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Fuzzy Logic Based Assessment of Periodic Variation of Water Quality of Nethravathi River in Dakshina Kannada District

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Abstract: The decision-making using comparison of stream water quality prescribed limits with various water quality indices has been developed to integrate water quality variables. This approach has few drawbacks such as some parameters in the index equations can influence the final score of WQI dramatically without valid scientific justification. There are limitations on which a wrong decision can be taken as it is dependent on the fix weight age assigned to different parameters, where as the weight age should be varied on the basis of season, rainfall, ambient temperature and other environmental factors. These indices are lacking to deal with uncertainties involved at various steps indecision-making. One way of avoiding the difficulty in uncertainty handling in water quality assessment is to introduce a margin of safety or degree of precaution before applying a single value to quality standards as the same technique was also used by other workers in the field of environmental sciences. These methodologies based on fuzzy sets theory are tested with real environmental problems to handle the uncertainty in imprecise environment in decision-making tools. It is proposed that methods based on fuzzy sets theory can be applied to deal with the uncertainties in the decision-making on the stream water quality, keeping the importance of uncertainty handling in the water quality assessment and versatility of the fuzzy set theory in the decision-making in the imprecise environment. In this project, we propose the fuzzy set theory for decision-making in the assessment of physico-chemical quality of Nethravathi River of Dakshina Kannada, Karnataka.

Keywords: Fuzzy logic; Membership ; Linguistic variable; Fuzzification

I. INTRODUCTION

Mangalore coast is a stretch of about 22 Kms at the western part of the Western Ghats of the Indian peninsula. This area is receiving a huge quantity of pollution load from the major industries and factories located nearby. This pollution load is discharged into the sea either directly or through the major west flowing rivers of the region, Nethravathi and Gurupura. The pollution load includes runoff of the sediment, waste from oil refineries, nutrients and pesticides, iron ore residues from the nearby iron are company and chemicals from the chemical factory from the point source. Water quality is also altered due to the addition of municipal and sewage wastes discharged into the sea [4].

The quality of water is one of the most important environmental, social and political issues at global level. Monitoring of water quality and qualitative decision-making on the basis of data is a challenge for environmental engineers and hydrologists as every step from sampling to analysis contains uncertainties. The regulatory limits for various pollutants/contaminants in stream water proposed by various regulatory bodies like World Health Organization, Bureau of Indian Standards and Indian Council of Medical Research are having certain limitations. Information on the status and changing trends in water quality is necessary to formulate suitable guidelines and efficient implementation for water monitoring, quality assessment and enforcement of prescribed limits by different regulatory bodies. Various methods are discussed in literature on stream water quality criteria and decision-making. But most of the reports on the water quality revealed that deterministic approach indecision-making by comparing values of parameters of water quality with prescribed limits provided by different regulatory bodies is used without considering uncertainties involved at various steps throughout the entire procedure. But, one of the most popular and commonly used methods during last few decades was Water Quality Index (WQI). Horton made a pioneering attempt to study the general indices, selecting and weighing different water quality parameters.

This methodology was, developed by National Sanitation Foundation (NSF),USEPA using Delhi technique as a tool in formal assessment procedure. The decision-making using comparison of stream water quality prescribed limits with various water quality indices has been developed to integrate water quality variables. This approach has few drawbacks such as some parameters in the index equations can influence the final score of WQI dramatically without valid scientific justification. There are limitations on which a wrong decision can be taken as it is dependent on the fix weightage assigned to different parameters, where as the weightage should be varied on the basis of season,

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rainfall, ambient temperature and other environmental factors. These indices are lacking to deal with uncertainties involved at various steps indecision-making. Due to these limitations of deterministic and WQI approach, an advanced classification method is required, which is capable of accounting for imprecise, vagueand fuzzy information in decision-making on water quality. Sii et al. have discussed the uncertainties involved in water quality using fuzzy membership with values ranging from 0 to 1 to form an applicable fuzzy set instead of the conventional scale of 0 to 100 in WQI methodology. The decision on the stream water quality assessment gives that the water is desirable, acceptable and not acceptable as per the guidelines from various regulatory bodies. But, in the borderline cases of water quality parameters, it becomes a Herculeantask as different types of uncertainties are involved at various part of experimental and measurement process right from sampling, sample storage, processing and analysis. The sets of the monitored data and limits should not be as crisp set, but as fuzzy.

One way of avoiding the difficulty in uncertainty handling in water quality assessment is to introduce a margin of safety or degree of precaution before applying a single value to quality standards as the same technique was also used by other workers in the field of environmental sciences. These methodologies based on fuzzy sets theory are tested with real environmental problems to handle the uncertainty in imprecise environment in decision-making tools. It is proposed that methods based on fuzzy sets theory can be applied to deal with the uncertainties in the decision-making on the stream water quality, keeping the importance of uncertainty handling in the water quality assessment and versatility of the fuzzy set theory in the decision-making in the imprecise environment. In this project, we propose the fuzzy set theory for decision-making in the assessment of physico-chemical quality of Nethravathi River of Dakshina Kannada, Karnataka.

II. BIRTH OF FUZZY AND FUZZY CONCEPTS

The idea of fuzzy sets was born in 1964, and in 1965 Lofti A. Jadeh a well respected professor in the department of Electrical Engineering & computer science at university of California presented a paper on FUZZY SETS 2[6].

This made to the development of new mathematical formulation called the FUZZY CONCEPTS by himself (Jadeh) & and his followers.

In the last 3 decades, significant progress has been made in the development of Fuzzy sets and Fuzzy logic theory in Engineering, Natural and socio-economic science [6].The successful applications of fuzzy sets and fuzzy logic can be attributed to the fact that the fuzzy theory reflects the true situation of the real world, where human thinking is dominated by approximate reasoning logic.

Fuzzy logic refers to a large subject dealing with a set of methods to characterize and quantify uncertainty in engineering systems that arise from ambiguity, imprecision, fuzziness, and lack of knowledge. Fuzzy logic is a reasoning system based on a foundation of fuzzy set theory, itself an extension of classical set theory, where set membership can be partial as opposed to all or none, as in the binary features of classical logic.

III. STUDY BACKGROUND

Various methods are discussed in literature on stream water quality criteria and decision-making. Most of the reports on the water quality revealed that deterministic approach in decision-making by comparing values of parameters of water quality with prescribed limits provided by different regulatory bodies is used without considering uncertainties involved at various steps throughout the entire procedure. Various experiments have been done on the basis of statistical data, on which we cannot depend on. There are limitations on which a wrong decision can be taken as it is dependent on the fix weightage assigned to different parameters, where as the weightage should be varied on the basis of season, rainfall, ambient temperature and other environmental factors.

IV. METHODOLOGY ADOPTED

The river water samples will be collected from 10 different stations in the district, applying the prescribed methodology for sampling. These samples will be analyzed for the different physicochemical water quality parameters as per standard procedure. The data of this analysis will be taken for the fuzzy synthetic evaluation (FSE) model to assess the quality of stream water using the parameters: Turbidity, Conductivity, pH, total dissolved salts (TDS), total alkalinity (TA), total hardness (TH), Dissolved oxygen (D.O), BOD and COD. The analysis of the water quality will be carried out using Matlab software.

V. STRETCH OF THE RIVER SELECTED FOR THIS PROJECT

The stretch of the river was selected from Ullal to Dharmasthala of about 90Km as shown on the map.

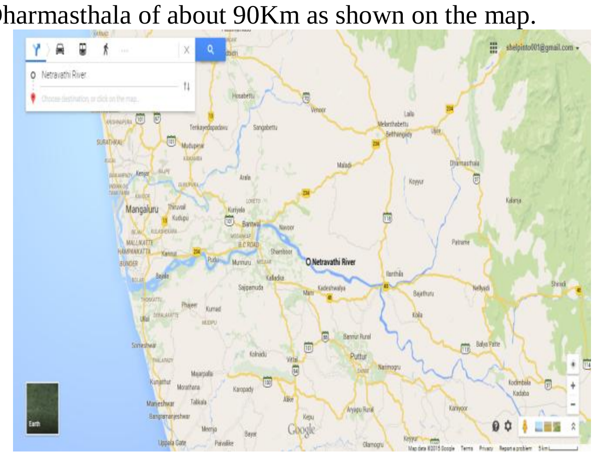

Fig 1: Stretch of the river

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VI. LOCATIONS SELECTED FOR THE COLLECTION OF SAMPLES

These locations were selected based on the maximum pollution load occurring at different stations in order to get the difference in periodic variation.

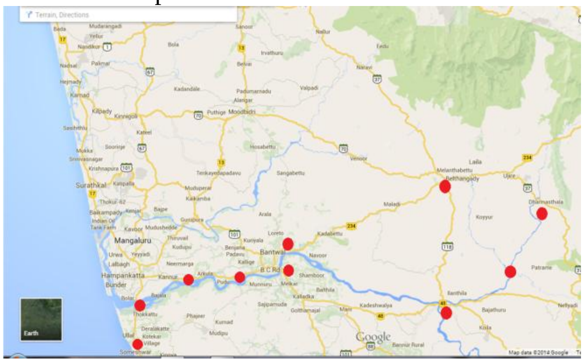

Fig 2: Locations selected for the collection of samples

VII. TESTS RESULTS FROM THE MONTH OF OCTOBER TO MARCH 2014-2015

The tests were conducted on the samples that were collected during the six months for 10 different stations and the test results are mentioned in the figures given below.

TRAIL 1: 22TH OCTOBER 2014

Tests conducted	Dharmasthala	Southadka	Belthangady	Uppinanagady	Panem'lore	Bantwal	Tumbe	Adyar	Nethravati bridge	Kotepura
TURBIDITY	16.3	10.3	12.1	17.5	12.4	34.6	36.4	26.4	25.6	11.5
CONDUCTIVITY	0.4	0.5	0.6	0.7	0.4	0.4	0.4	0.4	5.9	25.7
pH	7	7.5	7.54	7.48	7.47	7.52	7.72	8	7.9	7.8
D.O (mg/lt)	5.55	5.1	6.71	6.2	7.16	5.82	6.26	5.46	5.55	2.68
B.O.D(5 days @ 20°c)(mg/lt)	2.05	1	1.1	1.4	1.2	1.62	2.16	2.01	3.75	32.7
C.O.D	158	200	109	88	189	196	90	160	295	360
HARDNESS	7	7	6	5	10	10	10	21	352	1750
T.D.S	118	108	94	196	152	154	112	126	4734	19546
ALKALINITY	160	144	88	168	160	176	120	128	144	264

Fig 3: Tests results for the month of October

TRAIL 2: 23TH NOVEMBER 2014

Tests conducted	Dharmasthala	Southadka	Belthangady	Uppinanagady	Panem'lore	Bantwal	Tumbe	Adyar	Nethravati bridge	Kotepura
TURBIDITY	12.84	8.4	9.8	28.36	7.4	48.4	40.2	34.8	30.8	28.6
CONDUCTIVITY	0.7	0.3	0.4	0.2	0.5	0.5	0.2	0.3	6.8	17.8
pH	6.58	6.95	7.1	7.68	7.88	7.84	6.6	7.48	7.2	6.98
D.O (mg/lt)	5.01	4.39	7.31	6.8	7.38	5.2	6.31	6.8	5.21	2.9
B.O.D(5 days @ 20°c)(mg/lt)	2.58	1.3	1.2	1.85	1.3	2.2	1.9	1.81	2.75	38.9
C.O.D	160	190	98	140	160	156	86	130	300	320
HARDNESS	6	10	4	3	14	7	8	12	282	1684
T.D.S	96	138	83	190	132	186	128	148	5634	18698
ALKALINITY	164	174	62	198	142	184	162	146	108	240

Fig 4: Tests results for the month of November

TRAIL 3: 29TH DECEMBER 2014

Tests conducted	Dharmasthala	Southadka	Belthangady	Uppinanagady	Panem'lore	Bantwal	Tumbe	Adyar	Nethravati bridge	Kotepura
TURBIDITY	1.2	1.1	1.7	0.6	2.5	0.5	0.3	2.3	1.8	2.1
CONDUCTIVITY	0.4	0.6	0.5	0.4	0.4	0.4	0.4	15	36.5	43.8
pH	4.9	4.98	4.7	5.2	5.2	5.25	5.4	6.25	6.2	7.2
D.O (mg/lt)	5.32	4.4	6.98	6.24	5.13	6.84	6.21	5.84	6.48	1.42
B.O.D(5 days @ 20°c)(mg/lt)	2.38	2.41	1.11	2.18	1.41	1.42	2.4	1.32	2.32	42.84
C.O.D	109	98	130	94	223.4	160	60	134.2	240	300
HARDNESS	3	5	11	2	4	4	8	4	286	1582
T.D.S	108	26	48	5	36	10	244	42	29826	36160
ALKALINITY	52.5	60	30	52.5	45	450	45	105	142.4	187

Fig 5: Tests results for the month of December

TRAIL 4: 22TH JANUARY 2015

Tests conducted	Dharmasthala	Southadka	Belthangady	Uppinanagady	Panem'lore	Bantwal	Tumbe	Adyar	Nethravati bridge	Kotepura
TURBIDITY	1.31	0.68	1.8	4.12	6.4	0.98	4.6	4.82	1.1	3.48
CONDUCTIVITY	0.5	0.4	0.4	0.5	0.6	0.5	0.3	16.21	42.64	31.41
pH	7.84	6.51	4.1	4.44	6.81	4.34	6.72	4.68	7.82	6.31
D.O (mg/lt)	4.44	4.38	6.84	5.31	5.21	6.42	6.32	5.68	6.8	2.34
B.O.D(5 days @ 20°c)(mg/lt)	3.58	4.21	2.46	3.24	1.92	1.38	1.48	2.42	1.9	38.34
C.O.D	158	200	109	88	189	196	90	160	295	360
HARDNESS	6	12	13	17	5	8	10	7	342	2681
T.D.S	196	21	42	4	28	6	198	64	14862	48143
ALKALINITY	64.84	54	41	59.42	49	520	31	136	284.6	174.4

Fig 6: Tests results for the month of January

TRAIL 5: 20TH FEBRUARY 2015

Tests conducted	Dharmasthala	Southadka	Belthangady	Uppinanagady	Panem'lore	Bantwal	Tumbe	Adyar	Nethravati bridge	Kotepura
TURBIDITY	2.3	6.5	3.5	6.8	2.4	1.6	1.89	3.6	6.8	9.5
CONDUCTIVITY	0.4	0.56	0.62	0.84	0.6	0.42	0.86	0.46	26.5	30.45
pH	6.26	6.53	5.86	5.96	4.65	6.78	6.03	4.96	7.21	6.59
D.O (mg/lt)	4.65	5.65	5.45	6.23	6.75	6.23	5.89	7.23	5.35	6.89
B.O.D(5 days @ 20°c)(mg/lt)	4.65	1.23	4.65	2.35	1.23	6.52	4.65	1.36	6.52	34.6
C.O.D	12.6	32.63	28.63	18.63	32.65	20.69	14.35	45.36	205	321
HARDNESS	9	4	6	10	12	16	17	24	356	1896
T.D.S	350.63	286.25	362.25	305.63	286.56	356.45	440.2	359.65	1659	23568
ALKALINITY	105	65	95	34	45	53.6	78	123	186	146

Fig 7: Tests results for the month of February

TRAIL 6: 12TH MARCH 2015

Tests conducted	Dharmasthala	Southadka	Belthangady	Uppinanagady	Panem'lore	Bantwal	Tumbe	Adyar	Nethravati bridge	Kotepura
TURBIDITY	1.1	1.5	2.6	4.1	1.2	1.4	1.5	3.6	4.8	6.4
CONDUCTIVITY	0.57	0.42	0.52	0.57	0.61	0.62	0.71	0.64	28.4	34.8
pH	6.35	6.1	6.07	6.58	6.68	6.8	6.98	5.43	7.84	7.82
D.O (mg/lt)	5.9	6.5	5.4	6.7	6.8	6.6	6.4	6.9	6.5	7.1
B.O.D(5 days @ 20°c)(mg/lt)	3.05	2.3	5.6	2.5	2.6	1.56	3.52	2.56	6.52	38.5
C.O.D	9.6	28.8	30.4	20.8	25.6	14.4	14.6	38.68	192	288
HARDNESS	9	4	12	18	10	8	24	26	482	2635
T.D.S	353.4	260.4	322.4	353.4	378.2	384.4	440.2	396.8	17608	21576
ALKALINITY	96	40	64	24	40	56	72	94	160	152

Fig 8: Tests results for the month of March

TOLERANCE LIMITS FOR INLAND SURFACE WATER (IS: 2296-1982)

Based on the IS code these tolerance limit were taken and were used for comparison with the test values which helped in fuzzy analysis to vary the membership functions

TABLE 1 Tolerance limits for inland surface

SL NO	CHARACTERISTIC	TOLERANCE LIMIT
1	Ph value	6.5 – 8.5
2	Dissolved Oxygen(mg/l)	4 – 6
3	BOD(5 days at 20°c) mg/l	0 – 30
4	COD (mg/l)	0 – 200
5	Total Dissolved Solids(mg/l)	0 – 1200
6	Hardness (mg/l)	0 - 500

VIII. FUZZY IMPLEMENTATION

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Fuzzy logic embeds human knowledge into working algorithms. In situations involving highly complex systems and whose behaviors are not well understood .By this approximate, fast, solution is warranted. It is applicable when model is unknown or impossible to obtain. It's an important tool in generic decision making [19]. Having introduced the fundamental concept of a fuzzy set, it is natural to see how it can be used. Like a conventional set, conventional set, a fuzzy set can be used to describe the value of a variable [6].

For example, if the variable is linguistic one say "site conditions" which can take the values of excellent, fair, poor, etc. The full formation expressed in words or phrases in this example has a value but it is not clearly defined. These values scan be made susceptible to meaningful classifications.
i.e., U = {site conditions}
This universal set consists the sub sets as
U = {excellent, fair, poor}

In which membership values may be given for the subsets considering their ranges. In the manner, fuzzy sets can well be considered for quantifying qualitative factors. If the Degree of belief in a fuzzy set is say getting narrowed, then the linguistic variables can be described as say very excellent, very fair, very poor, etc. Instead of enumerating all these different linguistic descriptions, they can be generated from a core set of linguistic terms using "modifiers". In fuzzy theory we call these modifiers as HEDGES as discussed earlier [6]

IX. APPLICATIONS DONE ON THIS PROJECT

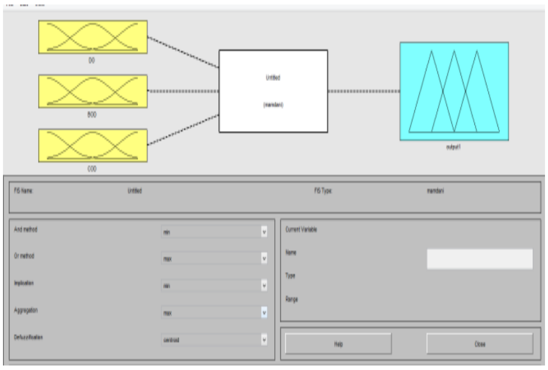

Fig 9: Fuzzy implementation made in this project

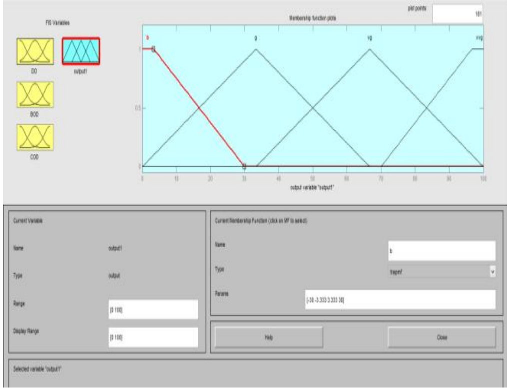

Fig 10: Membership function plots

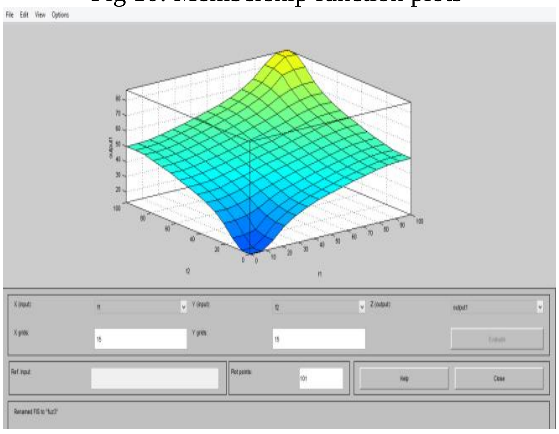

Fig 11: Plot of COD, BOD & DO

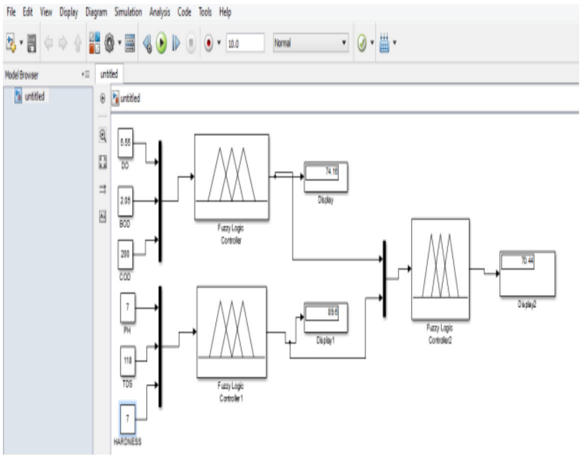

Fig 12: Simulated output

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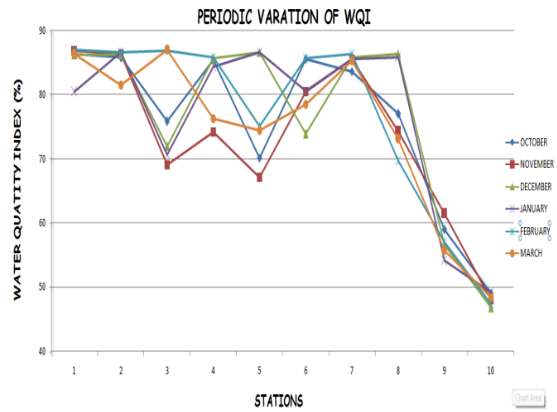

Fig 13: Periodic variation of the quality of water at different stations

X. REASONS FOR THE POLLUTION

As the sampling was done for six months a huge change in quality of water has been found. At certain stations the quality of water reduces to about less than 50% where as at certain stations the quality increases to about 80%.The pollution load increases because of the waste that is being left off to the steams. The river bed at some stations consists of sand and pebbles and also some rocks protruding from the water. At certain sites pilgrimage centers are located and hundreds of people take “Holy dip” and wash their clothes along the banks of this site every day. Human activities such as the cleaning of vehicles, washing of clothes, etc. as seen on the banks of these streams. There are even trading centers located at the banks of the rivers. The water is highly turbid in rainy season; looks brownish, muddy and various things such as clothes are thrown into the river, which causes lot of suspended floating material in the river water. The river bed consists mostly of silt with pebbles. At some sites, paddy field and areca nut gardens are located all round in the catchment. Various activities such as pujas, marriage ceremony etc takes place and attract devotees from locale. The water is even used for bathing and washing. Educational institutions situated near the banks of the river also let off the sewage waste and other wastes. The wastes from the nearby hotels are being sent to the river. The water is being polluted by human activities too. There are several fishery factory which lets the waste products into river without treatment. Sand mining too takes place in most of the places. The waste from the nearby houses such as sanitary wastes is directly let to the river.

Hence the periodic graph is being plotted in order to determine the variation at 10 different stations at different months and at different stations. From this the exact percentage of quality of water can be determined. By this project accurate analysis of the Nethravathi River can be generated from Fuzzy logic.

The Periodic variation of the water quality can be analyzed without much difficulty. Remedies for the improvement of water quality can be given based on the pollution load at different stations and by this farmers, local people are benefited and the most important environmental protection is the main field of target.

XI. CONCLUSION

Fuzzy logic is the flexible tool to develop classification model with a simple framework and constructed with natural language. In this study, water quality index value was obtained to express the classification of river in order to make water quality assessment more understandable especially in public consideration.It has been demonstrated that computing with linguistic terms within FIS improves the tolerance for imprecise data. We have assessed water quality in the Nethravathi river with physicochemical determinants [1].

Fuzzy model has demonstrated that water quality is below sustainable expected results in the Nethravathi River. The new index is believed to assist decision makers in reporting the condition of water quality and investigation of spatial and temporal changes in the river. The author believes that fuzzy logic concepts, if used logically, could be an effective tool for some of the environmental policy matters. Model based on FIS can be used for future determination of WQI for six parameters. More stringent methodologies are then required to mold the ideas of decision maker and manager to apply fuzzy model in practice[3].

REFERENCES

[1] Ni-Bin Chang HW, Chen and Ning SK. Identification of river water quality using the Fuzzy Synthetic Evaluation approach. Journal of Environmental Management. 2001;63(3):293–305.
[2] Fuzzy logic water quality index and importance of water quality parameters Air, Soil and Water Research 2009:2
[3] Chen HW, Chang NB. Identification of river water quality using the Fuzzy Synthetic Evaluation approach. Journal of Environmental Management. 2001;63(3):293–305.
[4] William Ocampo-Duque, Nuria Ferre-Huguet, Jose LD, Marta Schuhmacher. Assessing water quality in rivers with fuzzy inference systems: A case study. Journal of Environmental International. 2006;32(6):733–42.
[5] Pedrycz W, Card HC. Linguistic interpretation of self-organizing maps. Proc of the IEEE International Conference on Fuzzy Systems. 1992; 371–8.
[6] Zadeh LA. Fuzzy Sets. Information and Control. 1965;8:338–53.
[7] agels JW, Colley D, Smith DG. A water quality index for contact recreation in New Zealand. Water Sci. Technol. 2001;43(5):285–92.
[8] APHA–AWWA–WPCF (1998). Standard methods for examination of water and waste water (2–9, 2–48, 4–87, 4–134, 5–3, 9–47), 20th Edition. New York: APHA.
[9] Silvert W. Fuzzy indices of environmental conditions. Proc of Environmetnal Indicators and Indices. 2000; 130(1–3):111–9.
[10] Chai LL. River Quality Classification of Sungai Padas Using water Quality indices. FSAS. 1999. p. 319.
[11] Yilmaz Icaga. Fuzzy evaluation of water quality classification. Ecological Indicators. 2007;7(3):710–
[12] McNeil FM, Thro E. Fuzzy Logic: A Practical Approach. Academic Press, Boston MA. 1994. p. 294.
[13] William Ocampo-Duque, Nuria Ferre-Huguet, Jose LD, Marta Schuhmacher. Assessing water quality in rivers with fuzzy

inference systems: A case study. Journal of Environmental International. 2006; 32(6):733–42.

[14] Department of environment, Ministry of Science, technology and the Environment, Kuala Lumpur Malaysia. 1986.

[15] Pedrycz W, Card HC. Linguistic interpretation of self-organizing maps. Proc of the IEEE International Conference on Fuzzy Systems. 1992; 371–8.

[16] DOE WQS Phase 2 Study: Development of water Criteria and standards for Malaysia, Department of Environment, Ministry of Science, Technology and the Environment, Kuala Lumpur 1990.

[17] Timothy J, Ross. Fuzzy logic with engineering applications. John Wiley & Sons. 2004.

[18] APHA–AWWA–WPCF (1998). Standard methods for examination of water and waste water (2–9, 2–48, 4–87, 4–134, 5–3, 9–47), 20th Edition. New York: APHA.

[19] Adarsh, S., Mahantesh, B. (2006). Personal Communication, Resident Doctors of Medicine, Hanagal Shree Kumareshwara Hospital, Bagalkot, Karnataka, India. Bhargava, D. S. (1983).

[20] Use of a water quality index for river classification and zoning of the Ganga river. Environmental Pollution, B6, 51–67.

[21] Bhargava, D. S., Saxena, B. S., & Dewakar (1998). A study of geopollutants in the Godavary river basin in India. Asian Environment, 36–59 (IOS press).

[22] Bhujangaiah, N. S., & Vasudeva Nayak, P. (2005). Study of ground water quality in and around Shimoga city, Karnataka. Journal of Indian Council of Chemists, 22(1), 42–47.

[23] Burden, F. R., Mc Kelvie, I., Forstner, U., & Guenther, A. (2002).