Present Confrontations of Pollution in Mula-Mutha River (MAHARASHTRA, INDIA) Water and their Possible Solutions

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1. Contribution of rivers to India society.

Water is known as the most wonderful blessings of Mother Nature; water is also called as the synonym of ‘life’ on the Earth. Fresh water which is a vital source of human life as well as economic and cultural wellbeing of the societies is drawn mainly from river. Rivers are the internally renewable source of life in India. Rivers principally contribute through there usage *i.e.* drinking purposes, agricultural uses and power generations to the civilization. Rivers in India has social and spiritual impact on Indian population this is prominent reason why rivers have remained important through the ages. The names of different rivers like Ganga, Yamuna, Brahmaputra, Krishna, Kaveri, Sindhu and Godavari *etc.* have been the principal febric of socio-economic developments throughout the all spheres of India from the ancient ages.

Fertility of soil in the farms is largely contributed by rivers in that specific region. During the constant flow of water from the river large amount of fertile part of soil which is collected by river from its own flow will be deposited on the river bank. These fine-grained fertile soils are being deposited by flowing water over river beds are called as deposits of alluvial soils. This alluvial soil provides the most productive agricultural lands to the country. Large part of Indian agricultural area depends on the irrigation water from different rivers. This is the main reason why rivers are called as the backbones of the Indian agriculture. Ease in availability of fresh water from the rivers directs industrialists to establish their mammoth industries on the bank of the rivers. It provides easy transport of goods and also used in generation of electricity. The services provided by the rivers include flood control, transportation,

recreation, purification of human wastes and industrial wastes, habitat of plants and numerous animals, production of food *etc.* These adaptive capacities of the rivers to sustain the ecological balance is degrading day by day due to alarming pollution of water as well as river beds mostly by human beings to fulfil their greed. However, these ecological services by rivers are costly and in most of cases not replaceable. Though human being are aware of the horrible consequences of the degrading ecology of rivers as well as its water, there are very little effort to restore the finest gift of the nature *i.e.* river. Coherent policies are required that more equitably allocate water resources between natural ecosystem functioning and society's extractive needs.

2. Clean Earth Movement (Vasundhara Swachata Abhiyan).

Citizens group including CSIR-National Chemical Laboratory colony, Baner and Aundh area had taken up the challenge of cleaning of city area along with river area and plantation. Peoples from various regions (CSIR-National Chemical Laboratory colony, Baner and Aundh) work as volunteers for tree plantation and creation of awareness about cleaning of our rivers. These volunteers also have contributed to raise funds to create continuous contour trenches. Since 2006, every Sunday, over 60 to 70 citizens are participating enthusiastically at 7 am for a clean-up campaign and distribute their work. For the duration of 8 to 10 am, they used to coordinate the soil and water conservation work, tree plantation before and during the monsoons, watering and the sampling of river water for its further examination by the concerned officers of the municipal authority *etc*. This study has been carried out with the assistance of 'Clean Earth Movement' and under the direction of Mr. Anil Gaikwad from CSIR-National Chemical Laboratory.

3. Origin and factor responsible for pollution around in Mula-Mutha river.

Indian river systems constitutes of seven major rivers along with their several tributaries. Prominent sections of basin system of the rivers dispense their water into the Bay of Bengal. Other than this, the path of some of the rivers takes them through the western region of the country and drain into the Arabian Sea.[1]

Origin of all the rivers in country comes from one of the three main watersheds:

1. The Himalaya and the Karakoram ranges
2. Vindhya and Satpura ranges and Chotanagpur plateau
3. Sahyadri or Western ghats

Pune city situated near the Western Ghat mountain ranges and Mula-Mutha and Pavana rivers are the major source of living for the people in this area as they covers entire region of Pune district. Mula and Mutha rivers flow from two different dams in the direction of Pune. Mutha river flows from Kharkwasla dam and Mula river which originates from Mulshi dam flows toward Pune city bring together Mutha river at Sangam bridge which was situated 14 km away from Kharkvasla dam. Another Pavana river which covers the Pimpri-Chinchawad Municipal Corporation area and the rural area of Pune district comes from Pavana dam towards Dapodi and assemble with Mula river. These three river cover up huge portion of urban area as well as rural area of city and therefore it accumulate and collect very large portion waste in its flow from rural towards urban area. One of the key contributor to the waste creation in rivers are excess fertilizers and insecticides spraying on crops which comes as agricultural run-off during rainy season, these agriculture run-off prosper water hyacinth which is extremely difficult to remove from river banks latter. Disposal of domestic wastes, burning of fossil fuels, hospitals waste into the river banks also decrease the quality water. Small and large scale industries which are located at the depository of the rivers disperse large amount of harmful industrial effluents into the river banks.[2] Due to insertion of these

harmful chemicals and wastes into the river banks makes river water highly unsafe for human and aquatic life.



Image 1: River bank of Mula-Mutha river at near PMC

The inclusion of certain constituents, concentrations of harmful components in the streams of Pune river are mounting by every decade. Introduction of manure, fertilizers containing nitrites (NO_3^-), sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) components can induce healthy environment for unwanted aquatic plants and algae inside river water. If the extent of these manure and fertilizers containing nutrient exceed over certain limit in river water then these nutrient over stimulate the growth of aquatic plants and algae. The excessive growth of aquatic plants and algae's can choke the waterways of river path.

Sediments of animals and suspended solids of soil, fertilisers run-off, wash of ploughed of the farms, waste from construction logging sites of urban areas and weather-beaten riverbanks can create pile of unnecessary pollutants in the river water. As soon as these organic materials introduced in the river water, natural bacteria and protozoan present in water starts breaking these organic material on the cost of dissolved oxygen in the water. Consequently, if the level

of dissolve oxygen drops in the river water below 2-5 parts per million then it may be extremely unsafe for variety of aquatic species like fish and bottom dwelling animals. This sudden drop in dissolved oxygen level will ends-up with the interruption in the food chain which ultimately cause eutrophication.

4. Analysis water standard in the Mula-Mutha rivers.

In the present study, main emphasis has been given to the area restricted to stretch the banks of Mula-Mutha rivers as they covers major portion of rural and urban area. Examination of quality of water from these rivers can provide representative scenario of the health of river in Pune district. Whenever these rivers pass through the city, it receives heavy loads of agricultural runoff, suspended soil, wash of plowed of the farms from non point source, urban waste and industrial waste which are mainly organic waste and waste created by biological oxygen demand. Along with this, these rivers also receives large portion of about 600 tons of domestic sewage from municipal sewers and slum areas.

Sampling of river water sites is done according to different portion of Pune city which contributing large portion of pollution to river banks in Pune and its suburbs.

Table 1: In the present study six sampling sites have been considered which are as follows:

Entry no.	Station sites	Name of sampling site
1.	S1	Vitthalwadi (Mutha River)
2.	S2	Sangam Bridge (Mutha River)
3.	S3	Holkar Bridge (Mutha River)
4.	S4	Phule nagar Eravada (Mula River)
5.	S5	Band garden (Mula - Mutha)
6.	S6	Koregaon park (Mula-Mutha)

4.1 Qualitative investigation of river water in Pune in the urban area.

For the qualitative investigation of river water, water samples were collected in the month of November 2014 (First Week) through the continuous flow. The samples were collected by grab or catch samples method and collected in sterilized bottles using the standard procedure in accordance with the standard method prescribed by American Public Health Association (1995). Spectrophotometer (Digital Systronic Range 340 to 960 u/m) had been used for the analysis of collected samples and chemicals used to identify ingredients in the collected samples were of analytical grade pure.













Image 2: Images from S1–S6 station sites in the study area showing different sampling site for analysis

Table 2: Parameters and methods employed in the chemical examination of water samples:

Entry no.	Parameters of water analysis	Methods
1.	Magnesium	Titrimetric
2.	Calcium	Titrimetric
3.	Nitrate	Spectrometric
4.	Phosphate	Spectrometric
5.	Sulphate	Spectrometric
6.	Chloride	Gravimetric
7.	COD	Dichloromate reflux
8.	BOD	Azide modification
9.	DO	Azide modification
10.	P^H	Potentiometric
11.	Temperature	Thermometric
12.	Odor	Smelling

4.2 Physical and Chemical Parameter Involved in the Study of Mula-Mutha River.

The values obtained for the above mentioned station sites are given in the observation table **2** according to the parameter of analysis. From the observed values in the table **3** for all the station sits we can say that, value of magnesium concentration ranges from 7.11-18.20 Mg/l in sampling sites S1-S6 and calcium concentration ranges from 29.80-36.85 Mg/l in sampling sites S1-S6 of Mula-Mutha river are under recommended level. Since magnesium (Mg) which is an essential nutrient but it is abundantly available in the environment and food supply, it is generally assumed that Mg deficiency is not a problem.

However, in the literature there has been evidence which indicates that deficiencies may exist in both third world (developing countries of Africa, Asia, and Latin America) and

industrialized nations (*i.e.* Brazil). Mg deficiency could influence cardiac and vascular diseases, diabetes, bone deterioration, renal failure, hypothyroidism, and stress. Deficiency of Mg does not show any traditional symptoms because Mg in certain forms does not absorbed easily. The problem of Mg deficiency can readily solve for diabetics, alcoholics peoples by taking hypertension medication. For agriculture sector, too high magnesium containing fertilizer may adversely affect crop yields as the soils become more alkaline, it may harm the productivity of crop and decrease its yield.

Table 3: Statistical analysis water in the Mula-Mutha river.

Entry no.	Parameters	Sampling sites					
		S1	S2	S3	S4	S5	S6
1.	Magnesium (mg/l)	10.79	9.30	7.11	16.70	10.30	18.20
2.	Calcium (mg/l)	35.06	32.46	31.06	36.85	33.45	29.80
3.	Nitrate (mg/l)	18.50	15.00	14.50	15.20	13.10	17.20
4.	Phosphate (mg/l)	4.10	2.10	3.20	2.80	4.10	3.90
5.	Sulphate (mg/l)	34.04	15.78	26.56	12.78	16.70	19.50
6.	Chloride (mg/l)	49.72	42.79	65.60	71.30	51.42	51.39
7.	COD (mg/l)	573	412	471	389	403	421
8.	BOD (mg/l)	32	48.70	105	32	46	64
9.	DO (mg/l)	5.15	3.60	4.10	6.40	3.70	3.20
10.	P^H	8.90	6.70	7.90	9.20	8.10	9.30
11.	Temperature	30	28	28	30	28	31

Nitrate content in all samples which are collected from the station sits S1 to S6 are above danger level ranging from 13.1-18.5 mg/l *i.e.* maximum nitrate contamination level in drinking water should be below 10.0 mg/l. If nitrate content in drinking water is above 10.0 mg/l, it may cause shortness of breath and “blue baby syndrome” in children under the age of 6 months. In the present study, the samples which are collected from sites S1 and S6 shows higher nitrate concentration and can result in formation of nitroso-amines in chemical

reaction in river water. These nitroso-amines which are form during the chemical reaction in river water are highly carcinogenic in nature.

From the table **3**, we can say that phosphate contain in all the station sites are also above threatening level. In every station site it shows phosphate concentration level of phosphate above 1 mg/l, which can readily stimulate or accelerated eutrophication. For healthy environment in river water for aquatic organisms recommended phosphate concentration should be 0.01-0.03 mg/l for uncontaminated water. Concentration above 0.025-0.1 mg/l level of phosphate will automatically stimulate unwanted plant growth (*i.e.* water hyacinth). Above 0.1 mg/l phosphate concentration may accelerate growth of water hyacinth in path of river and consequently create nuisance.[3]

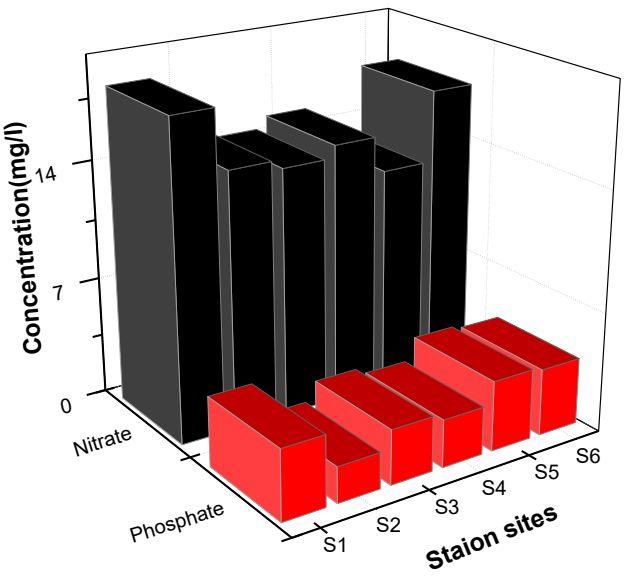


Figure 2: Comparison of Nitrate and phosphate concentration over various station sites of Mula-Mutha river

Sulphate and chloride concentration in all the station sites ranging from S1 to S6 are within the prescribed limit by World health organisation (WHO). Natural chemical process like leaching of gypsum and other common minerals are mainly responsible for the occurrence of

sulphate in water. If sulphate content in drinking water exceeding the concentration level of 400 mg/l, it will impart bitter taste to the drinking water, which may cause gastro-intestine irritation and cantharsis.[3] Soil porosity and permeability are the key aspects responsible for alteration of chloride concentration in river water.[4] Excessive chloride concentration may increase the rates of corrosion of metals which can adversely affect the development of bridges, pitting of iron pipes and other iron equipments.

Among all the samples taken from different station sites, extremely high value of chemical oxygen demand (COD) was shown by S1 and S3 sample sites *i.e.* 573 and 389 mg/l respectively. The extremely high values of COD in all samples from different river sites indicate that there is insufficient oxygen available in the river water. COD test is commonly used to indirectly measure the amount of organic compounds in water. Determination of COD indicates the amount of organic pollutants present in wastewater, which make as an COD useful tool of water quality measurements. Presence of water hyacinth and other compounds like polythene and garbage increase value of COD and make aquatic life in river water difficult.

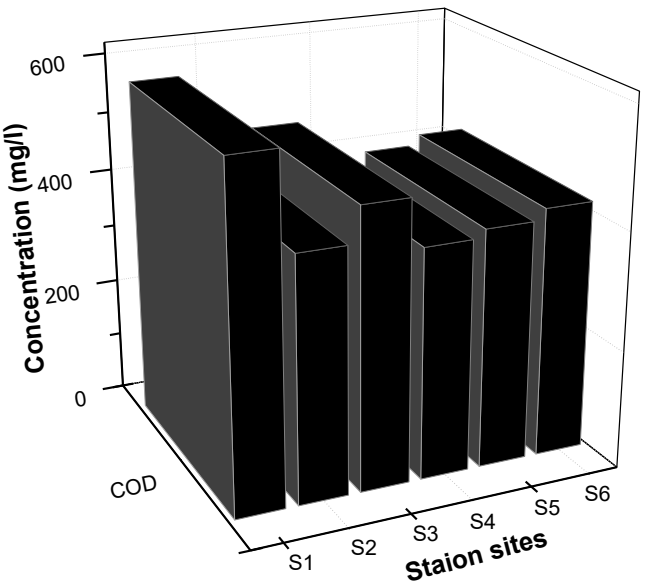


Figure 1: Comparison of various COD over different station sites of Mula-Mutha river

It is expressed in milligrams per litre (mg/l) also referred to as ppm (parts per million), which indicates the mass of oxygen consumed per litre of solution. Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present water at certain temperature over a specific time period. This test is widely used as a measure of the organic quality of water. BOD values in all the samples in the studied area varied from 32-105 mg/l. River water with high value of BOD is due to microbial activities related to the dumpsites. All sampling points showed BOD values within the prescribed limit by WHO.[5]

From the table 3, we can say that the dissolved oxygen (DO) value in the studied area varied between 3.6-6.4 mg/l. All the samples showed higher DO values higher than the prescribed limit by WHO. High amount of DO value imparts good taste to river water.[6]

The pH value for samples taken from all sample sites are ranges from 6.7-9.3. The pH should be maintained at least at neutral state to maintain quality of river water. An abnormal value of pH causes bitter taste to water, affects mucous membrane, causes corrosion and also affects aquatic life. Low pH (less than 6.5) can contribute to the corrosiveness of water and can allow leaching of impurities from pipes into drinking water. Among all the station sites highest temperature of water found in the sample S1, S4 and S6 which certainly affect marine life inside river water. The various chemical and biological reactions in water depend to a great extent on temperature. The observed values of temperature at these sampling points indicate that the water quality would be certainly affected by these values.[6]

4.3.1 Studies carried out globally to solve water pollution.

Can we use waste water for power generation? Yes.

For the first time, Younggy Kim and Bruce E. Logan engineers from *Department of Civil and Environmental Engineering, Pennsylvania State University, University Park, Pennsylvania,*

United States reported in there article of *Proceedings of the National Academy of Sciences* in 2011 that we can actually produce hydrogen gas from waste water. In their article, they have claim that hydrogen gas which is a potential source of clean energy can be produced from waste water and bacteria. Now they are planning to scale-up process for the supply sizeable amount of hydrogen for fueling of vehicles and appliances. [7]

There has been reports which claim that, hydrogen gas can be produced in microbial electrolysis but for that electrical energy from external source is necessary to complement the energy produce by bacteria.

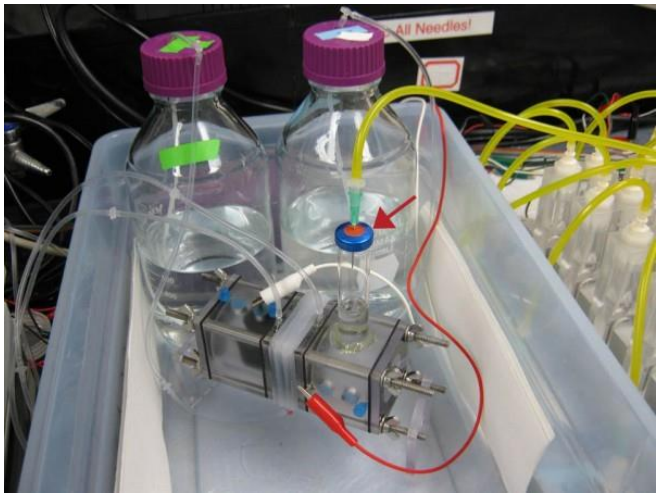


Image 3: Using a prototype system that uses only fresh water (bottle, *left*), salt water (*right*), and a chamber where certain types of energy-generating bacteria feed on nutrients (*foreground*), scientists have produced hydrogen gas (collected in chamber at arrow) without using any external sources of energy. (Courtesy: Penn State. "'Inexhaustible' source of hydrogen may be unlocked by salt water, engineers say." Science Daily. Science Daily, 19 September 2011. <www.sciencedaily.com/releases/2011/09/110919151317.htm>).

In these devices large elongated portion of permeable membranes is used to split salt water from fresh water, which sockets the voltage difference that exists between them but failed to generate electrical current required to produce hydrogen. If we have to generate hydrogen atoms in this process then we have to flow electron through fluid where they can combine with hydrogen ions to produce hydrogen gas.[8]

Engineers from *Department of Civil and Environmental Engineering, Pennsylvania State University, University Park, Pennsylvania, United States* have successfully combined the two types of devices to produce hydrogen without any exterior source of energy. A preliminary version of new device contains two small chambers, one holding the bacteria and their nutrients, the other holding salty water where the hydrogen was produced. These chambers were separated by five stacked cell through which fresh water and salt water circulated. According to these researchers, these stacked cells produce voltage between 0.5-0.6 volts, which was enough to generate hydrogen in the microbial fuel cell. These bacteria are actually feed on acetate compound. For each 30 millilitres of sodium acetate solution which was supplied to the bacteria, the device produce between 21-26 millilitres of hydrogen gas over the course of a day. Now researchers are working on the same concept using waste water and bacteria for hydrogen gas generation.

4.3.2 Plastic accumulation in Mula-Mutha river and their solutions



Image 4: Sample picture showing the effect of plastic being consumed by the fish.

Pune city is situated on the banks of Mula-Mutha river in a gentle rising and falling valleys with small hillocks and off western ghat ranges all around the city. Pune city is considered as a hotspot for tourism and IT sector in India, this will also contributes towards large

population of city which is about 8,242,142 in 2014. Present water requirement of Pune is 1091 million litres per day (MLD), which is largely fetched from Khadakvasala dam. The Pune city generates about 451 MLD sewage water. For the treatment of sewage Pune Municipal Corporation has constructed six Sewage Treatment Plants (STP's) having total treatment capacity of 325 MLD and remaining 125 MLD sewage is discharged untreated into the Mula-Mutha river.[9] This will further increase concentration of sewage and additional plastic garbage in riverbanks, which ultimately create identical situation as that of untreated water of river. Pune Municipal Corporation (PMC) is accountable for collection; transportation and disposal of solid waste.[10] Pune city generate about 1000-1200 tons of waste including plastic bags per day. Effective microorganisms (EM) Technology are used for composting of 600 tons of waste. Remaining 600 ton waste will remain untouched and therefore disperses in rivers per day. Disposal of sewage in river water thus resulted in deterioration of water quality of these rivers. Plastic accumulation is one of the most common form of man-made debris in the rivers and ocean.

Can it is possible to solve this problem? Yes. Recently Tracy Mincer and there co-workers of the *Woods Hole Oceanographic Institution United States,* provided an evidence which show that the overall amount of plastic generated on ocean sits mainly in the North Atlantic Ocean is surprisingly stable.[11] The amounts of plastic debris generated by the accumulation plastic are decreasing day by day. Researchers of the *Woods Hole Oceanographic Institution United States,* claim that the answer may lie within the "Plastisphere" or the ocean's "Hidden majority". The smallest forms of life in the 'ocean marine microbe's bacteria' and other single-cell organisms are the accountable factors behind decrease of plastic debris in the ocean sits. To indentify the effect of ocean marine microbe's bacteria called *Vibrio,* these researchers used a combination of high powered microscopy and state-of-the art DNA

sequencing to show that plastic marine debris are the habitat to a various range of microscopic organisms.[12]

These researchers discovered that microorganisms like these bacteria are mainly flourish on plastic debris. At the same time they transform this plastic debris into rich microbial sand. These plastic debris may provide stable residence to these small microbes. By using similar microorganisms we can actually control the plastic accumulation on river banks.

4.3.3 Answer to problem cause by water hyacinth or Jalparni.

Water hyacinth another biggest problem in Mula-Mutha river in Pune. About 2-10 tons of water hyacinth produced every year in Mula-Mutha river. Water hyacinth reproduced itself because of its 30 years of long lifespan. In the rainy season these water hyacinth block the river pathway and during the cleaning of the river bank it cause nuisance. [13]



Image 5: Pimpri-Chinchawad Municipal Corporation (PCMC) worker remove hyacinth.

Table 4: Average biomass composition of water hyacinth.[14]

Sr. no.	Components	% Composition

1.	Lignin	10
2.	Cellulose	25
3.	Hemicellulose	35
4.	Ash	20
5.	Nitrogen	03

A typical plant composed of biomass which includes cellulose, hemicellulose and lignin. Lignins comprise of phenylpropanoid groups, a polymer which surrounds hemicellulose microfibrils and bring the cellulose molecules together simultaneously. This Phenylpropanoid groups protect hemicellulose microfibrils against chemical degradation. Major limitation of lignin is that it cannot be converted into sugars. Usually a typical plant from which biofuel has been generated contains 30-50% cellulose, 20-40% hemicellulose and 15-30% lignins. If we compare the biomass content of usual plant and water hyacinth then we can say that, major constituents of water hyacinth are cellulose (20%), hemicellulose (33%) and lignin (10%).[13]According to composition of water hyacinth (Table 4) its lignin content is low, which means that utilization of water hyacinth as a source of bio fuel is possible. Major constituents of biomass like cellulose and hemicellulose are easily converted to fermentable sugar by chemical transformations. Therefore we can utilize enormous amount biomass for the biofuel industry.[14]

Aquatic plants like water hyacinth does not required any free land which is used for crop cultivation, and therefore provide incentive factor when it comes to biofuel production. According to recent reports genetic engineering of microorganisms used to increase ethanol production from hemicellulose by fermentation into oligosaccharides. The same report also claims that water hyacinth also capable of potential bioethanol and biofuel generation. By providing an alternative pathway for employment generation, water hyacinth gives beneficial root of earning.[14]

4.3.4. Production biogas from water hyacinth.

Due to over deposition of fertilization in farms during rainy season water which comes from farms in the form floods, provide nutrients to water hyacinth because of this reason they nurtures at a very rapid rate in rainy season. According to recent reports, nitrogen content in water hyacinth is very high. A definite blend of cow dung slurry and water hyacinth slurry can produce more biogas as compared to cow dung slurry alone.[15] After the utilization of biogas the residual slurry can be utilized as liquid fertilizer to the crops. As water hyacinth contain large amount of nitrogen it can be used to produce biogas and the by products can be used for production of bioethanol. This can be done by decomposition of fermentable saccharides.[15]

5. Conclusions.

In the present work physico-chemical properties of Mula-Mutha river water has been determined. According to our investigation high concentration nitrogen, phosphate, high value of pH, large amount of garbage, accumulation plastics and water hyacinth are the major problems in the Mula and Mutha river in the present time. These major problems can be solved by applying concept of waste material as source of energy. If we can able to generate electricity from waste river water and only then power generation problem will be solved which effectively solve the waste water problem. Conversion of water hyacinth into bioethanol or biofuel can solve future fuel problem similarly generation biogas from slurry of water hyacinth along with slurry of cow dung will give another way for green energy generation.

Finally, plastic accumulation in the river banks can be lowered by treating them with microorganism like *Vibrio*. These microorganisms will help to decompose these plastic debris into river sand thus lower the concentration of plastic debris in the river.

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