*International Research Journal of Environment Sciences*_____ ISSN 2319–1414
Vol. **2(12),** 74-80, December **(2013)** *Int. Res. J. Environment Sci.*

Building Block Methodology Assisted Knowledge-Based System for Environmental-Flow Assessment of Suswa River of Dehradun Dist., India: A Reminiscent Framework

Kanchan D. Bahukhandi[1*] and Neelu J. Ahuja[2]
[1]Deptt of Health, Safety and Environment, University of Petroleum and Energy Studies, Dehradun – 248007, UK, INDIA
[2]Deptt of Computer Science and Engineering, University of Petroleum and Energy Studies, Dehradun – 248007, UK, INDIA

Available online at: www.isca.in, www.isca.me
Received 8th November 2013, revised 27th November 2013, accepted 16th December 2013

Abstract

Water is one of the most important natural resources for life, but unfortunately is at a continual depletion, threatened by industrialization, urbanization, deforestation and modern agricultural practices. Suswa, the tributary of Song, is a historic river dotted with ancient inhabitations and villages situated on the northern boundary of the Rajaji National Park. Increased urbanization and unplanned infrastructure have deteriorated the water quality as well as quantity of the river. Huge quantities of untreated sewage continuously passing in it has drastically disturbed the local ecosystem, and greatly deteriorated the minimum flow. There is a pronounced need to put in efforts towards maintaining a minimum flow of the river for sustaining biodiversity and other purposes. Thus, this makes environmental flow assessment and management to be taken up at priority. The present paper recommends and provisions the development of a building-block methodology assisted knowledge-based system for e-flow assessment and management for Suswa river of Dehradun district. The building block methodology works on the principle of drawing post-analysis recommendations from specialist groups such as hydrologists, geo-morphologists, water quality experts, sociologists, environmentalists and information technology experts. The given inputs assist the knowledge-based system in putting forward cumulative findings (assessment), recommendations drawn thereof, measures to be taken and advice, for maintenance of minimum flow with objective of maintaining quality and quantity of the river.

Keywords: Suswa river, environmental-flow, knowledge-based system, building-block methodology.

Introduction

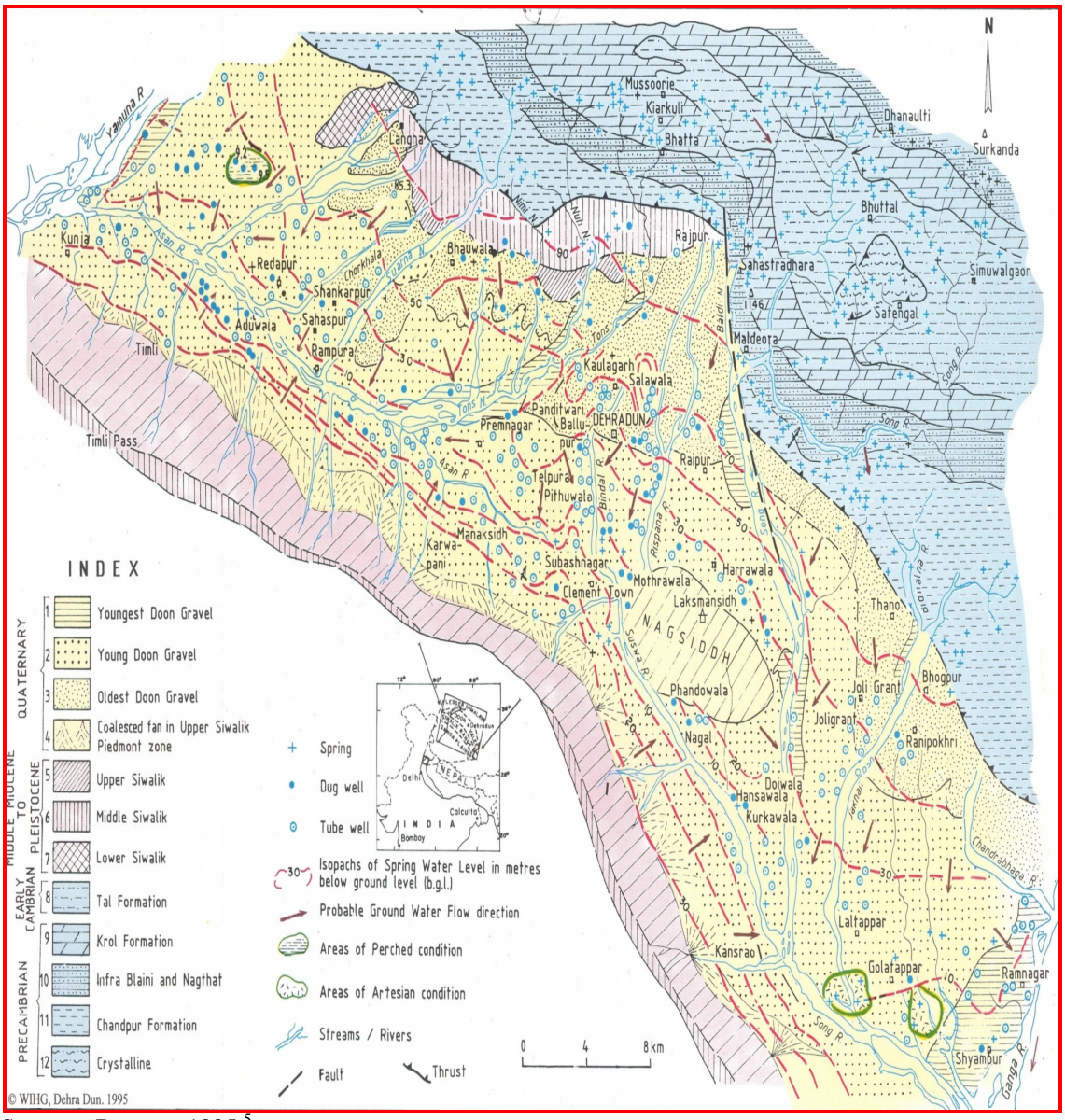
Water is one the most important natural resource which has been continuously depleting due to industrialization, urbanization, deforestation and modern agricultural practices. Changes in flow regimes of rivers are caused by several reasons, such as excessive utilization of water, discharge of urban, industrial and domestic waste. This results, in growing deterioration in the condition (health) of riverine ecosystems further causing irreversible changes in natural flow of the river. This causes loss of fisheries, land through bank collapse, additionally, adding to increased levels of pollution leading to health problems, loss of rare species, livelihood of people reliant on rivers, entrepreneurship programs, development in agriculture and other allied sectors viz, horticulture, animal husbandry.

Concern over worldwide deterioration in the health of rivers has historically centered mainly on water quality problems majorly in last 2-3 decades. With increasing demands for water from a burgeoning human population, rivers' flow regimes are being manipulated in many ways, but with two main trends[1], Swara – UP WWF 2006). River flow is either reduced due to diversion for agricultural land, or due to discharge of waste, amplified, due to deforestation and encroachment of river bed causing flood, or increased flow during monsoon and post monsoon season WWF 2012, 2009[2]. Both may happen in the same river at different times of the year, resulting in a general tendency towards reversal of flow patterns. Maintenance of natural biodiversity is the key to health of ecosystems and sustainable utilization. This was the major emphasis of Agenda 21 at the 1991 Environmental Summit meeting in Rio de - Janeiro (United Nations UN 1992). In this regard, the definition of biodiversity proposed by Noss[3], this recognizes components, structures, and functions of ecosystems at the scales of landscape, community, population and genes.

The study area identified is the catchment of the Suswa river, which discharges its water in river Ganga. Dehradun district is situated in NW corner of Uttarakhand state and extends from N Latitude $29^0$58' to 31^0 02' 30" and E Longitude $77^0$34' 45" to $78^0$18' 30". It falls in Survey of India Toposheets Nos. 53E, F, G, J and K. The district is bounded by Uttarkashi district on the north, Tehri Garhwal and Pauri Garhwal districts on the east and Saharnpur district (UP) on the south. Its western boundary adjoins Sirmour district of Himachal Pradesh separated by Rivers Tons and Yamuna. Doon valley is drained by the Asan and Song rivers. A single valley, apparently, consists of two

shallow valleys, the Western and the Eastern Doon valley respectively. The river Suswa joins tributary Song river near Raiwala which finally joins river Ganga at Hardwar. The basins of Asan and Song river are separated by a ridge starting from Mussoorie and passing through Dehradun to Asarodhi. The easterly flowing rivers join river Ganga and the westerly flowing rivers join river Yamuna. Ganga enters the district near Rishikesh where Chandrabhaga river joins it. Suswa is one of the main tributaries of the river Song. Suswa flows SE, draining the eastern Doon along with its ephemeral tributaries like Bindal Rao, Rispana Rao etc. and joins River Song near Raiwala. Song has its origin in adjoining Tehri district. Initially it runs parallel to the Mussoorie Mountain chain in NW direction for few kilometers and then takes a sudden turn in SE direction and joins Suswa River south of Doiwala near Raiwala.

There is no STP (Sewage Treatment Plant) in Dehradun city for treating the sewage leading to city's sewage being discharged directly into the river Suswa just after its origin at Maturawala. The river Suswa serves as a conveyor of sewage (drain) as it passes through the Rajaji National Park forest area. Suswa river, the tributary of Song, in Dehradun district of Uttarakhand, is highly polluted. In order to conserve its aquatic biodiversity, maintaining quality and quantity of river, the management of minimum river flow is necessary. It is essential to understand how much water is required for the river to sustain its social, cultural and ecological function. Managing flow of river can give fresh lease of life to dying river WWF 2012 [4]. The present work presents a reminiscent framework for e-flow management through knowledge-based (expert) system for Suswa river.



Source : Bartarya 1995 [5]

Affects and Challenges: The degradation of water is not only ecological problem but also societal problem. The human civilizations have always been developing in and around rivers, and the trend continues even today. Presently, most cities, urban areas, townships and villages are in and around rivers and owing to misuse, there has been severe pressure on water resources. This has resulted in depletion in water quantity, as well as quality of water for both present and future use. In water resource planning and management it is important to predict with accuracy the flow and water quality of water bodies 6. The Physio-chemical analysis and aquatic biodiversity of the river has been carried out by number of researcher i.e Chang, Sohngen, King and Thorma[7-12]. Flow and water quality are important in predicting the pollutant load within the water bodies. In managing water quality it is important to determine aggregate of point and non-point source pollution loads in order to set maximum allowable loads from each source that contribute to pollution of a river[13]. It is an important area to work on rivers which are threatened by fishing, mining of beds for sand, gravel and stones, all of which have led to depletion of habitat for birds and aquatic fauna. The Song river is polluted with toxic discharge from distilleries and limestone mining near Mussoorie area. Sulphur Springs, although now on a small scale, were once prevalent on a large scale.

This has caused considerable soil erosion and landslides, making these mountain slopes completely barren. This area was also once habitat (1,650-2,000 m) for the now critically endangered[14] Himalayan Quail Ophrysia superciliosa. The wetland at Asan Barrage has problems with siltation and has other set of problems such as, the prolonged period of water discharge required for cleaning it out, increasing number of motor boats, growing weeds e.g. Eichhornia crassipes, Ipomoea fistulosa and Typha elephantine, and loss of habitat for migratory water birds[15] emphasized on the concept of e-flow (Environmental-Flow) and its significance in current environmental decision-making. The Brisbane Declaration 2007 defines E-Flows, as: *'Environmental Flows describe the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.'*

The local community of the Siwalik range depends on Suswa river for their livelihood. The river water had been used for irrigation and other domestic purpose. Agricultural practices involve animal husbandry, horticulture, floriculture and apiculture, which has severely affected and caused changes or disturbances to the flow of river. The river is habitat for aquatic biodiversity. The small streams which discharge their water in Suswa river forming Watershed of Suswa are dried or their flow is reduced causing deterioration of quality and quantity of the river further causing loss of biodiversity in Suswa river of Dehradun distrcit[16-23].

Effort towards restoration of e-flow management would involve as pre-work, to survey the region and interview inhabitants, in order to assess the irrigation pattern affected due to disturbance of the flow of Suswa river. Additional information would be gained through administering questionnaires to local community of the village adjoining the river Suswa village. Villagers will be involved for detailed analysis of connecting streams and permitted potential of the area for agricultural development and other entrepreneurship programmes, without affecting and disturbing e-flow.

Building Block Methodology

The present work advocates the use of Building Block Methodology which brings together various experts from different fields envisioned as geo-morphology, hydrology, biology, sociology, water quality assessment, and Information Technology. Each of these, work in their individual domain specifics, supported with literature review and relevant studies to compile current condition, and draw recommendations for managing the e-flow, in terms of measures for maintaining the minimum e-flow required. The application of Knowledge Based System and Artificial Neural Network Model for river water quality management had been used by Abdul Ghani[24]. The information technology group uses the recommendations and measures from all the other groups and generates a compiled, comprehensive e-flow management regime and strategy through knowledge-based system. Post the routine process of site-selection and zonation, each of the groups initiate their activities. The Suswa river would be divided appropriately into 2-3 zones based on geology, slope, climate, size and confluence with tributaries. Zonation will be carried out on the basis of hydrology, geology, land use and geomorphological assessment. Further necessary initial inputs are base maps including drainage and township from the Survey of India maps and satellite images. The section below presents the contribution from each of the expertise heads, in respective areas, forming the building blocks of the overall proposed system.

Geo-morphological group initiates with mapping of the sediment sources in the river catchment and measurement of suspended sediments. The objective is to predict the consequences of changing flows of Suswa river on the sediment input-output. Hydrological analyst group works on measurement of discharge of the river at minimum two stations along the course of Suswa river, with an objective to check the flow variability in different months, season and in different years. Biological survey group works on sampling of aquatic biodiversity (sampling of riverine mammal, reptiles, birds, fish communities, benthic invertebrate, phyto and zoo-plankton communities, amphibian and riparaian vegetation to determine composition of the community, to identify their flow requirements. The purpose is identification of flow-sensitive species defining their seasonal habitat requirement, in terms of current flow, velocity and depth of the river. Water quality expert group, conducts analysis of physical, chemical and biological parameters of water quality, with an objective to generate impact assessment by point sources and the other

diffused sources of water pollution. Socialist group would work towards identification of people who are directly dependent on a riverine ecosystem. The purpose is to identity preferences for management objectives of the river. It will provide an index of social importance taking into account the number of people directly depending on riverine ecosystem. The IT group finally is entrusted with the responsibility to design and develop a knowledge based (an expert) system that would serve as an assessment tool, facilitating the entry of assessment/analysis data (from all above mentioned groups) and further by using rule-based decision making, to recommend the most suitable flow management strategy in a scenario-wise manner. Major role of IT here is to respond to the recommendation of other groups, estimating the effects that the recommended flows would have in mitigating pollution or water quality issues. Additional aim of the system would be to disseminate the environmental flow knowledge to the interested communities.

The section below elaborates on the work by various group specialists. Hydrological Analysis (Hydrology group) will study and summarize the natural flow regime at each site. Hydrological analysis is carried out to monitor or to check that the availability of flow within the recommended limit or not. The flow of water in a river channel and the physical structure of the channel are intimately related in a cycle of cause and effect in space and time. Local hydraulics and channel morphology are the primary determinants of the availability of physical habitat which, in turn, is a major determinant of ecosystem functioning. Study of Hydraulic section cross section will provide the link between ecological knowledge and flows. Flow variability between different seasons would be studied. Analysis of the frequency of the floods of different sizes will help in guiding the high flow recommendation by ecologist and hydrologists. Geomorphological Survey (The geomorphological group) will work on the flow velocity and depth required to move, sort and deposit different sizes of sediments so as to maintain different channel size. The gomorphological survey would include assessment of the types and sources of sediment in the river. Its aim would be to analyze the channel morphology in terms of geomorphological features and their stability to predict the consequences of changing flow types.

There are three important geomorphological issues to consider in applications of the BBM[25] i.e i. assessment of channel dynamics and potential impacts of impoundments, ii. selection of representative BBM sites and iii. application of the BBM routines to each site. These activities take place at the catchment scale, river network scale and reach or site scale, respectively. Biological Survey (The biodiversity group) would work with focus on sampling of riverine fish communities, benthic flora and invertebrate fauna, plankton (phyto and zoo-plankton communities), and riparaian vegetation to determine composition of the community, to identify their flow requirements. Also emphasis would be on identifying flow sensitive species and identifying their seasonal habitat requirements in terms of current velocity, depth and wetted perimeter. The riverine biota will be used as an indicators of the types of the flow that will be require to maintain different level of ecosystem health and most important its integrity.

Water Quality Analysis (The water quality group) would respond to the recommendation of other groups, estimating the effects that the recommended flows would have in mitigating pollution. Two major attributes of a river that affect ecosystem structure and functioning are water quantity and water quality. Water quantity issues (flow, velocity, depth and other hydraulic parameters) are the principle foci of EFAs. However, aquatic organisms also respond to water quality, and exhibit specific tolerance ranges and preferences for different chemical constituents. Thus, efficient functioning of river ecosystems requires provision not only of a suitable hydrological regime, but also of water of a suitable quality. Water quality is described in the South African Water Quality Guidelines (DWAF 1996a) as the physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems. Water quality requirements are assessed in parallel with the flow requirements. Various water quality variables will be used to understand the current status of the river. Impact assessment will be carried by analyzing physical and chemical and biological parameters. Sampling and monitoring for water samples will be carried in all the months (Jan – December) for a pre-decided sample period. Present water quality conditions will be compared with reference conditions and applicable guidelines in order to, categorize the present state. The samples would be analyzed for the physico-chemical, trace metals and microbiological parameters following standard methods such as, APHA 21st edition. Secondary data related to water chemistry from the state department and published and unpublished literature would be collected, as well. Provided below is the preliminary detail regarding parameters proposed to be analyzed. The parameters such as temperature, pH, conductivity, DO, etc will be measured in field. The samples for major ions and trace elements will be brought to lab in pre-cleaned polyethylene bottles for analysis. A separate set of samples will be collected for bacteriological analysis. The result will be interpreted with respect to natural composition of water and their controlling factors and changes that take place once it passes through urban area.

Social Survey's objective is social assessment, to provide information on the use of riverine resources by rural communities, and on the importance of a healthy riverine ecosystem, from a community perspective, for sustaining their livelihoods. The fisherman and farmers are directly depend on riverine ecosystem. The major outcome proposed development of an ecological framework in support of a socio-environmental study that will ensure that the social consultant collects data in a way that they can be used by the biophysical specialists and contribute to the development of a framework and guidelines for future studies of this nature.

Prepositioning Knowledge Based System: Identification of river water quality using the fuzzy synthetic evaluation approach and application of Knowledge Management System on flow and water quality modeling have been studied by few researchers[6,14,26,27,28,] additional aim of the system would be to disseminate the environmental flow knowledge to the interested communities.

Information Technology expert group would design and develop an expert system that would serve as an assessment tool, facilitating the entry of assessment/analysis data (from all above mentioned groups) and using rule-based decision making, to recommend the most suitable flow management strategy in a scenario-wise manner. A KBS is a system that closely resembles the human logic in the decision making process from various sources of knowledge. The aim of the proposed prototype system would be to demonstrate the use of knowledge-based system to assess the water quality of Suswa river and identify the potential sources as well as recommend remedial measures to be taken to minimize the river pollution. The objective is to contribute to the effectiveness of determining the status of the river water quality and the needed actions. It shall assist in improvement of the water quality and enhance the decision making of water quality managers. In response to the user's query, the identification of the segment of the river, the predicted loading is greater than the water quality threshold, would be done. Further analysis in view of data received from other groups, shall lead to development of management strategies and serving as an early warning system, sending alerts to water quality managers, on the incident of exceeding allowable limit for the drinking water intake points on said river segment[21].

The choice of using logical representation for assessing systems is frequently desirable or necessary, when available data are scarce or the current state of knowledge about a problem domain is too imprecise for classical mathematical methods. Sullivan et. al. (2004)[31] advocated the use of KBS, to provide logically and mathematically robust evaluation of imprecise information and is particularly, relevant in managing resources, ecosystem and the environmental pollution.

Discussion

The knowledge based system will be used to assess the water quality of the river and to identify the potential sources as well as, recommend the remedial measures, to be taken to reduce the pollution[30,31]. River with little or no flow and an excess of waste water are likely to become source of disease. E-flow assessment methods are required for defining recommended flow with higher confidence level from perspective of accuracy and clarity. It will provide detail information related to consequences for biodiversity, livelihoods and other aspects watershed management due to changing flow pattern. The environmental flow assessment would done for mitigation purposes, to advise on releases that would reduce the impacts of a proposed development, or for the purposes of restoration, to advise on flows that would partially reverse past degradation. Thus it can be used to help guide decisions on the management of extant or possible future water-resource developments.

A set of recommendations regarding minimum E-flow are required to keep the river and all aspects of functioning in desired condition, i.e protecting biodiversity and communities. All the recommendations would be of immense help to central and state government organizations, to take effective measures for managing the minimum flow of the river. Estimated changes in E-flow pattern including physical changes in watershed of Suswa river have their own importance from knowledge point of view. The Application of knowledge based system (expert system) for providing information on minimum flow required for conservation and preservation is a novel concept holding potential that needs to be explored.

The report on E-flow would act as a technical manual for E-flow assessment for other rivers. It will provide background information about present state of Suswa river and develop a measures on environmental and social objectives for the river. It is intended to give an idea of importance of flows, as a major driver of environmental condition in the river and to outline the available expertise, understanding and methodologies being developed in India and world-wide. The study will develop frameworks to strengthen the mainstream implementation of E – Flow for sustainable management of rivers. It will help in management of land, and water resource for agricultural development. The E flow reports promise value to government departments, i.e. Central Ground Water Board, Water Works Department, MDDA (Mussorrie Dehradun Development Association), Dehradun Nagar Nigam, Jila Panchayat Dept. and Municipal Cooperation, for incorporating all the recommendation development plan.

Conclusion

The present work is a conceptualization of framework for development of a knowledge-based system which is assisted by building block methodology of e-flow management. The system proposes to gather inputs from specialist groups, which serve are building blocks, and build comprehensive strategies and recommendations for assessment and management of e-flow for Suswa river of Dehradun district and Uttarakhand.

References

1. Samkhtin V. U. and Anputhas, An assessment of Environmental Flow Requirements of Indian River Basins, *Research Report No. 107, IWMI* **(2006)**

2. WWF Keeping river alive: An overview of Environmental Flows and their assessment for all levels of users. By JHO Keeffee and T Le Quesne. WWF Water Securities Series 2,

Published by WWF – UK , *Godalming, Surrey*, 39 pages **(2009)**

3. Noss Reed F., Indicator for Monitoring Biodiversity : A Hierarchical Approach, US Environmental Protection Agency, *Journal of Conservation Biology* **(1999)**

4. Chopra Ravi, Examining Environmental Flows Critical for River Ecosystems in India, WWF, **(2012)**

5. Bartarya S.K, Hydrogeology and Water Resources of Intermontane Doon Valley, *Journal of Himalayan Geology, (Wadia Institute of Himalayan Geology),* **Vol. 6**, No. 2 **(1995)**

6. Chang N.B., Chen, H.W. and Ning S.K., Identification of river water quality using the Fuzzy Synthetic Evaluation approach,. *Journal of Environmental Management* **63**, 293-305 **(2001)**

7. Mikia M., Mady-Goma Dirat I., Tsoumou A., Mabanza J., Vouidibio J. and Diatewa M., Preliminary Data on the Ichtyofaun of Djiri River (Affluent of right bank of Congo River), *Int. Res. J. Environment Sci.,* **2(10),**1-6 **(2013)**

8. Devi Moirangthem Banita, DasTapati and Gupta Susmita,Limnological Studies of Temple Ponds in Cachar District, Assam, North East India *Int. Res. J. Environment Sci.,* **2(10),** 49-57 **(2013)**

9. Tailor Manthan A. and Mankodi Pradeep C., Physico-Chemical status of Danteshwar pond of Vadodara City, Gujarat India and its Environmental Implications, *Int. Res. J. Environment Sci.,* **2(10),** 58-62 **(2013)**

10. Thorat Prerana B. and Charde Vijay N.,Physicochemical Study of Kanhan River Water Receiving Fly Ash Disposal Waste Water of Khaperkheda Thermal Power Station, India, *Int. Res. J. Environment Sci.,* **2(9),** 10-15 **(2013)**

11. Chandrakiran and Sharma Kuldeep,Assessment of Physico-Chemical Characteristics of Sediments of a Lower Himalayan Lake, Mansar, INDIA *Int. Res. J. Environment Sci.,* **2(9),**16-22 **(2013)**

12. Abdul Ghani P.H., Knowledge Based System for River Water Quality Management, *European Journal of Scientific Research*, **ISSN 1450-216 X Vol. 33 No. 1,** 153-162 **(2009)**

13. Sohngen B. & Yeh C.Y., Total Maximum Daily Loads (TMDLs), http://ohioline.osu.edu/ae-fact/0007.html. Accessed on 3 April 2006 **(1999)**

14. Chau K.W., Chuntian C. and Li C.W., Knowledge management system on flow and water quality modeling. *Journal of Expert Systems with Applications*, **22(4),** 321-330 **(2004)**

15. Samir Mehta (2012) Towards Restoring Flows into the Earth's Arteries A Primer on Environmental Flows, Latha Anantha & Parineeta **(2012)**

16. Bartarya S.K, Bahukhandi K.D, Impact Assessment of Urbanization and Industrialization on surface and groundwater quality of Dehradun district of Uttarakhand, *Global Journal of Engineering Design and Technology*, GJET**, 1(1)**, **(2012)**

17. Bahukhandi K.D, Presented /paper on Assessment of Water quality in Dehradun district in National Symposium on Advance in Biotechnological Research in Agri-Horticultural Crops for Sustaining Productivity, Quality Improvement and Food Security on September 14th to 16, 2011 organized by Centre of Excellence in Agricultural Biotechnology, Deptt. Of Biochemistry and Physiology, College of Biotechnology at Sardar Vallabhbhai Patel University of Agri. & Tech., Merrut (UP) **(2011)**

18. Bahukhandi K.D., Siddiqui N.A., Impact assessment of Urbanization on water quality, *Environmental Pollution Control Journal* **, 12(1)**, **(2008)**

19. Bahukhandi K.D and Bartarya S.K, Hydrochemistry of Surface and groundwater of Doon valley, Has been presented and published in proceeding volume on *Fifth International Groundwater Conference* (IGWCC) jointly organized by Association of Geologist and Hydrologist at Aurangabad, Maharashtra, **3**, 1109-1119 **(2012)**

20. Bahukhandi K.D. and Bartarya S.K., Hydrochemistry of Surface and Groundwater Haridwar district, Uttarakhand, *International Conference on Chemical, Biological and Environmental Engineering*, ICBEE-BAN_012 (**2011)**

21. Dudeja D., Kuamr B. ,Suresh, Biyani A.K., Hydrochemical and water quality assessment of groundwater in Doon Valley of Outer Himalaya, Uttarakhand India, *Environ Monit Assess* **(2011)**

22. Jain C.K., Bhatia K.K.K. and Sharma M.K., Groundwater quality evaluation in Doon valley (p.37), Dehradun, *Unpublished report no. CS (AR) 10/96-97, National Institute of Hydrology ,* Roorkee **(1997)**

23. Jain C.K., Ground water quality district Dehradun, National Institute of Hydrology, Jal Vigyan Bhawan, CS(AR) **10** 96-97 **(2002)**

24. Pauziah Hanum Abdul Ghani*, Mohd Kamil Yusoff, Latifah Abd. Manaf, Knpwledge based system for river quality management, Prpceedings of Postgraduate Qollquium Sem 2009/2010 **(2010)**

25. Wadeson R.A. and Rowntree K.M., Application of the hydraulic biotope concept to the classification of stream habitats, Aquatic Ecosystem Health and Management, **1**, 143-157 **(1998)**

26. Wang X., Mike H., Scott D.D., Charlotte W.H. and Changming D., A river water Quality Model integrated with a web based geographic information system, *Journal of Environmental Management*, **75(3),** 219-228 **(2005)**

27. Cecilio A., Joan C., Pablo R., Montserrat B., Antonia G., Sergio C., Fuzzy expert system for the detection of episodes of poor water quality through continuous measurement **(2004)**

28. Nasiri F., Maqsood I., Huang G., Fuller N., Water quality index: A fuzzy river-pollution decision support expert system, *Journal of Water Resources Planning and Management,* **133(2)**, 95–105 **(2007)**

29. Sullivan T.J., Saunders M.C., Tonnessen K.A., Nash B.L. and Miller B.J., Application of a regionalized knowledge-based model for classifying the impacts of nitrogen, sulfur, and organic acids on lakewater chemistry, Knowledge-based system, **18**, 55-68 **(2005)**

30. Mohd. Zahit A., The Application of the Artificial Neural Network Model for River Water Quality Classification with Emphasis on the Impact of Land use Activities: A case Study from several catchment in Malaysia. PhD Dissertation, University of Nottingham, United Kingdom **(2005)**

31. King and Therma, Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Holistic Methodologies, *Environment Autralia*, **(1994)**