Studies on Sediment Physico-Chemical Properties of the Ulhas River flowing along Dombivli City near Mumbai

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ABSTRACT. Ulhas River which is one of the most polluted rivers of Mumbai receives heavy pollution load from the nearby Dombivli industrial belt. Previous studies reported along the Dombivli industrial belt has indicated that the pollution level is so much alarming that it has created threat to nearby residential areas and also to the Ulhas River flowing in the outskirts of the Dombivli City. It is feared that the toxic chemicals present in the industrial waste might affect the sediment ecosystem of the river. Hence this has provoked us to carry the systematic and detailed study of physico chemical properties of the sediment samples collected along the Ulhas River. The study was done during the year 2012 and 2013, at the sites where the industrial discharge from Dombivli industrial belt Phase I and Phase II joins the Ulhas River. The study was performed to understand the physico chemical properties such as pH, alkalinity, chloride and phosphates. Results of the study reveal that there is an urgent requirement for systematic and regular monitoring of pollution level along the Ulhas River which will further help in improving the industrial waste treatment procedure adopted, along the Dombivli industrial belt. It is expected that such scientific studies will be useful to determine the extent of pollution control measures required in order to avoid long term irreparable damage to the Ulhas River ecosystem.

1. INTRODUCTION

India has undergone the phase of revolution in the industrial sector. Subsequently, the waste generation and discharge from these industries has also increased. However, this quantum of growth is not proportional to the increase in number of waste treatment facilities and the stringiness of pollution control measures followed by the industries. The reason being, there are many small scale industries, which may compromise the requirements for treatment of generated wastes, since they do not afford huge investment for pollution control facility due to very thin profit margin. Though major industries have waste treatment facilities, the overall effect is that the water of Ulhas river is polluted due to the discharge of industrial waste. This has resulted to increase in pollution of air, water and sediment. The quality of water and sediments is significantly impacted. In most of the stretches, it is found that almost all rivers are polluted by some industry or the other [1]. All industries in India are bound to adhere to the strict guidelines of the Central Pollution Control Board (CPCB), but still the environmental situation is far from control. There are sufficient evidences in India available, related to the mismanagement of industrial wastes [2-7]. The physico chemical properties of sediments are affected by the untreated waste. Sediments act as a natural buffer and filter system in the material cycles of water and the sediment quality, quantity or both have an impact on the ecological quality [8]. Sediments are the important habitat and serve as a main nutrient source for organisms in aquatic life. Bacteria inhabit the sediments. Organic matter is decomposed with the help of these bacteria. The aquatic productivity is also impacted due to the

metabolic activity of benthic macro invertebrates which are present in the sediments. There is an interchange of important macronutrients going on continuously between the sediments and overlying water [9]. Toxic effect on sediment dwelling organisms and fishes are observed, due to accumulation of pollutants over a long period, as a result of biological and geochemical mechanisms. This results to decrease in the chances of survival, reduction in growth, impaired reproduction and decreased diversity of species [10, 11]. Important information related to the long term quality situation can be obtained from sediment testing and is independent of current inputs as compared to water testing [12,13]. Other influences minimally affect or do not affect the sediment testing. Water testing does not help to clearly differentiate between true and temporary suspension substances, stirred up from the sediments. Sediments act as a sink and source of contaminants in aquatic systems. Sediments will help to speculate sources of contamination. Pollutants remain in the sediments over long periods of time, depending on the chemical persistence, the physical-chemical and biochemical characteristics of the substrata. The suspended and precipitated substances eventually settle down at the bottom and serve as a reservoir for trace substances of low solubility, low degree of degradability and many pollutants [14-16]. Information related to natural and anthropogenic influence on the water bodies, which is environmentally significant, can be obtained from the chemical analysis for characterization of sediments [17-22]. Thus, to evaluate the quality of total ecosystem of a water body, in addition to the water sample analysis, the analysis of sediment is of equal importance [23-31]. The Ulhas River is one of the important water bodies in Thane District in the state of Maharashtra. It flows along the Dombivli city near Mumbai, during its journey to the sea. There are two industrial phases in Dombivli MIDC (Maharashtra Industrial Development Corporation) zones, namely Phase I and Phase II. At two different locations along the Ulhas River, the effluents from these two phases are discharged into the Ulhas River. It is known that the Ulhas River is heavily polluted due to discharge of toxic pollutants and solid wastes from the industries and localities situated along Dombivli, Ulhas Nagar, Bhiwandi, Ambivli and Thane City based on the previous research [32-34]. Thus it is expected that this reservoir can serve as a model for studying the physico chemical properties of sediments. Systematic and periodic monitoring is very essential to assess the extent and severity of sediment contamination to evaluate the effects of contaminated sediments on marine environment and fresh water. We therefore initiated such a study to understand the Physico Chemical Properties of the sediment of Ulhas River along the Dombivli city situated near Mumbai, India. The study was performed to understand the physico-chemical parameters like pH, alkalinity, chloride, phosphate, cyanide and fluoride. The results will help in understanding the effectiveness of pollution control measures already is existence; extent of pollution control needed; rational planning of pollution control strategies and their prioritization.

2 MATERIALS AND METHODS

2.1 Area of study

The study was carried out along the banks of Ulhas River where the effluents released from industries of Dombivli MIDC (Maharashtra Industrial Development Corporation) Industrial belt Phase I and Phase II are discharged. In 1964, Dombivli industrial area was established by Maharashtra Industrial Development Corporation. The industrial belt is located in south of Ulhas River and covers an area of about 347.88 hector. Many small / medium / large scale fine chemicals, dyes manufacturing, agrochemicals, textile, pharmaceutical, engineering, metallurgical and paint manufacturing industries are located in this industrial belt which contribute heavy pollution in the surrounding area [35-43]. The industrial effluent generated from the industrial area is about 14 MLD which is regularly discharged through open drainages into the nearby flowing Ulhas River [44]. Following suitable location/s for sampling of sediments were identified:

Sampling Point S1: Before the discharge of effluent (D1) from Dombivli MIDC Phase I.

Sampling Point S2: After the discharge of effluent from (D1) Dombivli MIDC Phase 1.

Sampling Point S3: After the discharge of effluent from (D2) Dombivli MIDC Phase II.

Sampling Point S4: After the discharge of effluent from (D2) Dombivli MIDC Phase II.

The sampling locations are as shown in (Figure 1).

Figure1 : Effluent discharge and sampling locations in Ulhas River along Dombivli City.

2.2 Climatic conditions

Dombivli enjoys a tropical climate with mean annual temperature of about 24.3°C to 32.9 °C. The hottest and most dry part of the year is April and May and the temperature rises to 38.0 °C. Humidity present in the atmosphere is usually 58 to 84% and sea breeze in the evening hours is a blessing to combat the high temperature and humidity during summer months. The average southwest monsoon rainfall is in the range of 1850 mm to 2000 mm. The average annual rainfall in the region is the range from 1286 to 1233 mm [44].

2.3 Sample planning, collection and preservation

The study on pollution status along the Ulhas River was carried out in year 2012 and 2013. Sediment sampling was done every week along identified locations of the Ulhas River along Dombivli city area. The samples collected for four months were mixed separately to give gross sample of one season. This was followed for all the three seasons – summer, rainy and winter for a period of twenty four months. The samples were collected by hand-pushing plastic core tubes (7 cm diameter) as far as possible into the sediment. Sediment samples were thoroughly mixed, placed in polythene bags and kept in a dry place until analyses. The samples were the air dried and ground using agate mortar. The samples were further sieved with 0.5 mm mesh size sieve to remove stones, plant roots and to obtain sediment of uniform particle size. These sediment samples were then thoroughly mixed and packed in polythene bags.

2.4 Quality Assurance

To avoid any contamination, plastic-made implements were used for sampling and collection of sediment samples. Polythene bags were used to store the sediment samples. To avoid contamination from the environment during their transport from sampling locations to the laboratory, they were well covered. To avoid any cross contamination during grinding, tools and work surfaces were carefully cleaned. The relevant laboratory apparatus were soaked in nitric acid before analysis followed by rinsing thoroughly with tap water followed by deionised distilled water, to ensure that all traces of cleaning reagents are removed. The glassware used in the analysis was washed with distilled de-ionised water. All calibrated instruments were used for analysis. Reagents were standardized with primary standards to determine their actual concentrations. Analytical grade chemicals and reagents were used for analysis.

2.5 Physico-chemical Study

The present study provides a detailed description of the physico-chemical properties of sediment samples, collected at four different locations from the Ulhas River along the Dombivli City, near the discharge of effluents from the industrial belt of Dombivli. The physico-chemical parameters studied were pH, alkalinity, phosphate and chloride. For physical and chemical analysis of sediment samples, standard techniques and methods were followed [45, 46]. Average value of three replicates was taken for each determination.

3. RESULTS AND DISCUSSION

The sediment samples collected at various sampling points from the Ulhas River flowing along the Dombivli city near Mumbai in year 2012 and 2013 were analyzed for their Physico Chemical properties. The average analytical results are presented in Table 1.

Table 1: Physico Chemical properties of sediment at various locations during the year 2012 and 2013.

Sampling Point	Year	Season	pH	Alkalinity (mg / L)	Chloride (ppm)	Phosphate (ppm)
S1	2012	Rainy	7.01	2189	389	401.36
S1	2012	Winter	6.89	3049	406	552.3
S1	2012	Summer	7.14	2874	746	746
AVERAGE	2012		7.01	2704	513.67	566.55
S1	2013	Rainy	7.11	3811.5	598	423.65
S1	2013	Winter	7.06	2486	783	706.32
S1	2013	Summer	6.8	3048	1001	2589
AVERAGE	2013		6.99	3115.17	794	1239.66
S2	2012	Rainy	7.19	2866	491	669.65
S2	2012	Winter	7.08	3614.5	556	1006
S2	2012	Summer	6.99	3297	807	1182
AVERAGE	2012		7.09	3259.17	618	952.55
S2	2013	Rainy	7.3	3418	761	705.45
S2	2013	Winter	7.05	2800	960	1206.45
S2	2013	Summer	6.69	3692.5	1300	4700
AVERAGE	2013		7.01	3303.5	1007	2203.97
S3	2012	Rainy	7.14	3571	664	993.21
S3	2012	Winter	7.08	4157	879	1368
S3	2012	Summer	6.99	4089	1001	1483
AVERAGE	2012		7.07	3939	848	1281.4
S3	2013	Rainy	7.26	3181.5	801	1170.1
S3	2013	Winter	7.56	3100	205.7	1982
S3	2013	Summer	6.9	6119	9600	7000
AVERAGE	2013		7.24	4133.5	3535.57	3384.03
S4	2012	Rainy	7.08	3174	685	979.6
S4	2012	Winter	7.09	3547.5	914	1457
S4	2012	Summer	6.85	4269	1204	1300
AVERAGE	2012		7.01	3663.5	934.33	1245.53
S4	2013	Rainy	7.09	3331	887	1204
S4	2013	Winter	7.51	3681.5	296	2016
S4	2013	Summer	7.02	5589	9015	7106
AVERAGE	2013		7.21	4200.5	3399.33	3442

The average values of pH of sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 2.

Figure 2: Variation in the pH of sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

The average pH in 2012 at sampling points S1, S2, S3, S4 was 7.01, 7.09, 7.07 and 7.01 ppm respectively. The average pH in 2013 at sampling points S1, S2, S3, S4 was 6.99, 7.01, 7.24 and 7.21 respectively. The average pH in year 2012 was 7.05 which increased to 7.11 in year 2013. The lowest pH of sediment was 6.99 in year 2013 at sampling point S1 whereas the highest pH was 7.24 in the year 2013 at sampling point S3. pH is a measure of the acidity or alkalinity of water. Most of the chemical reactions in aquatic environment are controlled by any change in pH value. Hence pH is an extremely important parameter. Extreme pH i.e. either highly acidic or highly alkaline may kill or have a serious impact on marine life. Waters with pH value below 6 can be hazardous to aquatic life. Waters with pH value of about 10, though exceptional, but may reflect contamination by strong base such as NaOH and Ca(OH)_2 [47]. Thus, pH plays a vital role in deciding the quality of waste water effluent.

The average values of alkalinity of the sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 3.

Figure 3: Variation in the average alkalinity of sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

The average value of alkalinity in 2012 at sampling points S1, S2, S3, S4 was 2704 mg/L, 3259.17 mg/L, 3939 mg/L and 3663.5 mg/L respectively. The average value of alkalinity in 2013 at sampling points S1, S2, S3, S4 was 3115.17 mg/L, 3303.5 mg/L, 4133.5 mg/L and 4200.5 mg/L respectively. The trend indicates that there was an increase in the average value of alkalinity after the addition of effluent discharged from Dombivli MIDC Phase I and Phase II. Also, if we compare the average values of alkalinity at each sampling point, there is an increase in concentration per year.

The average values of chloride in sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 4.

Figure 4 : Variation in the average value of chloride in sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

The average value of chloride in 2012 at sampling points S1, S2, S3, S4 was 513.67 ppm, 618 ppm, 848 ppm and 934.33 ppm respectively. The average value of chloride in 2013 at sampling points S1, S2, S3, S4 was 794 ppm, 1007 ppm, 3535.57 ppm and 3399.33 ppm respectively. The trend indicates that there was an increase in chloride concentration after the addition of effluent discharged from Dombivli MIDC Phase I and Phase II. The average value of chloride in 2012 was 728.5 ppm which has increased by 200% to 2183.98 ppm in year 2013. Chloride occurs in all natural waters and its concentration varies widely. Plants do not survive or grow in chlorinated as well as unchlorinated water. Consumption of chlorinated water develops athero-sclerosis in wild animals [48]. In sediments, these chloride pollutants may accumulate and get released in river water. This may lead to the increase in chloride concentration in water and may exceed the limit of 1.0 mg/L Max for Total residual chlorine, for inland surface water [49].

The average values of phosphate in sediment at different sampling points for year 2012 and 2013 are shown in Table 1 and the variation is represented in Figure 5.

Figure 5: Variation in the average values of phosphate in sediment at different sampling locations along Ulhas River during the year 2012 & 2013.

The average value of Phosphate in 2012 at sampling points S1, S2, S3, S4 was 566.55 ppm, 952.55 ppm, 1281.4 ppm and 1245.53 ppm respectively and that in 2013 at sampling points S1, S2, S3, S4 was 1239.66 ppm, 2203.97 ppm, 3384.03 ppm and 3442 ppm respectively, which shows an increasing trend per year and per sampling point. The average value of Phosphate in 2012 was 1011.51 ppm which has increased by 154% to 2567.42 ppm in year 2013. Phosphorus pollution causes eutrophication. The process of a river's biological death due to depleted bioavailable oxygen is termed as eutrophication. Excess phosphorus causes algal blooms. The blooms favour the survival of less desirable fish over more desirable commercial and recreation species, thus impacting fisheries. Phosphorus pollution caused enormous blooms of the Blue-Green Algae which is a form of cyanobacteria. These bacteria produce toxins that damage water quality, aquatic ecosystems and fisheries. Excess phosphorus and nitrogen helps the rapid growth of Phytoplankton, creating dense populations or blooms. Such dense blooms limit the amount of sunlight available to submerged aquatic vegetation. Thus the plants cannot photo-synthesize which is essential for survival. Absence of sunlight can kill aquatic grasses. Phosphate pollutants settle and get accumulated in bottom sediments from where they may be released back to the surface water under certain conditions. This which will subsequently increase the concentration of dissolved phosphates (as phosphorous) above the permissible limit of 5.0 mg/L Max, set for inland surface water [49].

4. CONCLUSIONS

There is a significant increase in the generation and discharge of industrial waste due to the rapid industrialization, along the Dombivli industrial belt. These effluent wastes are discharged into the Ulhas River flowing along the Dombivili City near Mumbai. There are many small scale industries, which may compromise the requirements for the treatment of effluent wastes, since they do not afford high investment for pollution control facility as they have very thin profit margin. Though major industries have waste treatment facilities, the overall effect is that the water of Ulhas river is polluted. Sufficient evidences related to the mismanagement of industrial wastes are available which demonstrates the same situation. The present experimental data highlights the

increasing high level of pollution of Ulhas River along the Dombivli City near Mumbai. This is due to the release of industrial effluent from Dombivli industrial belt Phase I and Phase II. The average value of chloride in 2012 was 728.5 ppm which has increased by 200% to 2183.98 ppm in year 2013. The average value of Phosphate in 2012 was 1011.51 ppm which has increased by 154% to 2567.42 ppm in year 2013. The positive observation is that cyanide and fluoride is not detected in the river sediments. Overall it can be concluded that the pollution has increased in year 2013 as compared to that in year 2012. It is also observed that the pollution has increased after the discharge of industrial effluents into the Ulhas River along Dombivli city. It can be concluded that there is a need of further systematic and regular monitoring of pollution level along the Ulhas River which will further help in improving the industrial waste treatment procedure adopted, along the Dombivli industrial belt. The present data on physico chemical properties of the sediments of Ulhas River along the Dombivli city will help in rational planning of pollution control strategies and their prioritization; to assess the nature and extent of pollution control needed; to evaluate effectiveness of pollution control measures already in existence. It will also help to provide a means for evaluating the long term accumulation contaminants in the sediment ecosystem of the Ulhas River.

References

- [1] Zingde M.D., Govindan K., Health status of coastal waters of Mumbai and regions around. In: Environmental Problems of Coastal Areas in India (ed. Sharma, V. K.), Bookwell Publ., New Delhi, (2001) 119–132.
- [2] Rajaram T., Das A., 'Water pollution by industrial effluents in India: Discharge scenarios and case for participatory ecosystem specific local regulation', *Futures* 40 (2008) 56.
- [3] Khurshid S., Abdul B., Zaheeruddin, Usman S.M., 'Effect of waste disposal on water quality in parts of Cochin, Kerala', *Indian J. Environ. Health*, 40 (1998) 45 .
- [4] Pachpande B.G., Ingle S.T., 'Recovery of the chromium by chemical precipitation from tannery effluent', *Orient J. Chem.*, 20 (2004) 117.
- [5] Prabha S., Selvapathy P., 'Heavy metal pollution in Indian Rivers', *Indian J. Environ. Prot.*, 17 (1997) 641.
- [6] Singare P.U., Lokhande R.S., Pathak P.P., *J. Environmental Protection*, 1 (2010) 121.
- [7] Singare P.U., Lokhande R.S., Pathak P.P., 'Study on Physico-Chemical properties and Heavy Metal Content of the Soil Samples from Thane Creek of Maharashtra, India', *Interdisciplinary Environmental Review*, 11 (2010) 38.
- [8] Stronkhorst J., Brils J., Batty J., Coquery M., Gardner M., Mannio J., O'Donnell C., Steenwijk J. and Frintrop P., Discussion document on Sediment Monitoring Guidance for the EU Water Framework Directive., Version 2. EU Water Framework Directive expert group on Analysis and Monitoring of Priority Substances, May 25th, 2004.
- [9] Abowei, J.F.N. and Sikoki, F.D., *Water Pollution Management and Control*, Double Trust Publications Company, Port Harcourt; ISBN: 978-30380-20-16 (2005) 236.
- [10] Mucha, A.P., Vasconcelos, M.T.S.D., and Bordalo, A.A., Macrobenthic community in the Douuro Estuary: relation with trace metals and natural sediment characteristics, *Environmental Pollution* 121(2) (2003) 169 –180.
- [11] Praveena, S. M., Ahmed, A., Radojevic, M., Abdullah, M. H., Aris, A. Z., Factor-cluster analysis and enrichment study of mangrove sediments-an example from Mengkabong, Sabah., *Malaysian J. Anal. Sci.*, 11(2) (2007) 421-430.
- [12] Hodson P.V., Water quality criteria and the need for biochemical monitoring of contaminant effects on aquatic ecosystem. In: *Water Quality Management: Freshwater Eco-toxicity in Australia*, Hart, B.T. (ed.), Melbourne Water Studies Center (1986) 7-21.
- [13] Haslam S.M., *River pollution: An ecological perspective*, Belhaven Press. London, (1990) 253.
- [14] Biney C., Amazu A.T., Calamari D., Kaba N., Mbome I.L., Naeve H., Ochumba P.B.O., Osibanjo O., Radegonde V., and Saad M.A.H., 1994, Review of heavy metals in the African aquatic environment., *Ecotoxicology and Environmental Safety*, 31, 134-159.

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- [15] Barbour M.T., Gerritsen J., Snyder B.D., and Stribling J.B., USEPA Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers. Periphyton, Benthic Macroinvertebrates, and Fish., Second Edition. EPA/841-B-98-010. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. (1998).
- [16] Barbour M.T., Gerritsen J., Snyder B.D., and Stribling J.B., Rapid bioassessment protocols for use in and wadeable rivers—Periphyton, benthic macroinvertebrates, and fish (2d ed.): U.S. Environmental Protection Agency, Office of Water, EPA 841-B—99-002, (1999).
- [17] Lokhande, R.S., Singare, P.U., and Pimple, D.S., Quantification Study of Toxic Heavy Metals Pollutants in Sediment Samples Collected from Kasardi River Flowing along the Taloja Industrial Area of Mumbai, India., *The New York Science Journal* 4(9) (2011) 66-71.
- [18] Singare, P.U., Distribution Behaviour of Trace and Toxic Metals in Soil and Sediment along the Thane Creek Near Mumbai, India., *Interdisciplinary Environmental Review*, 12(4) (2011) 298–312.
- [19] Singare, P.U., Lokhande, R.S., and Bhattacharjee, S.S., Physico-Chemical Analysis of the Sediment Samples collected from Thane Creek of Maharashtra, India., *Interdisciplinary Environmental Review*, 12(2) (2011) 95-107.
- [20] Menounou, N., Presley, B.J., Mercury and Other Trace Elements in Sediment Cores from Central Texas Lakes., *Arch. Environ. Contam. Toxicol.* 45(1) (2003) 11–29.
- [21] Spooner, D.R., Maher, W., and Otway, N., Trace Metal Concentrations in Sediments and Oysters of Botany Bay, NSW, Australia., *Arch. Environ. Contam. Toxicol.* 45(1) (2003) 92–101.
- [22] Sahu, S.K., Ajmal, P.Y., Pandit, G.G., and Puranik, V.D., Vertical distribution of polychlorinated biphenyl congeners in sediment core from Thane Creek area of Mumbai, India., *Journal of hazardous materials*, 164(2-3) (2009) 1573-1579.
- [23] Lokhande, R.S., Singare, P.U., and Pimple, D.S., Pollution in Water of Kasardi River Flowing Along Taloja Industrial Area of Mumbai, India., *World Environment (In Press)* (2011).
- [24] Lokhande, R.S., Singare, P.U., and Pimple, D.S., Toxicity Study of Heavy Metals Pollutants in Waste Water Effluent Samples Collected From Taloja Industrial Estate of Mumbai, India., *Resources and Environment (In Press)* (2011).
- [25] Lokhande, R.S., Singare, P.U., and Pimple, D.S., Study on Physico-Chemical Parameters of Waste Water Effluents from Taloja Industrial Area of Mumbai, India. *Inter-national Journal of Ecology (In Press)* (2011).
- [26] Singare, P.U., Lokhande, R.S., and Bhanage, S.V., Study of water pollution due to Heavy metals in Kukshet lakes of Nerul, Navi Mumbai, India. *International Journal of Global Environmental Issues*, 11(1) (2011) 79–90.
- [27] Singare P.U., Lokhande, R.S., and Jagtap, A.G., Water pollution by discharge effluents from Gove Industrial Area of Maharashtra, India: Dispersion of heavy metals and their Toxic effects., *International Journal of Global Environmental Issues*, 11(1) (2011) 28–36.
- [28] Singare, P.U., Lokhande, R.S. and Naik, K.U., Impact Assessment of Pollution in some Lake water Located at and around Thane City of Maharashtra, India: Physico chemical properties and Toxic effects of Heavy metal content., *Interdisciplinary Environmental Review*, 12 (3) (2011) 215-230.
- [29] Singare, P.U., Lokhande, R.S., and Bhanage, S.V., Water pollution study of the Shirvane and Nerul lakes situated at Nerul, Navi Mumbai, India., *Interdisciplinary Environmental Review*, 12(1) (2011) 1-11.
- [30] Singare, P.U., Lokhande, R.S., and Jagtap, A.G., Study of Physico-chemical quality of the Industrial Waste Water Effluent from Gove Industrial Area of Bhiwandi City of Maharashtra, India., *Interdisciplinary Environmental Review*, 11(4) (2010) 263-273.
- [31] Singare, P.U., Lokhande, R.S., and Naik, K.U., A Case Study of Some Lakes Located at and Around Thane City of Maharashtra, India, with Special Reference to Physico-Chemical Properties and Heavy Metal content of Lake Water., *Interdisciplinary Environmental Review*, 11(1) (2010) 90-107.

-
- [32] Menon J.S., and Mahajan S.V., 'Site-wise mercury levels in Ulhas River estuary and Thane Creek near Mumbai, India and its relation to water parameters', *Our Nature*, 8, (2010) 170.
- [33] Rathod S.D., Patil N.N., Quadros G., Athalye R.P., 28–30 November 2002, 'Qualitative study of finfish and shellfish fauna of Thane creek and Ulhas River estuary', in *Proc. of the National Seminar on Creeks, Estuaries and Mangroves – Pollution and Conservation*, Vidya Prasarak Mandal's B.N. Bhandodkar College of Science, Thane, India, 135 –141.
- [34] Singare P.U., 'Study on accumulation of non-biodegradable solid wastes along Ulhas River of Thane, Mumbai', *Interdisciplinary Environmental Review*, 13 (2012) 1.
- [35] Singare P.U., Dhabarde S.S., *European Journal of Environmental and Safety Sciences*, 2 (2014) 5.
- [36] Singare P.U., Dhabarde S.S., *Interdisciplinary Environmental Review*, 15 (2014) 20.
- [37] Singare P.U., Dhabarde S.S., *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 56.
- [38] Singare P.U., Dhabarde S.S., *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 48.
- [39] Singare P.U., Dhabarde S.S., *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 40.
- [40] Singare P.U., Dhabarde S.S., *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 32.
- [41] Singare P.U., Dhabarde S.S., *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 24.
- [42] Singare P.U., Dhabarde S.S., *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 16.
- [43] Singare P.U., Dhabarde S.S., *International Letters of Chemistry, Physics and Astronomy*, 3 (2014) 8.
- [44] Action Plan for Industrial Cluster "Dombivali", Maharashtra Pollution Control Board, November 2010. <http://www.mpcb.gov.in>
- [45] APHA, AWWA and WEF, *Standard methods for the examination of water and wastewater*, 20th edition, Clesceri, L.S. Greenberg, A.E. and Eaton, A.D. (Eds.), American Public Health Association, American Water Work Association, Water Environment Federation, Washington D.C. (1998).
- [46] M.L. Jackson, *Soil Chemical Analysis*, New Delhi, Prentice-Hall of India Private Limited, (1973).
- [47] Langmuir, D., *Aqueous Environmental Chemistry*, Prentice-Hall, Inc., New Jersey, (1997).
- [48] Hattersley, J.G., *The Negative Health Effects of Chlorine*, *The Journal of Orthomolecular Medicine*.15(2) (2000) 89-95.
- [49] The Environment (Protection) Rules 1986 Available on Internet: cpcb.nic.in/GeneralStandards.pdf