 4-7 shows the monthly variations in physico-chemical parameters of Gonivada lake, Lokikere lake, ShagaleHalla and Hadadi lakes of Davangere district. pH of all the four water bodies are alkaline in nature and total alkalinity of these water bodies are high. Electrical conductivity is maximum in Shagalehalla and minimum in Lokikere lake. Turbidity is highest in Hadadilake and lowest in Shagalehalla. Calcium, potassium, Sulphate, TDS and chloride ions were minimum in Lokikere lake and maximum in ShagaleHalla. Whereas, nitrogen was highest in Gonivada lake and lowest in Hadadi lake. Phosphate content was maximum in Hadadi lake due to agricultural runoff from the surrounding areas. Sodium level reaches minimum in Gonivada lake and maximum in Shagalehalla. Many parameters are maximum in Shagalehalla due to surface runoff from the surrounding areas and human activities. McGowan[10] reported that total hardness is expressed in milligrams of calcium carbonate equivalent/litre. Water containing $CaCO_3$ at concentrations below 60 mg/l is considered soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard. Hence, the present four water bodies are included under the hard to very hard category. Vyas et al[11]and Tiwari[12] reported that most of the fresh water bodies globally are tends to be polluted due to domestic sewage, industrial effluents, agricultural runoff, idol immersion, etc. Mishra et al.[13] illustrated that Rani Lake water shows minimum DO, Highest BOD, COD, turbidity, hardness, TDS, chloride, alkalinity, phosphate and nitrate during the years 2008-2009. The values were found beyond the permissible limit of Indian Standards. Their findings clearly show that Rani lake was polluted and eutrophic in nature due to discharge of sewage and anthropogenic activity by human beings.As indicated by BIS the permissible level reaches of pH esteem for drinking water is 6.5 to 8.5.Abnormal estimations of pH in water causes severe taste, influences mucous layer, causes erosion in pipelines and furthermore influences sea-going life. The standard attractive constraint of alkalinity in consumable water is 200 mg/l as per BIS[25]. Abundance alkalinity in water is likewise hurtful for water system which prompts soil harm by adjusting the soil pH which improve soil pH to an extraordinary apply and decrease crop yields. According to

Indian specifications for Drinking water the desirable limit of TDS is 500 mg/l and as far as possible level is 2000 mg/l. Surpassing the reasonable furthest reaches of complete hardness causes poor washed with cleanser, crumbling of the nature of garments, scale arrangement and skin irritation[26,27]. As indicated by BIS for drinking water, desiring limit of chloride is 250mg/l, and as far as tolerable limit is 1000 mg/l. Sulfate happens normally in water because of filtering from gypsum and other regular minerals. Sulfate content in drinking water surpassing the 400 mg/L give severe taste and may cause gastro-digestive tract disturbance and cantharsis[27,28] . Thirumala and Kiran[29] reported that Total broke up solids have indicated the noteworthy connection with the electrical conductivity, chloride, alkalinity, sulfate, complete hardness, calcium and magnesium.

4.1 Statistics for Physical Parameters

Table 2 to 7 depicts One-way ANOVA with post-hoc Tukey HSD Test with Scheffe, Bonferroni and Holm multiple comparison for physical parameters (Turbidity, pH, Electrical conductivity, TDS) of four water bodies of Davangere district, Karnataka.EC and TDS shows significant relationship while, Turbidity and pH showed insignificant relation to each other.

Table 1: Range of water quality parameters as compared with BIS standards in four water bodies of Davanagere district, Karnataka

Parameter	Hadadi	Lokikere	Gonivada	ShagaleHalla	BIS Desirable limit [26]
pH	7.9-8.4	8.5-8.7	8.4-8.6	8.2-8.5	6.5-8.5
EC	750-856	155-210	950-1010	1630-1750	-
Tur	4-6	2-5	3-6	1-3	10
Total Alk.	380-400	120-340	420-480	390-420	200
TH	232-258	95-115	250-350	650-760	300
Ca	40-60	36-56	46-76	60-80	75
SO_4	15-22	0.5-1.5	38-48	90-110	150
NO_3	204-220	445-490	1100-1200	470-490	45
PO4	0.3-0.5	0.1-0.3	0.1-0.3	0.1-0.2	-
TDS	495-510	78-97	620-680	1050-1200	500
Na	50-65	55-64	50-60	86-97	-
K	3.1-4.2	1.6-2.5	5.0-6.8	6.2-7.9	-
Cl	90-98.6	28-38.5	104-150	340-445	250

All the parameters are expressed in mg/l except pH & EC (µmhos/cm) in physico-chemical parameters of Hadadi lake,Davangere

Table 2: One-way ANOVA with post-hoc Tukey HSD Test with Scheffé, Bonferroni and Holm multiple comparison for physical parameters in four water bodies of Davangere district, Karnataka

Parameter →	A (Tur)	B (pH)	C (EC)	D (TDS)	Pooled Total
Observations N	28	28	28	28	112
Sum	99.0000	233.4600	25,510.0000	16,263.0000	42,105.4600
Mean	3.5357	8.3379	911.0714	580.8214	375.9416
Sum of squares	413.0000	1,947.8566	31,300,462.0000	13,031,085.0000	44,333,907.8566
Sample variance	2.3320	0.0482	298,482.5873	132,784.6706	256,799.2212
Sample std. dev.	1.5271	0.2195	546.3356	364.3963	506.7536

Table 3: One-way ANOVA of independent Parameters

Source	sum of squares SS	degrees of freedom v	mean square MS
Parameter	16,860,433.3257	3	5,620,144.4419
Error	11,644,280.2290	108	107,817.4095
Total	28,504,713.5547	111	

Table 4: Post-hoc Tukey HSD Test

Parameters pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	0.0774	0.8999947	insignificant
A vs C	14.6251	0.0010053	** p<0.01
A vs D	9.3031	0.0010053	** p<0.01
B vs C	14.5477	0.0010053	** p<0.01
B vs D	9.2257	0.0010053	** p<0.01
C vs D	5.3220	0.0015391	** p<0.01

** ***Significant***

Table 5: Scheffé multiple comparison

Parameters pair	Scheffé TT-statistic	Scheffé p-value	Scheffé inference
A vs B	0.0547	0.9999562	insignificant
A vs C	10.3415	4.4409	** p<0.01
A vs D	6.5783	5.7165	** p<0.01
B vs C	10.2868	5.5511	** p<0.01
B vs D	6.5235	7.3468	** p<0.01
C vs D	3.7632	0.0039045	** p<0.01

***** Significant***

Table 6: Bonferroni and Holm results: all pairs simultaneously compared

Parameters pair	Bonferroni and Holm TT-statistic	Bonferroni p-value	Bonferroni inference	Holm p-value	Holm inference
A vs B	0.0547	5.7387707	insignificant	0.9564618	Insignificant
A vs C	10.3415	0.0000	** p<0.01	0.0000	** p<0.01
A vs D	6.5783	1.0532	** p<0.01	7.0211	** p<0.01
B vs C	10.2868	0.0000	** p<0.01	0.0000	** p<0.01
B vs D	6.5235	1.3688	** p<0.01	6.8442	** p<0.01
C vs D	3.7632	0.0016385	** p<0.01	0.0005462	** p<0.01

***** Significant***

Table 7: Bonferroni and Holm results: only pairs relative to A simultaneously compared

Parameters pair	Bonferroni and Holm TT-statistic	Bonferroni p-value	Bonferroni inference	Holm p-value	Holm inference
A vs B	0.0547	2.8693853	insignificant	0.9564618	insignificant
A vs C	10.3415	0.0000	** p<0.01	0.0000	** p<0.01
A vs D	6.5783	5.2658	** p<0.01	3.5105	** p<0.01

***** Significant***

4.2 Statistics for Chemical Parameters

Table 8 to 13 shows One-way ANOVA with post-hoc Tukey HSD Test with Scheffe, Bonferroni and Holm multiple comparison for Chemical parameters (Total hardness, Calcium, Sulphate, Chloride) of four water bodies of Davangere district, Karnataka. According to Tables 10-12 total hardness and chloride showed significance relation but calcium and sulphate depicted insignificance relationship to each other.

Table 8: Descriptive statistics of independent Parameters.

Parameter →	A (TH)	B (Ca)	C (SO_4)	D (Cl)	Pooled Total
Observations N	28	28	28	28	112
Sum	9,610.0000	1,596.0000	1,116.6000	4,494.6000	16,817.2000
Mean $\bar{}$	343.2143	57.0000	39.8786	160.5214	150.1536
Sum of squares	4,738,404.0000	95,842.0000	81,894.0000	1,235,581.4600	6,151,721.4600
Sample variance	53,337.5820	180.3704	1,383.9106	19,040.8092	32,671.7011
Sample std. dev.	230.9493	13.4302	37.2009	137.9884	180.7531
Std. dev. of mean SE	43.6453	2.5381	7.0303	26.0774	17.0796

Table 9: One-way ANOVA of independent variables

Source	sum of squares	degrees of freedom vv	mean square MS	F statistic	p-value
Parameter	1,630,106.6700	3	543,368.8900	29.3941	5.6732
Error	1,996,452.1486	108	18,485.6680		
Total	3,626,558.8186	111			

Table 10: Post-hoc Tukey HSD Test results

Parameters pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	11.1392	0.0010053	** p<0.01
A vs C	11.8055	0.0010053	** p<0.01

A vs D	7.1102	0.0010053	** p<0.01
B vs C	0.6663	0.8999947	insignificant
B vs D	4.0289	0.0266018	* p<0.05
C vs D	4.6953	0.0066450	** p<0.01

*** Significant*

Table 11: Scheffé multiple comparison

Parameters pair	Scheffé TT-statistic	Scheffé p-value	Scheffé inference
A vs B	7.8766	1.1601	** p<0.01
A vs C	8.3478	1.1172	** p<0.01
A vs D	5.0277	4.4119	** p<0.01
B vs C	0.4712	0.9738265	insignificant
B vs D	2.8489	0.0489607	* p<0.05
C vs D	3.3201	0.0144656	* p<0.05

**** Significant***

Table 12: Bonferroni and Holm results: all pairs simultaneously compared

Parameters pair	Bonferroni and Holm TT-statistic	Bonferroni p-value	Bonferroni inference	Holm p-value	Holm inference
A vs B	7.8766	1.6972	** p<0.01	1.4143	** p<0.01
A vs C	8.3478	1.5254	** p<0.01	1.5254	** p<0.01
A vs D	5.0277	1.1909	** p<0.01	7.9394	** p<0.01
B vs C	0.4712	3.8307774	insignificant	0.6384629	Insignificant
B vs D	2.8489	0.0315255	* p<0.05	0.0105085	* p<0.05
C vs D	3.3201	0.0073675	** p<0.01	0.0036837	** p<0.01

****Significant***

Table 13: Bonferroni and Holm results: only pairs relative to A simultaneously compared

Parameters pair	Bonferroni and Holm TT-statistic	Bonferroni p-value	Bonferroni inference	Holm p-value	Holm inference
A vs B	7.8766	8.4859	** p<0.01	5.6573	** p<0.01
A vs C	8.3478	7.6272	** p<0.01	7.6272	** p<0.01
A vs D	5.0277	5.9545	** p<0.01	1.9848	** p<0.01

**** Significant***

4.2.1 *Conclusion from ANOVA*

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that the one or more Parameters are significantly different. These post-hoc testswould likely identify which of the pairs of parameters are significantly different from each other.

4.3 *Tukey HSD Test*

One-way ANOVA is lower than 0.01 level and Tukey's HSD test to each of the six pairs of parameters which exhibits statistically significant difference.

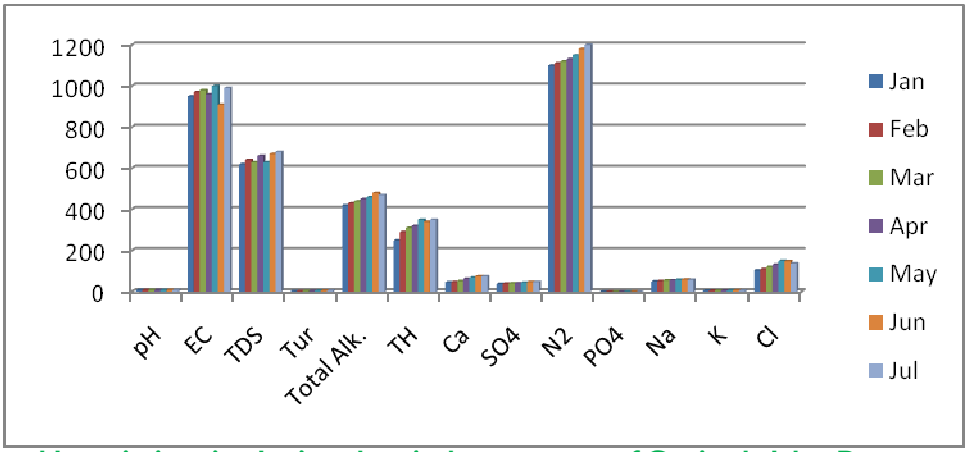

Fig 4: Monthly variations in physico-chemical parameters of Gonivada lake, Davangere district

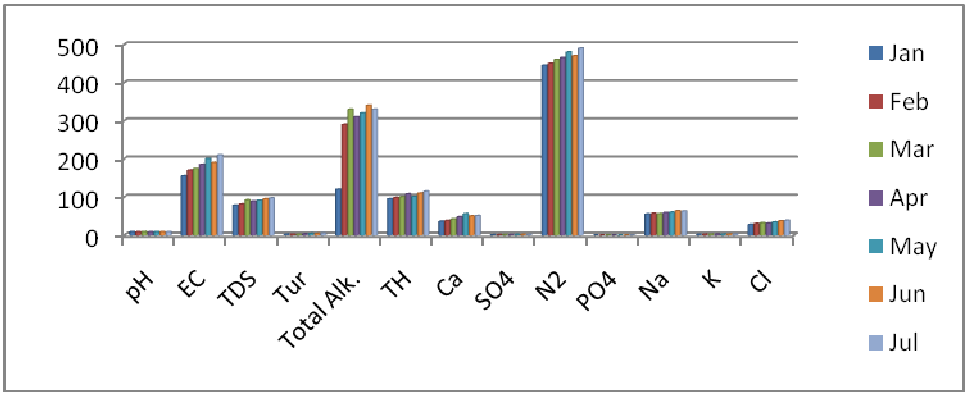

Fig 5: Monthly variations in physico-chemical parameters of Lokikere lake, Davangere

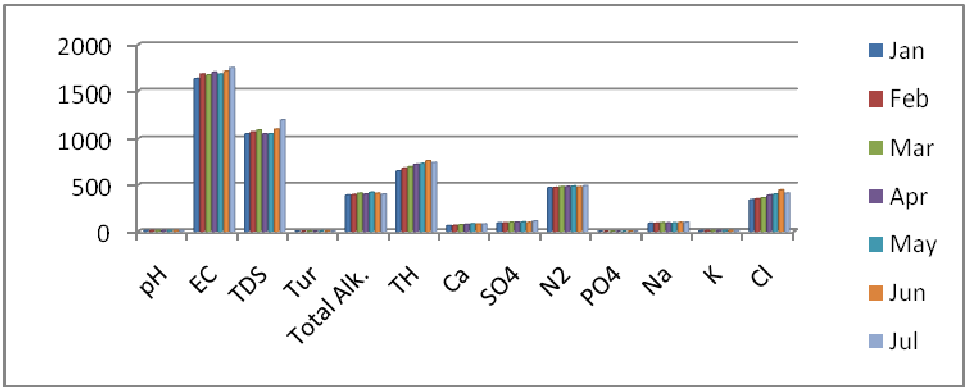

Fig 6: Monthly variations in physico-chemical parameters of Shagalehalla, Davangere

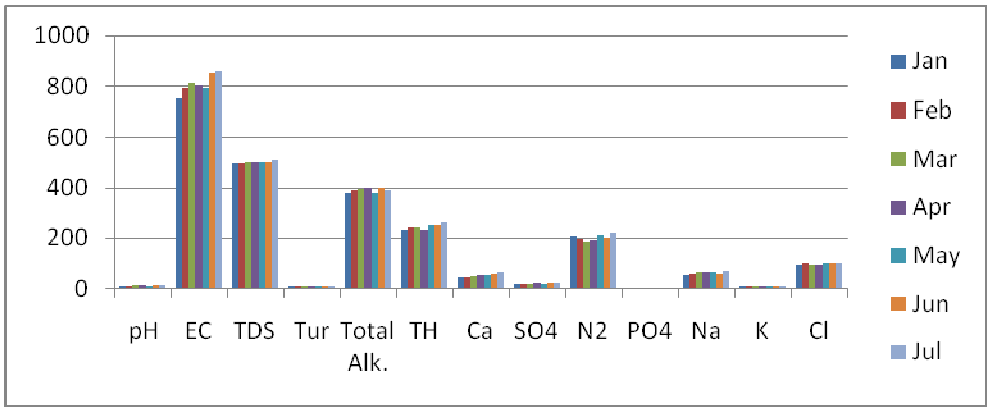

Fig 7: Monthly variations in physico-chemical parameters of Hadadi lake, Davangere

5. CONCLUSION

The information on physico-chemical parameters of four water bodies of Davangere district shows that these exhibit moderate degree of pollution. The evaporation rate is higher in summer months.The water samples should be used byhuman beings especially fordrinking and cooking after water treatment (Primary and secondary treatment). From the present investigation, it may be concluded that the physic-chemical characteristics of the water indicates that they are moderately eutrophic in nature and there is an urgent need for preventive measures. One Way ANOVA for physico parameters showed the "F statistic value of 52.1265 and "P" value of 1.112. Likewise, for chemical parameters "F" value and "P" values are 29.3941 and 5.6732 respectively. The p-value consequent to F-statistic in one-way ANOVA is lower than 0.05 level and Tukey's HSD test to each of the six pairs of water quality parameters exhibits statistically significant difference.

6. AUTHORS CONTRIBUTION STATEMENT

Authors are grateful to Government First Grade College, Davangere and Kuvempu University, Shankaraghatta for providing research facilities. Authors conceptualized and gathered the data with regard to this work. Dr.Rajappa and Dr.Manoharaanalyzed these data and necessary inputs were given towards the designing of the manuscript. All the authors discussed the methodology and results and contributed to the final manuscript.

7. CONFLICT OF INTEREST

Conflict of interest declared none.

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