J. Mater. Environ. Sci. 6 (3) (2015) 613-618
ISSN: 2028-2508
CODEN: JMESCN

Ecological Health Assessment of Chambal River, India

Naresh Singh Yadav, M.P Sharma, Amit Kumar

Biomass and Ecosystem lab, Alternate Hydro Energy centre, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, 247667, India

Received 23 July 2014; Revised 28 September 2014; Accepted 28 September
*Corresponding author: amit.agl09@gmail.com, Tel: +919045939559, Fax: +911332273517

Abstract
The rapid decline in river water quality is an alarming signal to environmentalist. An attempt has therefore been made to study ecological health of Chambal River using multiple indices viz. NSFWQI, CTSI & SDI. The results show that overall ecological health is in good range of 1-2. The water can be used for irrigation, bathing, aquaculture etc except drinking purposes. The present ecological health of river is also attracting large number of aquatic birds and animals.

Keywords: Ecological health, NSFWQI, Simpson diversity index, Carlson trophic state index

1. Introduction
The river, lakes, wetlands etc. are important for the sustenance of human life since centuries but are presently under constant threats due to the discharge of sewage industrial effluents, municipal solid waste, agricultural waste etc which are badly impairing the water quality. Joshi et al., [1] ecological health index (EHI) which enables the comparison between spatial and temporal assessments. Ecological health is a term that relates to ecosystem productivity, its biological diversity and its resilience to the negative impacts of a variety of pressures. The concept of river health originates from river ecosystem health and it is not confined to river ecosystem only. The river has both, natural and social attributes each contributes to overall health of water bodies. Ecosystem health is formed by the interaction between river biota and their hydro-geochemical environment. River health depends on the diversity of habitats, plants and animal species, the effectiveness of the linkages and the maintenance of ecological processes. Riparian habitat is a key element of river functioning [2-5]. The rivers and streams habitat [5] can support a high biodiversity, especially, in large floodplain rivers [6], protect the main channel from temporal changes [7] and provide refuge and food for wildlife [8]. The structure and function of this riparian habitat can either be extremely complex and heterogeneous as in floodplain rivers or relatively simple as alongside the headwater streams. It is, therefore, difficult to compare riparian habitats along the river continuum. Yadav et al., [9-11] found that the water quality of Chambal river of M.P is good and can serve the purpose of irrigation, bathing, aquaculture etc except drinking. The water quality may be used as primary biological indicator that can provide information on the lateral and vertical dimensions of stream ecosystems [12]. The status of riparian habitat is not often used to describe river 'health' but several methods can be used to evaluate the biological or habitat condition of rivers [13-15], river health and ecological integrity [16]. Literature reveals that very few studies are available on the river health assessment in India based on riparian vegetation and hence the biodiversity river health.
This paper deals with evaluation of ecological health of the study stretch of Chambal River based on the Simpson biodiversity index, NSFWQI & TSI. The paper concludes that the health of the Chambal River is good to medium range in winter and summer respectively.

2. Study Area
Chambal River, with vast tract of ravines, originates from Mhow near Indore in Madhya Pradesh (MP), India and is the main tributary of Yamuna River part of greater Gengetic drainage system in the central India. The total length of Chambal River is 960 kms with catchment area 143,219 Km^2 and average discharge of 456m^3/s. The river flows in the North-North East through Madhya Pradesh (M.P) passing through some parts of Rajasthan forming a boundary between MP and Rajasthan and finally turning towards south east direction to merge with Yamuna in Etawah (UP). Location of Chambal River and the sampling points is as shown in figure 1 and Table 4 & 5.

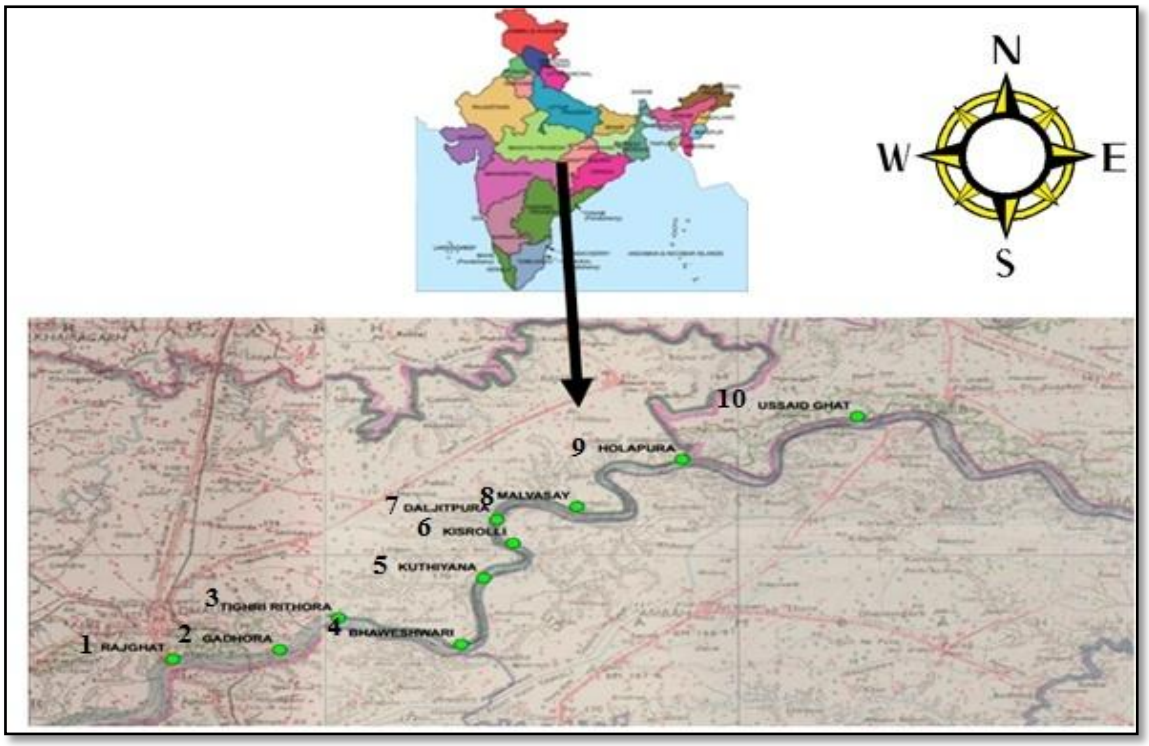

Figure 1: Study stretch of Chambal River with sampling locations

3. Ecological health of rivers

Ecological health is the expression of ecosystem productivity, biological diversity and its resilience to the negative impacts of a variety of pressures such as excess nutrients, proliferation of weeds and invasive aquatic fauna, algal bloom, low oxygen, heavy metal, pesticides, foreshore degradation etc. Hydrology primarily, controls the ecological health of river systems through its impact on flow, channel geomorphology, water quality and habitat availability. Chambal River is widely perceived to be of high ecological quality with abundant flow volume and high water quality. However, historical and current river flow regulations and land use changes have altered the physiochemical characteristics of Chambal River with adverse consequences on aquatic biota. Riparian vegetation, Simpson Diversity Index, Carlson TSI and NSFWQI are considered to define the overall ecological health of river in the present study. Each aspect is discussed as below:

3.1 Riparian vegetations

The riparian zone can act as buffer between the river and its surrounding catchment. Assessment of riparian zones is an effective tool to assess the river based on nutrients, sediment runoffs, maintenance of food-web and other important links between the terrestrial and aquatic environments. Riparian vegetation, consisting of macrophytes, native grasses, sedges, forbs, climbers, shrubs, trees etc is a function of location, time and interactions between the physical conditions created by geomorphic and hydrologic processes in the stream channel and responses by the plants [17-19]. A floristic survey of trees, shrubs, herbs, grass and aquatic species was performed by [20] least count quadrat method in which each species was collected, mounted, labeled and systematically arranged in a herbarium [21]. Identification of riparian plants was done with the help of literature [22-24]. Riparian vegetation also stabilizes the bank sediments to reduce erosion and provide buffer between the river and its catchment to reduce the amount of sediment and nutrients entering the river and provides suitable habitats for animals living on the bank and in the water. Reduction in water height may be lethal to seedlings of riparian plants and thus may limit or prevent the growth of new species [25-26]. However, long-standing disturbance of the river and riverbank creates conditions that reduce the local native biodiversity in the plant community and can foster the invasion of non-native plant species [27]. Both of these factors can impact the riverbank health. Based on the available plants i.e. grasses, herbs, & trees, the biodiversity were evaluated in this paper.

3.2 Simpson Diversity Index (SDI)

Species biodiversity is used to indicate the 'biological health' of a particular habitat. SDI is a dominance index that differentially assigns weight to common species [28]. It can be calculated as 1 – D, where D is diversity index calculated as:

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

n: total number of individuals of a given species, and N : the total number of all species collected.

It measures the probability of two individual selected from a sample to belong to different species. The value range from 0 - 1, with 1 representing the highest diversity i.e. larger number of species and more stable ecosystem indicating that the environment is less hostile and less damaging to the ecosystem as a whole whereas '0' represents poor diversity.

3.3 Carlson Trophic State Index (CTSI)

The nitrogen, phosphorus and other biologically useful nutrients determine the trophic state of water body through Trophic State Index (TSI). Nutrients like nitrogen and phosphorus tends to be limiting in standing water bodies and the increased concentration tend to result in increased plant growth followed by corollary increase in subsequent trophic levels. The CTSI can be calculated using the following formulae [29]:

a. TSI for Chlorophyll-a (CA) TSI = 9.81In Chlorophyll-a (ug/L) +30.6 (1)
b. TSI for Secchi depth (SD) TSI = 60-14.41In Secchi depth (m) (2)
c. TSI for Total phosphorus (TP) TSI = 14.42 In Total phosphorous (ug/l) + 4.15 (3)
CTSI = [TSI (TP) +TSI (CA) +TSI (SD)]/3 (4)

3.4 Calculation of NSFWQI

NSFWQI, an excellent management and general administrative tool in communicating water quality information, is widely applied to different geographical areas all over the world for calculating WQI of water bodies. It can be mathematically expressed as:

$$\textbf{NSF WQI} = \sum_{i=1}^{p} W_i I_i$$

Where, I_i is the sub-index for ith water quality parameter; W_i is the weight (in terms of importance) associated with ith water quality parameter; p is the number of water quality parameters. The NSFWQI ratings are given in Table 1.

Table 1: NSFWQI ranges for water quality [30]

S. No	Ranges	Water quality status	Color code
1.	90-100	Very good	Blue
2.	70-90	Good	Green
3.	50-70	Medium	Yellow
4.	25-50	Bad	Orange
5.	0-25	Very bad	Red

***3.5** Ecological Health Index (EHI)*

Joshi et al., (2013) calculated Ecological Health Index (EHI) of rivers lakes based on NSFWQI & CTSI as shown in Table 2. The equation suggested by Joshi et al., (2013) are modified by Athalye and Salaskar for calculating EHI as expressed by equation 5.

Table 2: EHI based on WQI & CTSI (Joshi, S., 2013)

NSFWQI	Carlson's TSI	EHI value	EHI Range	Status
0 – 25	10-30	1	< 1	Excellent
25.1 – 50	31-50	2	1-2	Good
50.1 – 75	51-70	3	2-3	Medium
75.1 – 100	71-90	4	3-4	Poor
Above 100	>90	5	4-5	Very poor

Based on the WQI, SDI & CTSI, the overall EHI can be calculated using equation:

EHI = [EHI of CTSI + EHI of WQI + 1/ SDI]/3 **(5)**

The EHI ranges are explained in Table 3 to know the status of ecological health of the river/water bodies.

4. Material and Methods

The Water quality data collected is based on water sampling at 10 locations along the study stretch of the Chambal River. Water samples were analyzed for NSFWQI, C-TSI, SDI and EHI using standard methods of analysis [31]. The entire stretch on riparian vegetation of the river was divided into 100 plots each of 1m×1m at a distance of 100m from the bank of river on both the sides. Each plot was kept at the distance of approximately 0.5 km from each other. All terrestrial plants (tall, medium and small), aquatic vegetation, annual grass, perennial grass, herbs, shrubs and trees etc were collected. The data was used to calculate SDI for each plot and averaged in both the season. Similarly, EHI was calculated at all the locations in both the season.

Table 3: EHI ranges and its explanation

S. No	EHI	Ecological Quality Status	Explanation
1.	0–1	Excellent	• The biology is similar to an average and unpolluted river of this size, type and location. • There is a high diversity, usually with several species.
2.	1–2	Good	• The biology shows minor differences from excellent and falls a little short of that expected for an unpolluted river of this size type and location. • There may be a small reduction in the number of families that are sensitive to pollution • It indicates the first signs of organic pollution and a moderate increase in the number of individual creatures in the families that tolerate pollution.
3.	2–3	Medium	• The biology shows large differences from that expected for an unpolluted river of this size, type and location. • Sensitive families are scarce and contain only small numbers of individual creatures. • There may be a range of those families that tolerate pollution and some of these may have high numbers of individual animals.
4.	3–4	Poor	• The biology is restricted to animals that tolerate pollution, with some families dominant in terms of the numbers of individual creatures. • Sensitive families will be rare or absent.
5.	4–5	Very Poor	• The biology is limited to a small number of very tolerant families, often only worms, midge larvae, leeches and the water hog louse. • These may present in very large numbers. • In the very worst case, there may be no life present in the river.

5. Results and Discussions

The NSFWQI, CTSI & SDI at all locations in winter & summer 2014 for study stretch of Chambal River is given in Table 4 & 5. Figure 2 & 3 is the graphical expression of EHI at all location of the river. The study reveals that EHI at all location is found in the range of 1-2 showing that the river is in good ecological health. Figure 2 & 3 represents graphically the EHI/ ecological health of study stretch of Chambal River in both the season.

Table 4: Calculation of EHI during winter 2014

Sl. No	Sampling point (designation)	Latitude	Longitude	NSF WQI		SDI	C- TSI		EHI	
1	Rajghat (A)	77˚54'15.7"	26˚39'33.5"	65.29	Medium	0.98	32.33	Oligotrophic	2.00	Good
2	Godora (B)	77˚58'10.5"	26˚40'00.9"	69.86	Medium	0.98	30.84	Oligotrophic	2.00	Good
3	Tighrerithora (C)	78˚00'19.2"	26˚41'37.4"	69.42	Medium	0.98	28.23	Oligotrophic	1.67	Good
4	Bhaveshri (D)	78˚04'47.5"	26˚40'17.6"	69.29	Medium	0.98	27.54	Oligotrophic	1.67	Good
5	Kuthiana (E)	78˚05'28.5"	26˚43'08.8"	67.14	Medium	0.98	28.83	Oligotrophic	1.67	Good
6	Kisrauli (F)	78˚06'40.8"	26˚45'24.8"	68.00	Medium	0.98	29.96	Oligotrophic	1.67	Good
7	Daljeetpura (G)	78˚06'05.5"	26˚46'33.6"	67.28	Medium	0.98	30.00	Oligotrophic	1.67	Good
8	Malvasi (H)	78˚09'00.6"	26˚47'15.2"	68.43	Medium	0.98	32.00	Oligotrophic	2.00	Good
9	Holapura (I)	78˚12'50.5"	26˚47'37.7"	67.71	Medium	0.98	32.63	Oligotrophic	2.00	Good
10	Kusaidghat (J)	78˚19'14.5"	26˚51'48.2"	67.00	Medium	0.98	33.00	Oligotrophic	2.00	Good

Figure 2 shows that EHI of the river is in good range (1-2) in the location C, D, E, F &G having slightly better ecological health (EHI: < 2.0) compared to other locations (EHI: 2) in winter. Reason behind the relatively good range in these locations may be due to the self purifying ability of river owing to the sedimentation of suspended solid and oxidation of soluble material. As per figure 3, the EHI at all the locations except C (EHI: <2.0) is approaching towards medium range i.e. experiencing more pollution in summer than winter, even though the overall EHI is in good range. From these results, it is concluded that overall ecological health of the study stretch is good but at some of the locations, the ecological health is more polluted than other locations. It is

recommended, that the water of the study stretch is not fit for drinking but suitable for irrigation, bathing, aquaculture etc and can support large number of aquatic plants and animals as evidenced by high SDI observed on both the bank of river.

Table 5: Calculation of EHI during summer 2014

Sl. No	Sampling point (designation)	Latitude	Longitude	NSF WQI		SDI	C- TSI		EHI	
1	Rajghat (A)	77°54'15.7"	26°39'33.5"	67.00	Medium	0.99	31.13	Oligotrophic	2.00	Good
2	Godora (B)	77°58'10.5"	26°40'00.9"	69.43	Medium	0.99	31.20	Oligotrophic	2.00	Good
3	Tighrerithora (C)	78°00'19.2"	26°41'37.4"	69.57	Medium	0.99	27.03	Oligotrophic	1.70	Good
4	Bhaveshri (D)	78°04'47.5"	26°40'17.6"	70.14	Medium	0.99	33.20	Oligotrophic	2.00	Good
5	Kuthiana (E)	78°05'28.5"	26°43'08.8"	68.57	Medium	0.99	32.02	Oligotrophic	2.00	Good
6	Kisrauli (F)	78°06'40.8"	26°45'24.8"	69.57	Medium	0.99	33.24	Oligotrophic	2.00	Good
7	Daljeetpura (G)	78°06'05.5"	26°46'33.6"	67.14	Medium	0.99	33.27	Oligotrophic	2.00	Good
8	Malvasi (H)	78°09'00.6"	26°47'15.2"	69.71	Medium	0.99	34.08	Oligotrophic	2.00	Good
9	Holapura (I)	78°12'50.5"	26°47'37.7"	69.43	Medium	0.99	36.32	Oligotrophic	2.00	Good
10	Kusaidghat (J)	78°19'14.5"	26°51'48.2"	66.57	Medium	0.99	38.62	Oligotrophic	2.00	Good

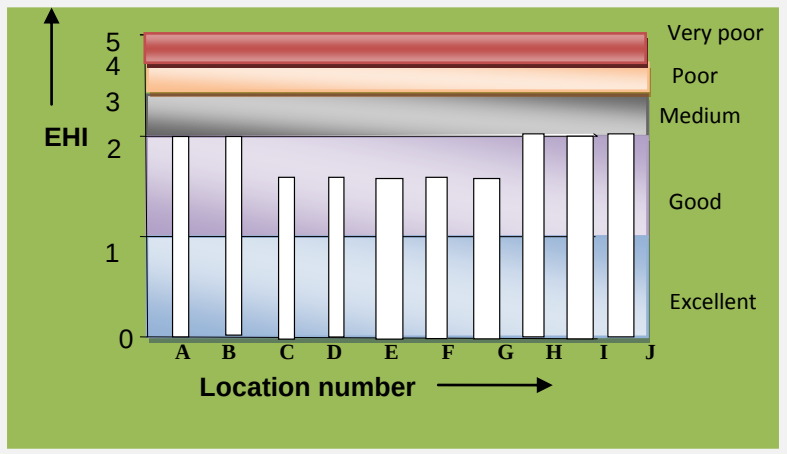

Figure 2: EHI of Chambal River during winter 2014

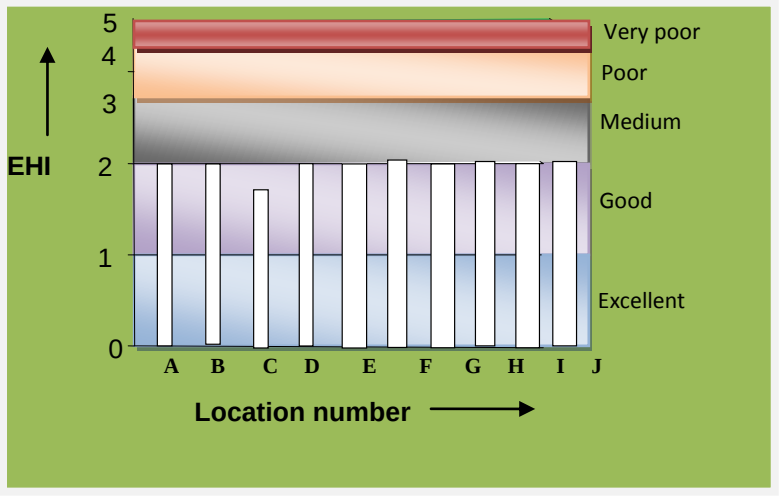

Figure 3: EHI of Chambal River during summer 2014

Conclusions

Based on the NSFWQI, SDI & CTSI, the EHI of study stretch of Chambal River is found as good. The overall EHI at all the location is better in winter than summer. At some locations, the EHI is approaching towards medium quality while others are in good range. The water can be used for irrigation, bathing, aquaculture etc not for drinking purposes. The present ecological health of river is also attracting large number of aquatic birds and animals. In order to bring it to excellent EHI (0-1), conservation measures need to be taken well in advance.

Acknowledgement-One of the authors (NSY) is thankful to National River Conservation Directorate (NRCD), Ministry of Environment and Forests, Government of India, New Delhi for providing the financial assistance in the form of sponsorship for M. Tech degree programme in Environmental Management of Rivers and Lakes (2012-14) offered by the AHEC, Indian Institute of Technology, Roorkee, India.

References

1. Joshi S., *SERI news*, 7(2013), << http://seriecotech.com/blog/?p=377>>, assessed on 23 march 2014.
2. Dudgeon D., *Hydrobiologia.* 294 (1994) 65–85.
3. Huggenberger P., Hoehn E., Beschta R., Woessner W., *Freshwater Biology*, 40 (1998) 407–425.
4. Tabacchi E., Correll D.L., Hauer R., Pinay G.P., Tabacchi A.M, Wissmar R.C., *Freshwater Biology*. 40 (1998) 497–516.
5. Ward J.V., *Biological Conservation*, 83 (1998) 269–278.
6. Naiman R.J, Diecamps H., Pastor J., Johnson C.A., *Journal of the North American Benthological Society*, 7 (1988) 289–306.
7. Whiting P.J., Pomeranets M., *Journal of Hydrology*, 202 (1997) 121–136.
8. Bodie J.R, Semlitsch R.D., *Oecologia*, 122 (2000) 138–146.
9. Yadav N.S., Sharma M.P., Kumar A., Pani S., Water Quality Assessment of Chambal River in National Chambal Sanctuary of Madhya Pradesh. *Ecological sustainability: Concept, Principle, Evidences and Innovations*, ISBN: 978-93-83083-75-6, (2014a), 44-52.
10. Yadav N.S., Kumar A., Sharma M.P., *J. Integ. Sci. Techn*., 2 (2014) 52-56.
11. Yadav N.S., Sharma M.P., Kumar A., *J. Mat. Envir. Sci.*, 5 (2014) 1781-1785.
12. Bunn S.E, Davies P.M, Mosisch T.D., *Freshwater Biology*. 41 (1999) 333–345.
13. Holme N.T.H., Boon P.J., Rowell T.A., *Aquatic Conservation: Marine and Freshwater Ecosystems*. 8 (1998) 555–578.
14. Kelly M.G., Cazaubon, A., Coring E., Dell' uomo A., Ector L., Goldsmith B., Guasch H., Huerlimann J., Jarlman A., Kawecka B., Kwandrans J., Laugaste R., Lindstrom E.A., Leitao M., Marvan P., Padisak J., Pipp E., Prygiel J., Rott E., Sabater S., Van Dam H., Vizinet J., *Journal of Applied Phycology*. 10 (1998) 215–224.
15. Turak E., Flack L.K., Norris R.H., Simpson J., Waddell N., *Freshwater Biology*. 41 (1999) 283–298.
16. Karr J.R., *Freshwater Biology.* 41 (1999) 221–234.
17. Boulton A.J., *Freshwater Biology.* 41 (1999) 469–479.
18. La Fayette R.A., DeBano L.F., Biodiversity in riparian communities and watershed management, Watershed planning and analysis in action, edited by R. E. Riggins, E. B. Jones, R. Singh and P. A. Rechard, New York: American Society of Civil Engineers, 1990, 533-48.
19. CSLC, California's rivers: A public trust report. Sacramento: California State Lands Commission, 1993, pp.384.
20. Misra R., Ecology Work Book, Oxford and IBH publication, Kolkata, 1968, pp. 244.
21. Jain S.K., Rao R.R., A hand book of field and Herbarium methods, Today & Tomorrow Printers & Publishers: New Delhi, 1976.
22. Kanjilal U.N., Kanjilal, P.C., Das, A., De, R.N. and Bor, N.L. 1934-40. Flora of Assam.
23. Dutta A.C., Dictionary of Economic and Medicinal Plants, Assam Printing Works, Jorhat, Assam, India, 1985, pp. 23.
24. Cook C.D.K., Aquatic and Wetlands plants of India, Oxford University Press, New. York, 1996, pp. 385.
25. Ward J.V., Tockner K., *Freshwater Biology*. 46 (2001) 807-819.
26. Rood S.B., Mahoney J.B., *Environmental Management*, 14 (1990) 451-464.
27. Gilvear D.J., Cecil J., Parsons H., *Wiley online library*. 10 (2000) 53-71.
28. Cianfrani C.M., Sullivan S.M.P., Hession W.C., Watzin M.C., *Aquatic Conservation: Marine and Freshwater Ecosystems*, 19 (2009) 147-156.
29. NSFWQI, www.water-research.net/watrqualindex/index.htm assessed on May 15, 2014.
30. Carlson, R.E., *Limnology and Oceanography*. 25 (1980) 378-382.
31. APHA, Standards methods for the examination of water and wastewater, American Public Health Asociation, 20th edition, Washington, 198 (1998).