ISSN 0973 – 6921 ; E – ISSN 2319 – 5983 *J. Environ. Res. Develop.*
Journal of Environmental Research And Development **Vol.10 No. 04, April-June 2016**

PHYSICO-CHEMICAL CHARACTERISTICS AND PHYTOPLANKTON DIVERSITY IN SOME FRESH WATER BODIES OF GOA, INDIA

Sawaiker R. U. and Rodrigues B. F.*

Department of Botany, Goa University, Taleigao Plateau, Goa (INDIA)

Received January 10, 2016 *Accepted May 10, 2016*

ABSTRACT

The freshwater bodies on the surface of globe are environmental assets. They harbour organisms that generate oxygen in the surrounding environment which is utilized by members of all trophic levels. These aquatic assets also provide habitats to a large number of diverse aquatic organisms. Rapid industrialization and urbanization has greatly decreased the available water resources in India. This paper describes physico-chemical characteristics of four fresh water bodies viz., Syngenta Lake, Khandola Pond, Lotus Lake and Curtorim Lake in Goa, India along with their phytoplankton diversity. Seventy one algal species belonging to five classes were identified from the study sites. Seasonal variations were observed in most of the physico-chemical parameters and they were above environmentally acceptable limits. Excepting Khandola Pond, the sites were affected by pollution.

Key Words : Eutrophication, Fresh water bodies, Phytoplanktons, Pollution, Urbanization

INTRODUCTION

Lakes are ecological security zones and true indicators of sustainable urban development. They provide opportunities for recreation, study of local aquatic life and ornamental purposes. As a result of increasing land use conflicts and effluent disposal, water bodies and their catchments in the urban regions have become the ultimate casualties[1]. Yet conservation of water bodies is in the interest of mankind in ecological, cultural and tourism values. As they are so important, it is imperative and challenging to assess their present condition. In the present paper, physico-chemical characteristics and phytoplankton diversity of four fresh water bodies are presented.

MATERIAL AND METHODS

Two water bodies each from North Goa (Syngenta Lake and Khandola pond) and South Goa (Lotus Lake and Cutorim Lake) were selected for the study from Jan-Oct 2014. Water samples were collected in the early hours as daily vertical migrations of organisms occur in response to sunlight and nutrient concentrations from the surface near the landward margins. Monthly analyses of water samples from all the selected water bodies were carried out for a period of ten months using standard procedures[2]. In the phytoplan-kton study one litre of water sample was collected in sterile plastic bottles and Lugol's solution (0.7 ml/100 ml of sample) added immediately for sedimentation. The bottles were subsequently left undisturbed for 24 h. The phytoplankton fixed and settled at the bottom of the containers after decanting the supernatant fluid were collected and preserved in bottles containing 4% formaldehyde preservative. The remaining sample was concentrated by centrifugation at 1500 rpm and the total volumes made to 10ml. Algal samples were examined immediately after fixation using a light microscope. Dimensions were measured using a micrometry technique and photomicrographs were taken using Nikon DS Fi 2camera. Identification was carried out using standard bibliographies and monographs[3-8].

RESULTS AND DISCUSSION

Phytoplankton ecology plays an important role for indicating the eutrophication. Their distribution is majorly forced by seasonal

*Author for correspondence

fluctuations in physic-chemical parameters. Factors such as seasonality, period of sunshine, wind patterns, depth of lake, temperature, pH, turbidity, dissolved oxygen, nutrient enrichment like phosphate ultimately influence the occurrence phytoplankton in the lake[9].

The results of the phytoplankton diversity recorded during the study are shown in **Table 1**. In all 71 algal species belonging to five classes viz., Cyanophyceae (15spp.), Dinophyceae (1sp.), Bacillariophyceae (17spp.), Eugleno - phyceae (5spp.) and Chlorophyceae (33spp.) were identified from the study sites. Some of the genera known to be indicators of organic pollution viz., *Scenedesmus, Chroococcus, Melosira* and *Navicula* were recovered from Syngenta, Lotus and Curtorim Lakes. Khirsagar[10] determined water quality of river Mula and reported that *Scenedesmus, Pediastrum, Oscillat oria, Melosira, Navicula* and *Nitzschia* are indica tors of organic pollution. Palmer[11] stated that pre sence of *Scenedesmus* indicates eutrophic water.

Table 1 : Phytoplankton diversity in the study sites

S/N	Species	Study sites			
		Syngenta Lake	Khandola Pond	Lotus Lake	Curtorim Lake
1.	*Euglena acus* (Muller) Ehrenberg	+	-	+	+
2.	*Euglena minuta* Prescott	+	-	+	+
3.	*Euglena oxyuris*s Schmarda	+	-	+	+
4.	*Ankistrodesmus falcatus* (Corda) Ralfs	+	-	+	+
5.	*Tetralantus lagerheimii* Teiling	-	-	+	-
6.	*Cruciginia quadrata* Morren	-	-	+	+
7.	*Pinnularia gibba* Ehrenberg	+	-	+	+
8.	*Pinnularia graciloids* Huste	+	-	+	+
9.	*Sehroederia indica* Philipose	+	-	+	+
10.	*Melosira islandica* Muller	-	-	+	+
11.	*Nostoc muscorum* Agardh ex Bornet and Flahault	+	-	+	+
12.	*Clostredium diane* Ehrenberg	+	-	+	+
13.	*Trachalomonas volvocina* Ehrenberg	-	-	+	+
14.	*Oocystis gigas* Archer	+	-	+	+
15.	*Phacus asymmetrica* Prescott	+	-	+	+
16.	*Cymbella chandolensis* Gandhi	+	-	+	+
17.	*Chroococcus limnaticus* Lemmermann	+	-	+	+
18.	*Chroococcus minor* (Kutzing) Nageli	+	-	+	+
19.	*Closterium dianae* var. Minus (Schroder) Willi Krieger	+	-	+	+
20.	*Closterium baillyanum* (Breb.) Breb.	+	-	+	+
21.	*Gomphonema parabolum* Kutzing	+	-	+	+
22.	*Oscillatoria princeps* Vaucher *ex* Gomont	+	-	+	+
23.	*Oscillatoria tenuissima* (Smith and Sowerby) C. Agardh ex Forti	+	-	+	+
24.	*Merismopedia punctata* Meyen	+	-	+	+
25.	*Scenedesmus quadricauda* (Trupin) Brebisson	+	-	+	+
26.	*Actinastrum hantzschii* var elongatum G. M. Smith	+	-	+	+
27.	*Pediastrum tetras* (Ehrenberg) Ralfs	+	-	+	+
28.	*Scenedesmus bernardii* G. M. Smith	+	-	+	+
29.	*Anabaena circinalis* Rabenhorst ex Bornet	+	-	+	+

	and Flahault				
30.	*Navicula halophila* (Gurnow) Cleve	+	+	+	+
31.	*Navicula rediosa* (Kuetz.)	+	+	+	+
32.	*Cosmarium ceylanicum* West and G. S. West	+	-	+	+
33.	*Cosmarium cucurbitinum* A.M. Scott and R.Gronblad	+	-	+	+
34.	*Pinnula ria dolosa* Gandhi	+	+	+	+
35.	*Bulbochaete setigera* C. Agardh ex Hirn.	+	-	+	+
36.	*Euastrum ansatum* Ehrenberg	+	-	+	+
37.	*Netrium digitus* (Ehrenberg) Itzigsohn and Rothe	+	-	+	+

Variations in physico-chemical characteristics of the selected water bodies are presented in **Table 2** to **Table 5**. The pH of water ranged from5.9 to 7.8. Maximum range was recorded in Lotus Lake, from 5.9 to 7.8. The phytoplankton diversity also showed variations that may be attributed to the changes in pH values. Physico-chemical and biological characteristics of water bodies are known to influence each other[12] and pH range of 5 to 8.5 was reported to be ideal for phytoplankton growth[13].

Table 2 : Physico-chemical analysis of water samples of Syngenta Lake (Jan. – Oct. 2014)

Parameter	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.
pH	6.10 ±0.05	5.90 ±0.11	6.20 ±0.02	6.20 ±0.02	6.30 ±0.01	6.40 ±0.01	6.80 ±0.17	6.40 ±0.00	6.23 ±0.01	6.09 ±0.00
Temp. (^{o}C)	25.00 ±1.2	28.00 ±0.20	28.00 ±0.20	30.00 ±0.45	31.00 ±0.8	30.80 ±0.72	28.40 ±0.06	27.40 ±0.40	28.40 ±0.06	29.00 ±0.10
TDS (mg L^{-1})	620.00 ±8.76	745.00 ±32.90	685.00 ±12.90	634.00 ±4.10	645.00 ±0.42	621.00 ±8.43	687.00 ±13.56	606.00 ±13.43	616.00 ±10.10	604.00 ±14.10
DO (mg L^{-1})	8.11 ±0.06	6.80 ±0.50	6.80 ±0.50	6.08 ±0.73	6.01 ±0.76	6.89 ±0.46	9.60 ±0.42	10.54 ±0.74	12.06 ±1.25	10.20 ±0.63
Nitrates (mg L^{-1})	0.20 ±0.09	0.72 ±0.08	0.82 ±0.10	0.31 ±0.05	0.54 ±0.02	0.33 ±0.05	0.41 ±0.02	0.50 ±0.006	0.53 ±0.01	0.48 ±0.00
Phosphates (mg L^{-1})	0.10 ±0.02	0.12 ±0.02	0.23 ±0.01	0.10 ±0.02	0.24 ±0.02	0.27 ±0.03	0.25 ±0.02	0.19 ±0.03	0.20 ±0.00	0.15 ±0.01

Legend : values are mean of three replicates. ± = Standard deviation

Table 3 : Physico-chemical analysis of water samples of Khandola Pond (Jan. – Oct. 2014)

Parameter	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.
pH	7.14 ±0.24	6.10 ±0.07	6.00 ±0.10	6.10 ±0.07	6.00 0±0.1	6.80 ±0.14	6.40 ±0.01	6.20 ±0.04	6.40 ±0.01	6.40 ±0.01
Temp. (^{o}C)	25.00 ±0.22	28.00 ±0.76	28.00 ±0.76	30.00 ±1.43	31.00 ±1.76	30.80 ±1.70	30.80 ±1.70	28.40 ±0.90	27.40 ±0.56	28.40 ±0.90
TDS (mg L^{-1})	41.20 ±1.08	49.60 ±1.71	40.23 ±1.40	43.70 ±0.24	51.54 ±0.00	38.70 ±1.91	32.60 ±3.94	47.60 ±1.04	50.21 ±1.91	49.30 ±1.61
DO (mg L^{-1})	7.20 ±0.59	7.40 ±0.52	8.60 ±0.10	7.90 ±1.08	8.00 ±0.310	7.20 ±0.59	9.32 ±0.20	10.95 ±0.64	11.97 ±0.98	11.44 ±0.81
Nitrates (mg L^{-1})	0.27 ±0.12	0.23 ±0.04	0.56 ±0.05	0.47 ±0.02	0.36 ±0.03	0.50 ±0.031	0.58 ±0.042	0.34 ±0.01	0.38 ±0.00	0.31 ±0.08
Phosphates (mg L^{-1})	0.01 ±0.02	0.02 ±0.02	0.01 ±0.02	0.04 ±0.01	0.02 ±0.02	0.02 ±0.02	0.30 ±0.2	0.25 ±0.05	0.15 ±0.02	0.15 ±0.02

Legend : values are mean of three replicates. ± = Standard deviation

The water temperature throughout the sites varied from 25 to 31°C, maximum in May (late summer and early rainy season) and minimum in January (the late rainy and winter season). Water temperature plays an important role in controlling the occurrence and abundance of phytoplanktons[14].

The Total Dissolved Solids (TDS) were least at Khandola Pond (32.60 to 51.45 mg L^{-1}), greater at Syngenta Lake (604 to745 mg L^{-1}), greater still at Lotus Lake (616 to 1078 mg L^{-1}) and highest at Curtorim Lake (922 to 1389 mg L^{-1}). Beeton[15] attributed an increase in TDS in St. Lawrence Great Lakes to cultural eutrophication and suggested the separation of Oligotrophic and Eutrophic lakes based on TDS values. Oligotrophic lakes have TDS less than 100 ppm, while eutrophic lakes have TDS more than 100 ppm. This increase in TDS above 100 ppm in Syngenta, Lotus and Curtorim lakes indicate cultural eutrophic-ation.

Table 4 : Physico-chemical analysis of water samples of Lotus Lake (Jan. – Oct. 2014)

Parameter	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.
pH	7.80 ±0.46	6.60 ±0.06	6.46 ±0.02	6.00 ±0.10	5.90 ±0.14	6.00 ±0.10	6.73 ±0.10	6.00 ±0.10	6.50 ±0.03	6.00 ±0.10
Temp. (°C)	25.50 ±1.10	29.00 ±0.14	29.00 ±0.14	30.00 ±0.38	31.00 ±0.72	30.00 ±0.38	30.00 ±0.38	26.20 ±0.86	28.40 ±0.10	29.00 ±0.14
TDS (mg L^{-1})	616.50 ±83.15	673.20 ±64.15	782.00 ±27.88	968.00 ±34.10	997.00 ±43.77	962.00 ±32.10	1078.00 ±70.77	910.00 ±14.77	825.00 ±13.55	845.00 ±6.88
DO (mg L^{-1})	6.07 ±0.63	6.60 ±0.44	6.79 ±0.38	8.12 ±0.04	5.68 ±0.76	9.22 ±0.41	10.30 ±0.77	9.44 ±0.48	9.35 ±0.45	8.14 ±0.05
Nitrates (mg L^{-1})	1.43 ±0.14	1.58 ±0.33	1.66 ±0.30	1.76 ±0.26	1.81 ±0.20	2.16 ±0.14	4.55 ±0.64	3.16 ±0.24	3.38 ±0.24	4.45 ±0.61
Phosphates (mg L^{-1})	0.01 ±0.20	0.03 ±0.20	0.10 ±0.17	0.25 ±0.010	0.25 ±0.10	0.30 ±0.10	2.41 ±0.58	1.92 ±0.41	0.78 ±0.03	0.60 ±0.02

Legend : values are mean of three replicates. ± = Standard deviation

Table 5 : Physico-chemical analysis of water samples of Curtorim Lake (Jan. – Oct. 2014)

Parameter	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.
pH	6.80 ±0.09	6.90 ±0.06	6.70 ±0.10	6.90 ±0.06	6.72 ±0.10	7.60 ±0.14	7.68 ±0.17	7.52 ±0.14	7.68 ±0.03	6.40 ±0.05
Temp. (°C)	25.50 ±1.10	29.00 ±0.14	29.00 ±0.14	30.00 ±0.38	31.00 ±0.72	30.00 ±0.38	30.00 ±0.38	26.20 ±0.86	28.40 ±0.10	29.00 ±0.14
TDS (mg L^{-1})	1124 ±17.66	1207 ±45.33	1308 ±79.00	1240 ±56.33	1285 ±71.33	1389 ±106.00	1317 ±82.00	1210 ±46.32	1118 ±15.65	922.00 ±49.65
DO (mg L^{-1})	8.95 ±0.20	8.14 ±0.47	8.51 ±0.34	8.94 ±0.20	7.98 ±0.52	8.55 ±0.33	9.19 ±0.10	11.76 ±0.72	11.03 ±0.47	12.77 ±1.06
Nitrates (mg L^{-1})	0.80 ±0.28	1.27 ±0.10	1.50 ±0.06	1.78 ±0.03	2.57 ±0.28	1.32 ±0.01	2.27 ±0.17	2.76 ±0.34	1.43 ±0.08	1.27 ±0.10
Phosphates (mg L^{-1})	0.01 ±0.00	0.02 ±0.10	0.01 ±0.00	0.04 ±0.10	0.12 ±0.07	0.15 ±0.06	1.72 ±0.45	0.49 ±0.14	0.55 ±0.06	0.30 ±0.01

Legend : values are mean of three replicates. ± = Standard deviation

Dissolved oxygen (DO) ranged between 6.01 mg L^{-1} and 12.06 mg L^{-1} at Syngenta Lake, 7.20 to 11.97 mg L^{-1} at Khandola Pond, 5.68 to 10.30 mg L^{-1} at Lotus Lake and 8.14 to 12.77 mg L^{-1} at Curtorim Lake. Dissolved oxygen acts as a regulator of metabolic activities of organisms and thus governs metabolism of biological community as a whole. It is also used as an indicator of trophic status of the water[16]. Increased amount of dissolved oxygen observed during monsoon is known to be due to increased solubility of oxygen[17], lower levels of dissolved oxygen in summer is due to higher temperature and low solubility of oxygen in water[18].

The nitrate levels showed variations in the water bodies and ranged from 0.20 to 0.54 mg L^{-1} in Syngenta Lake, 0.23 to 0.58 mg L^{-1} in Khandola

Pond, 1.43 to 4.55 mg L^{-1} in Lotus Lake and 0.80 to 2.76 mg L^{-1} in Curtorim Lake. Phosphate concentrations also showed variations and ranged from 0.10 to 0.25 mg L^{-1} in Syngenta Lake, 0.01 to 0.30 mg L^{-1} in Khandola Pond, 0.01 to 2. 41 mg L^{-1} in Lotus Lake and 0.01 to 0.55 mg L^{-1} in Curtorim Lake. The study has revealed that during monsoon season, pollutants like nitrates and phosphates are entering the water bodies from the surrounding area, especially from farmlands, resulting in elevated concentrations of nitrates and phosphates. Eutrophic conditions are observed during pre- and post-monsoon seasons at Syngenta, Lotus and Curtorim Lakes, supporting the growth of phytoplankton. Increased levels of nitrates and phosphates indirectly harm the environment by causing bacterial growth and huge algal blooms[19]. Studies suggest that due to continuous runoff of high-mineral content into the water form the quality of water-dwelling organisms in lakes[20]. Higher concentrations of nitrates are useful in irrigation, but entry into water resources increases the growth of nuisance algae and triggers pollution due to increases in algal density[21-32].

CONCLUSION

Results of the physico-chemical profile of the water bodies present an enigmatic picture with certain parameters indicating an oligotrophic regime, others pointing towards eutrophy. The analysis of water quality suggests that most of the parameters are above the required limits. The Lotus and Curtorim lakes are influenced by domestic activities, sewage flow, cattle washing by rural communities and small scale industrial effluents, while the Syngenta Lake is affected by organic pollution. Khandola Pond however, is not affected by any of the above anthropogenic stresses. Studies on continuous monitoring of these water bodies to collect further data on physical, chemical and biological characteristics needs to be undertaken. Conservation of water bodies is imperative for ecological, cultural and touristic values, as are important to mankind in various ways.

REFERENCES

1. Udayashankara T. H., Anitha K. G., Sneha R., Ayesha S. and Mohammed S., Study of water quality and dynamic analysis of phytoplanktons in four fresh water lakes of Mysore, India, *Int. J. Innov. Res. Sci. Engin. Technol.*, **2**(7), 2600-2609, **(2013).**
2. APHA, *Standard Methods for Examination of Water and Wastewater*. American Public Health Association. Washington, DC, **(2012)**.
3. Krishnamurthy V., Algae of India and Neighbouring Countries 1. *Chlorophy*, Science Publishers, Inc. USA, 210, **(2000).**
4. Prasad B. N. and Misra P. K., *Fresh water algal flora of Andaman and Nicobar islands,* Vol. I and II. Bishan Singh Mahendra Pal Singh Dehradun, India, **(1992).**
5. Prescott G. W., *The Algae* : *A Review.*, Otto Koeltz Science Publishers, West Germany, **(1969).**
6. Edmondson, W. T., *Fresh Water Biology*, **2nd Edn.**, John Wiley and Sons INC. New York. London, Sydney, **(1966).**
7. Desikachary T. V., *Cyanophyta.* ICAR, New Delhi, 159, **(1959).**
8. Iyengar M. O. P., On the algae of some muddy rain water pools, *Proc. of the 27th Ind. Sci. Cong.*, III, 128, **(1940).**
9. Giripunje M., Fulke A., Khairnar K., Meshram P. and Paunikar W., A review of phytoplankton ecology in freshwater lakes of India. *Lak. Reser. Pon.*, **7**(2), 127-141, **(2013).**
10. Kshirsagar A. D., Use of algae as a bioindicator to determine water quality of River Mula from Pune City, *Univ. J. Environ. Res. Technol.*, **3**(1), 79-85, **(2013).**
11. Palmer C.M., *Algae and Water Pollution*, Castle House Publishers Ltd., England, 89-92, **(1980).**
12. Verma J. and Mohanty R.C., Phytoplankton and its correlation with certain physico-chemical parameters of Danmukundpur pond, *Pol. Res.*, **14**(2), 233-242, **(1995).**
13. Robert D. S., Robert W. H and Evereff L. G., Phytoplankton distribution and water quality indices of lake head (Colorodo River), *Phycol.*, **10**(1), 232 -333, **(1974).**
14. Nazneen S., Influence of hydrological factors on seasonal abundance of

phytoplankton in Kinjharlake, Pakistan, *Hydrobiol.* , **65**(2), 269-282, **(1980).**

15. Beeton A. M., Eutrophication of the St. Lawrence Great Lakes, *Limnol. Oceanog.*, **10**(1), 240-254, **(1965).**
16. Prasannakumari A. A., Ganagadevi T. and Sukeshkumar C. P., Surface water quality of river Neyyar- Thiruvananthapuram, Kerala, India, *Poll. Res.*, **22**(4), 515- 525, **(2003).**
17. Singh J. P., Yadava P. K., Singh S. and Prasad S. C., BOD contamination in Kali River at Sadhu Ashram in Aligarh, *Ind. J. Environ. Prot.*, **11**(5), 325-326, **(1991).**
18. Kaushik S. and Saksena D. N., The trophic status and habitat ecology of entomofauna of the water bodies at Gwalior, Madhya Pradesh. *In : Perspective in Entomological Research* (Agarwal, O. P., ed.), Scientific Publishers, Jodhpur, 241-261, **(1994).**
19. Yanamadala V., Calcium carbonate, phosphate binding, ion exchange filtration and accelerated denitrification improve public health standards and combat eutrophication in aquatic ecosystems, *Wat. Environ. Res.*, **77**(7), 300-301, **(2005).**
20. Engel B., Lim K. and Tang Z., Effects of calibration GIS runoff and pollutant estimation, *J. Environ. Manag.*, **78**(1), 35-43, **(2006).**
21. Trivedy R. K. and Goel P. K., Chemical and biological methods for water pollution studies, *Environ. Pub.*, Karad, Maharashtra, 14, **(1986).**
22. Dutta S. and Singh S., Assessment of ground water and surface water quality around industrial area affected by textile dyeing and printing effluents, Pali, Rajasthan, India, *J. Environ. Res. Develop.*, **8**(3A), 574-581, **(2014).**
23. Patel A., Fluid species studies on percolation through different soil mass, *J. Environ. Res. Develop.*, **8**(3A), 751-754, **(2014).**
24. Menon P. and Palathingal T. J., Effect of sewage irrigation on the morphology and physicology of *Amaranthus tricolor*, WILLD,. *J. Environ. Res. Develop.*, **9**(1), 83-93, **(2014).**
25. Dwivedi P., Dwivedi H. S. and Malik Bhawna, Study of physico-chemical parameters and microflora of river Khan, Ujjain, India, *J. Environ. Res. Develop.*, **9**(2),382-388, **(2014).**
26. Syed T. B., Role of NGOs in the protection of environment, *J. Environ. Res. Develop.*, **9**(3),705-712, **(2015).**
27. Manik V. S. and Manik S. R., Assessment of heavy metals in Chhatri Talao, district Amravati, India during festival season, *J. Environ. Res. Develop.*, **9**(4),1172-1175, **(2015).**
28. Biswas S., Culture of *Clarias gariepinus* by recycling biowaste generated in tourist beach of West Bengal, India : A case study, *J. Environ. Res. Develop.*, **8**(3A), 665-668, **(2014).**
29. Shah A. I. and Vyas B. M., Studies on effect of cobalt sulphate on fish *Labeo rohita*, *J. Environ. Res. Develop.*, **9**(1),169-176, **(2014).**
30. Mangesh G. and Asoria S. K., Customized constructed wetland : A proficient approach to treat domestic waste water, *J. Environ. Res. Develop.*, **9**(3A), 981-985, **(2015).**
31. Pandey S. C. and Bharadwaj P. S. and Peerzada M.P., Physico chemical analysis of water quality of Ratan Talao, Bharuch, Gujarat, India, *J. Environ. Res. Develop.*, **10**(2), 304-310, **(2015).**
32. Deshpande A., Patel D., Patel D., Jadeja J. and Desai K., Change in the land use pattern and water bodies of Vadodara city, India with respect to securing severe floods, *J. Environ. Res. Develop.*, **10**(1), 175-186, **(2015).**