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A REVIEW ON WATER HYACINTH (*EICHHORNIA CRASSIPES)* AND PHYTOREMEDIATION TO TREAT AQUA POLLUTION IN VELACHERY LAKE, CHENNAI – TAMILNADU

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ABSTRACT

Population increase in the last 50 years Chennai with current population of 4,681,087 (4.6 million) is one of the largest cities of South India. The Population density of Chennai is 26903, which is currently largest in the state of Tamil Nadu. Chennai has witnessed a tremendous growth in its manufacturing, retail, health care and IT sector in the last 10 years., The fast growth of population has caused rapid in increase the domestic sewage pollution This present study deals with the wastewater sewage discharge to the Velachery lake near southern chennai. It is proposed to control the pollution through water hyacinth (*Eichhornia crassipes).* Phytoremediation considered the best technology in order to solve the sewage pollution. The main objectives of the study is to reduce the sewage effluents load in the lake by a continuous phytoremediation process using E. crassipes and second use the lake ecofriendly for Aquaculture and Tourism.

INTRODUCTION

Water pollution is one of the most serious problems of modern civilization. The consumption of water has been doubling on every twenty years but the reduction of this period is expected if today's trends continue in water use continue (Velasevic and Djorovic, 1998). If today's trends in water use fresh water disposition on Earth only will be sufficient to meet one third of Its territory. If drastic efforts in water use are not made by year 2025, about 2.3 billion people will live in areas with chronic water shortage (WHO, 2005). Population of India and the per capita water availability is given in (Table 1). At present, the per capita surface water availability is about 1614 m^3 per year. Rise in population may reduce the per capita water availability to 1137 m^3 by 2065 (Jain 2011*).*Pollution caused by sewage discharged from cities and towns is the primary cause for degradation of water resources. (Rajagopalan.2005). Phytoremediation is a rapidly expanding area of environment science that holds great promise for cleaning up the polluted and contaminated environment. There are number of reports using native flora and microbes from various research laboratories of India. Algae, cynobacteria, vascular plants, and aquatic macrophytes have been used extensively in laboratory and field condition (Prasad.,2007). In fact, the current state-of-the-art technology for the remediation of metalpolluted soils is the excavation and burial of the soil at a hazardous waste site at an average cost of $1 000 000 per acre (Raskin et al., 1997). Aquatic plants have received very little recognition for their contributions to the environment or to their human need (Shetty .2005). Only during the past few decades the benefit of aquatic plants in improving water quality has been widely recognized (Vora and roa,1988,Boyd.,1970) As early as, (Dymond 1948) has suggested the possibility of using certain hydrophytes for removal of nutrients form wastewater effluents. A detailed account of the seasonal changes in vegetational cover, rate of biomass change and production of *E. crassipes*, growing under natural conditions in a perennial lake ('Ramgarh') of Gorakhpur (U.P.) India(Sahai and Sinha.1970) Terrestrial plants and lichens have also been used to monitor air pollution around industrial sites and in cities. Because of its low cost and lack of technical problems, phytoremediation has become very popular not only in India but also globally. In India considerable effort is being devoted in identifying indigenous plant species that can be used to remediate pollutants such as pharmaceutical wastes, arsenic, fly ash, and metals (Prasad 2007)

Aquatic plants, such as *Eichornia crassipes, Pistiea stratiotes, Lemna minor, Ceratophyllum demersum, Elodea nuttallii, and Typha lattifolia* have proved to be efficient adsorbers of heavy metals from natural and artificial systems(Rai.,1995).Water hyacinth (*Eichhornia cressipes*) has tremendous capacity to grow and multiply rapidly in polluted environs and is capable of scavenging inorganic and some organic compounds from water. These plants absorb and incorporate the dissolved

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materials into their own structure. It has been extensively used for the treatment of domestic and industrial wastes, as well as for nutrients absorption from wastewater with some success. (Gopal and Sharma 1981,Trivedy.,1983)This plant can be used for pollution abatement in which up to 40% of the wastewater can be recovered as pure(Haider et al .,1984). The literature shows that for treatment of paper mill effluent these plants were used (Narayan and Parveez.,2000). Water hyacinth (*Eichhornia crassipes)* is a free floating (but sometimes rooted) freshwater plant of the family *Pontederiaceae* that has proven to be a significant economic and ecological burden to many sub-tropical and tropical regions of the world. Water hyacinth is listed as one of the most productive plants on earth.

This phytoremediation technology is suitable in treating the Industrial wastewater since it can be used to treat contaminated soils, groundwater and wastewater that is both low-tech and low cost (Hinchman et a!, 1996). It can help the country in order to decrease the water pollution problems nowadays, that increase along with the rapid rate of economic development especially in chennai. There are many methods in order to treat the industrial wastewater depending on the suitability, one of them is phytoremediation. The phytoremediation of metals is a cost-effective green technology based on the use of metal-accumulating plants to remove toxic metals, including radionuclide, from soil and water. Phytoremediation takes advantage of the fact that a living plant can be considered a solar-driven pump, which can extract and concentrate particular elements from the environment (Raskin et al., 1997). The root of the plant will be absorb the metal pollutant that contain in the wastewater and enhance the quality of the water.(*Eichhornia crassipes*; a noxious weed and fast growing aquatic plant widely distributed in many tropical regions of the world) to liquid ethanol has successfully been performed.(Chartchalerm Isarankura.2007).

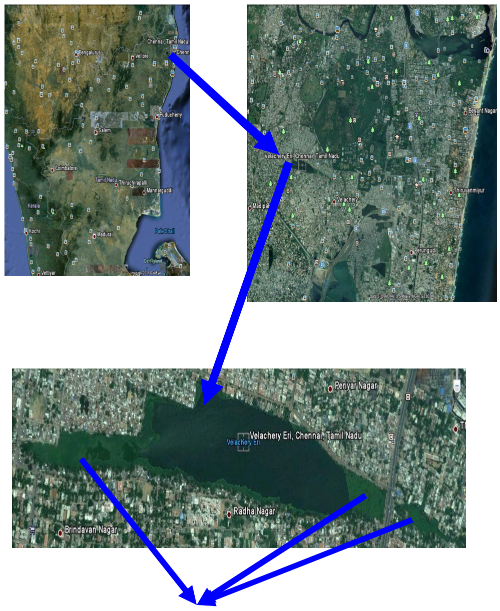
STUDY AREA DESCRIPTION

Lake Velachery is one of the prime lakes situated in the midst of the meteropolitian city of Chennai in Tamilnadu. This is an artificial lake created in 1988-89. It is one of the lakes with a good stock of water all through the year (Fig-1). Since Velachery is a low lying area, the monsoon rain water from the neighbouring areas are drained into this lake. It is located at 12^o 59'15'' latitude and 80 ^{o} 30'45'' longitude. It is a shallow water body with a surface area 265.48 acres and maximum depth of 3.8m(Rajabunizal and Ramanibai (2011).There are also about 2,000 families living in the southern bund. Even though some have toilets in the backyard, they conveniently direct the pipelines to the lake, causing extensive damage to the waterbody (Fig-2).The residents on Erikkarai Street in Gandhi Nagar, who don't have sewage connections, are also contributing to the pollution of the lake.

VELACHERY LAKE

Study Area - MAP

Tamilnadu **Chennai**



Growth of *Eichhornia crassipes*

Table1 Per capita availability and utilizable surface water in india (source jain 2011)

Geographic distribution

Year	Population (in million)	Per-capita surface water availability (BCM)	Per-capita utilizable surface water (BCM)
1951	361	5410	1911
2001	1027	1902	672
2011	1210	1614	570
2025	1459	1339	473
2050	1692	1154	408
2065	1718	1137	402

This tropical plant spread throughout the world in late 19th and early 20th century (Wilson *et al.*, 2005). It is widely reported that water hyacinth is indigenous to Brazil having first been described from wild plants collected from Francisco river in 1824. In Africa it was first reported in Egypt in 1879; in Asia around 1888, and in Japan around 1900; in Australia around 1890 (Cook, 1990). Water hyacinth originated in tropical South America, but has become naturalized in many warm areas of the world: Central America, North America (California and southern states), Africa, India, Asia, Australia, and New Zealand. Water hyacinth (*Eichhornia crassipes*) is the most predominant, persistent and troublesome aquatic weed in India. It was first introduced as an ornamental plant in India in 1896 from Brazil (Rao, 1988). In india, water hyacinth has stretched over 2,92,000 ha of water surface un the country (NPSC 2008) and its exuberance has been highly notived throughout the course of the river Thamirabarani, a prerennial river in south India (Murugesan *et al.*, 2002; Murugesan, 2001). Because of its beautiful blooms and foliage, water hyacinth has been carried by tourists, plant collectors and botanists to over 80 countries around the world in the last 100 years.

Water hyacinth has invaded freshwater systems in over 50 countries on five continents; it is especially pervasive throughout Southeast Asia, the southeastern United

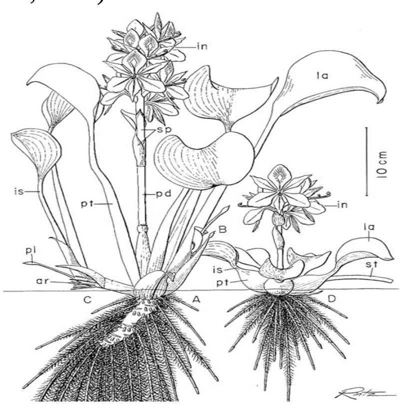
States, central and western Africa, and Central America (Bartodziej and Weymouth, 1995; Brendonck *et al*., 2003; Lu *et al*., 2007; Martinez Jimenez and Gomez Balandra, 2007). The capacity of water hyacinth (*Eichhornia crassipes* (Martius) Solms-Laubach) as a very promising plant with tremendous application in wastewater treatment is already proved (Jafari and Trivedy, 2005; Trivedy, 2001).

Chemistry of Water Hyacinth

Fresh plant contains 95.5% moisture, 0.04% N, 1.0% ash, 0.06% P_2O_5, 0.20% K_2O, 3.5% organic matter. On a zero-moisture basis, it is 75.8% organic matter, 1.5% N, and 24.2% ash. The ash contains 28.7% K_2O, 1.8% Na_2O, 12.8% CaO, 21.0% Cl, and 7.0% P_2O_5. The CP contains, per 100 g, 0.72 g methionine, 4.72 g phenylalanine, 4.32 g threonine, 5.34 g lysine, 4.32 g isoleucine, 0.27 g valine, and 7.2 g leucine (Matai and Bagchi, 1980). Water hyacinth roots naturally absorb pollutants, including such toxic chemicals as lead, mercury, and strontium 90 (as well as some organic compounds believed to be carcinogenic) in concentrations 10,000 times that in the urrounding water. (Jafari, 2010)

Taxonomy

Division: *Magnoliophyta*
Class: *Liliopsida*
Subclass: *Commeinidae*
Superorder:*Commelinanae*
Order: *Pontederiales*
Family: *Pontederiaceae*
Genus: *Eichhornia*
Specific epithet: *crassipes* (Martius) Solms-Laubach.
Cronquist (1988), Thorne (1992) and Takhtajan (1997) suggest following water hyacinth taxonomic placement (Center *et al*., 2002):



Morphology of waterhyacinth plants:

A. The "attenuated-petiole" rosette form produced in crowded conditions; B. An expanding axillary bud; C. A developing ramet; and D. The "bulbous-petiole" rosette form produced in open conditions. Abbreviations: ar - adventitious root; bb - bud bract; in - inflorescence; is - leaf isthmus; la - leaf blade; pl - primary leaf; pd - peduncle of flower spike; pt - leaf petiole; rh - rhizome; sp - spathe; st - stolon.

Water Hyacinth Habitats and Characteristics

The plant is a perennial aquatic herb (Eichhornia crassipes) which belongs to the family Pontedericeae, closely related to the Liliaceae (lily family). The mature plant consists of long, pendant roots, rhizomes, stolons, leaves, inflorescences and fruit clusters. The plants are up to 1 metre high although 40cm is the usual height. The inflorescence bears 6 - 10 lily-like flowers, each 4 - 7cm in diameter. The stems and leaves contain air-filled tissue which give the plant its considerable buoyancy. The vegetation reproduction is asexual and takes place at a rapid rate under preferential conditions. (Herfjord, Osthagen and Saelthun 1994).

Water hyacinths grow over a wide variety of wetland types from lakes, streams, ponds, waterways, ditches, and backwater areas. The treatment of textile wastewater with water hyacinth has some effects on the growth of the plant, the small size of which may be due to nutrient imbalance mainly of nitrogen in water (Thomas, 1983). The plant height may vary from a few inches to 3 ft (0.9 m). The leaves, growing in rosettes, are glossy green and may be up to 8 inches (20 cm) long and 6 inches (15 cm wide). The showy, attractive flowers may be blue, violet, or white and grow in spikes. The leaf blades are inflated with air sacs, which enable the plants to float in water. The seeds are very longlived.

Water hyacinth is aquatic vascular plant with rounded, upright and shiny green leaves and lavender flowers similar to orchids (U.S. EPA, 1988). Individual rosette is erect and free floating with numerous stolons (Center *et al*., 2005). Each one carries six to eight spirally arranged succulent leaves that are produced sequentially on a short vertical stem. Petioles are bulbous and spongy with many air spaces (U.S. EPA, 1988) which allow plants to float on a water surface. But floating leaves can vary in size and morphology according to growth conditions and the stage of colony development. Leaves with bulbous petioles are dominant in open water whereas elongated petioles (to 1.5 m in height) predominate in dense colonies (Center *et al*., 2005). The inflorescence consists of ten to thirty flowers with six violet blue or violet pink petals (Center *et al*., 2002). Top petal has gold yellow spot bordered with blue line which resembles the pattern of peacock eye (Aquatics, 2005; APIRIS, 2005). Root system of water hyacinth is dark blue in colour (Aquatics, 2005; APIRIS, 2005) with numerous stolons. New plants are formed at the end of these stolons.

Measured from flower top to root top *E. crassipens* usually reach height of 1.5 m and more (Center *et al*., 2005). When grown in wastewaters water hyacinth is smaller and it often reaches heights no more then 0.5 to 1.2 m (Reddy and Sutton, 1984).

Ecological Factors

Water hyacinth is heliophyte plant growing best in warm waters rich in macronutrients (Center *et al*., 2002). Optimal water pH for growth of this aquatic plant is neutral but it can tolerate pH values from 4 to 10 (Center *et al*., 2002). This is very important fact because it points that *Eichhornia crassipes* can be used for treatment of different types of wastewater. Optimal water temperature for growth is 28-30^{o} C (Center *et al.*, 2002). Temperatures above 33^{o} C inhibit further growth (Center *et al*., 2002). Optimal air temperature is 21-30 ^{o} C (U.S. EPA, 1988). If lasting for 12 hours temperature of -3^{o} C will destroy all leaves and temperature of -5^{o} C during the period of 48 hours will destroy whole plant (U.S. EPA, 1988). *E. crassipens* olerates drought well because it can survive in moist sediments for several months (Paraja, 1934; cit. Center *et al*., 2002).

Growth, development and reproduction

As mentioned above *E. crassipens* is fast growing perennial plant with great reproduction potential. Growth of water hyacinth is primarily dependant on: ability of plant to use solar energy, nutrient composition of water, cultural methods and environmental factors (U.S. EPA, 1988). Plant growth is described in two ways: first is by reporting the percentage of water surface covered of a period of time; second and more useful method is by reporting the plant density in units of wet plant mass per unit of surface area (U.S. EPA, 1988). So under normal conditions loosely packed water hyacinth can cover the water surface at relatively low plant density (10 kg/m2 wet weight) and it can reach maximum density of 50 kg/m2 wet weight before growth ceases (Reddy and Sutton, 1984). According to other authors this aquatic macrophyte can totally clog aquatic ecosystems by reach density of 60 kg/m2 wet weight outside of its native range (Julien and Orapa, 1999). Just like all other biological processes growth of *E. crassipens* depends on various ecological factors. Water hyacinth is growing fastest at temperatures from 20^{o} to 300^{o}C, but growth fully stops at temperatures from 8^{o} to 150^{o}C (Stephenson *et al*., 1980). This aquatic plant can reproduce in both generative and vegetative ways. That means new plants can be produced from seeds or they represent clones derived from stolon elongation due to division of auxiliary meristems of mother plant (Center *et al*., 2005). At first these new rosettes are attached to mother plant but stolons are very fragile so they easily break enabling young individuals to float away and colonise new areas (Wilson *et al*., 2005; Center *et al*., 2005). How fast in this colonisation? Only ten plants in just eight months can produce population of 655,330 individuals (Babu *et al*., 2003). So theoretically, by vegetative reproduction one plant can colonise water surface during one month by creating 8,191 new individuals. Water hyacinth is mainly reproduced by generative means in its natural habitat and it produces large number of seeds (Wilson *et al.*, 2005; Center *et al.*, 2005).

Numerous authors (Penfound and Earle, 1948; Gopal, 1987; Bock, 1966; Ueki and Oki, 1979; cit. Wilson *et al.*, 2005) who have been studying water hyacinth in its flowering period had obtained very similar results about its fenology and generative reproduction. The flowering period lasts for about fifteen days. When flowering cycle ends flower stalk bends and the spike is now under the water surface and seeds are released directly into the water (Center *et al*., 2002). Each inflorescence contains normally 1 to 20 seed capsules and capsule caries 3 to 250 seeds. The authors mentioned above also agree that in spite of the production of this large number of seeds there are only 3 to 3.4 seeds per plant each year that are eventually able to germinate (Wilson *et al*., 2005). Seeds usually germinate within 6 months but in wet sediments at the bottom they can contain germination for 15 to 20 years (Center *et al*., 2002). Seeds germinate in moist environment in sediments or in warm shallow water (Center *et al*., 2002) and after 30 to 40 days seedlings have 4 to 8 leaves (Wilson *et al*., 2005). Metthews (1967, cit. Wilson *et al*., 2005) points even assuming a relatively low germination rate with only 3 seeds per plant per year density of new seedlings can be higher then density of mature plants reaching levels of 11,000 plants/m2. Assuming every seedling with 4 to 8 leaves weights 10g and that seedling density is 100 seedlings/m2 then in two months, when conditions for germination and growth are suitable, the fresh weight of biomass can easily be over 1 kg/m2 (Wilson *et al*., 2005). So when maintaining and monitoring aquatic ecosystems or aquatic systems one must been in mind that whereever water hyacinth can produce new plants from seeds generative reproduction must not be underestimate as *E. crassipens* can colonise areas again very fast after applied control measures, dramatic changes in water level or after winter.

Fig1 Growth of *Eichhornia Crassipes* in velachery lake (photo taken by Author in.15-10-11)

Status of Aquatic weeds in Tamilnadu with *Eichhornia crassipes*

In the city of Chennai, Velachery lake , boundary of pallikarani drainage swamp, portion of adyar river, Buckingham canal and Otterinullah have turned eutrophic due to ***Eichhornia crassipes***. This is the case with water bodies around Trichy, Madurai,Triunelivi, in coimbatore, salem and other town. *Ipomoea aquatica* is the first order among water weeds causing menance. In Tamilnadu almost 80% of 39000 tanks are already infested with weed. Even very big lake like Chembarakkam lake , Dusi-Mamandur lake, kavaripakkam lake , veeranam lake etc are also affected by this weed (Varshney et al 2008)

***Eichhornia crassipes* in Pollution Aspect**

The present pilot-scale, field experiment was conducted to evaluate the efficacy of recycling water hyacinth material for sewage wastewater treatment. Field observations indicated that a highly polluted sewage discharge point tended to appear cleaner around the patches of dead water hyacinth (Chen et al., 2010). Our hypothesis was that the spongy tissue of water hyacinth stalks functioned like an adsorbent adsorbing particulate pollutants. Through its abundant surface area, the stalks promoted the growth of microorganisms, algae and zooplankton fostering a micro-ecosystem that became a natural
biological treatment environment.

In the past decades, the application of wastewater stabilization pond (WSP) has attracted attentions for swine effluent treatment in many countries (Mergaert et al., 1992; Seghezzo et al., 1998). Kiran et al. (1991) tested Eichhornia crassipes, Pistia stratiotes, Salvinia rotundifolia and Lemna minor and found that water hyacinth (E. crassipes) had a distinctively greater capacity of nitrogen and phosphorus removal during summer and rainy seasons Phosphorus pollution in aquatic environment are is generally attributed to three major sources: industry, agriculture and domestic sewage (Valero et al., 2007). Both laboratory and field studies have also demonstrated that water hyacinth plants are able to reduce the concentrations of a variety of pollutants in swine wastewater (Delgado et al., 1995; Williams, 2009).As mentioned above water hyacinth systems are very efficient in pollutant removal from wastewaters. Efficiency of nitrogen removal ranges from 10 to 90 % (U.S. EPA, 1988).

DISCUSSION

Two objectives are proposed in this study. First, to reduce the contaminant load of the velachery sewage effluents by a continuous phytoremediation process using E. crassipes and second, to use the lake suitable for aquaculture. Thus to increase the yield of fresh water fish like rohu,catla, mirgil and this lead the solve the social economic problems who live near the bund of the lake. Besides, as the slurry left over after the anaerobic digestion is rich in nitrogen, phosphorus, and potassium content, it may be used as a fertilizer to improve soil quality in agricultural applications.

Water hyacinth can be brought to make compost, mulching and to clean the sewage. It is a good way to change waste products into useful things. More research is needed in order to define the optimum water hyacinth density in the reservoirs to determine its influence on the water quality of the effluent (Jafari., 2010).Water hyacinth harvests have been put into valuable uses in several countries. Methods of converting the plant material into valuable products have emerged. Apart from its ornamental value, the plant has been found useful as a source of animal feed (Gopal, 1987), as a source of fertilizers for use in agriculture (Oyakawa *et al*., 1970; Majid, 1986), a source of biomass energy, a source of raw materials for building, handcraft making, paper and boards. In addition the plant has been found to be useful as a filter worth of solving man created problems of pollution in water bodies(Jafari., 2010). *Eichhornia crassipes* was found to be rich in flavonoids, amino acids, crude protein, cyanide, phosphate, organic matter and organic carbon. It grows in an almost neutral pH, substantial concentration of dissolved oxygen, an increased rate of biochemical oxygen demand (Nyananyo.,2007). An attempt had been made to focus on epobionts infestigation in freshwater habitat which has got local/regional importance towards the quality of water in velachery lake (Rajabunizal and Ramanibai (2011).. In regions where it can be found in abundance water hyacinth can be used like food for people because its leaves are rich in proteins and vitamin A (Lindsey and Hirt, 1999). It can be also utilized as green fertilizer or as mulch, compost and ash in regenerating degraded soils. In regard to its ability to remove different pollutants from water it can positively influence on fish populations in natural waters or on fish growing in artificial accumulations. It can easily replace straw as substrate for mushroom growing or it can be use as fodder (Lindsey and Hirt, 1999). It is interested that it can be used in energy production thereby combating deforestation. As briquettes or biogas it can be used for lighting a furnace and cooking in schools, restaurants or government institutions (Lindsey and Hirt, 1999).

The need to feed the increasing populations of the less developed nations and the aspirations of rural communities for a standard of living above that of mere subsistence, dictates that agriculture in these countries must become more productive. As the farming systems in the tropics become more intensified to meet this demand, so local Chennai corporation agencies to pay attention and must provide the technology to achieve this and ensure that increased productivity is sustainable, with the minimum of environmental degradation and loss of species diversity in Velachery Lake

CONCLUSION

In last few years a great interest has been shown for research of aquatic macrophytes as good candidates for pollutant removal or even as bioindicators for heavy metals in aquatic ecosystems (Aoi and Hayashi, 1996; Maine *et al.*, 1999). Water hyacinth just one of the great number of aquatic plant species successfully used for wastewater treatment in decades, was of particular importance. It is important to emphasize that *Eichhornia crassipes* has a huge potential for removal of the vast range of pollutants from wastewater (De Casabianca and Laugier, 1995; Maine *et al*., 2001; Mangabeira *et al.*, 2004; Sim, 2003) and that a great number of aquatic systems with water hyacinth as basic component were construct (U.S. EPA, 1988; Aoi and Hayashi, 1996). There is a need to prevent domestic sewage in velachery lake to regulate the pollution caused by outlets and industrial waste. Though the city had enough water to meet current requirements thanks to satisfactory water levels at its main reservoirs of Red Hills, Cholavaram, Poondi besides adequate supply from Veeranam, Chembarambakkam Lake and Telugu Ganga Project, Chennai was expected to face water shortage by

2026."Chennai will need around 2,250 Million Litre a Day (MLD) by 2026. Although, sources for about 1,950 MLD are identified, the solution lies in conservation and recycling to generate 300 MLD by 2026," Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) Managing Director Shiv Das Meena said. City like Chennai drinking water must be provided in piping system in each resident by metro water corporation ,so people in the Chennai they are not showing importance in lake reservoir and pond water for drinking and washing. So these lakes maily used for the letting out sewage in the open and also industrial waste too.(Shiv Das Meena.,(2007). Sewage being a rich source of organic and inorganic contaminants, when reach the water bodies through the inlets may cause heavy contamination(Rajabunizal and Ramanibai (2011). Moreover sewage is an ideal medium for the endogenous pathogens like viruses, bacteria and microparasites. Coliform bacteria and E.coli are very common forms in sewage. When such forms reach the water sources through sewage, it will affect the health of animals and human life(Rajabunizal and Ramanibai (2011).Velachery lake pollution should be balanced by *Eichhornia crassipes.* This healthy lake should be preserved for future generation for food requirement of the growing population will be about 450 million tons in 2050 as against the present highest food grain production of around 198 million tons. Two-third of this is obtained from irrigated food grain production areas. Thus, irrigation water requirements of the country are likely to exert tremendous pressure on our water resources in the future. Water scarcity may become more common in many parts of the world because the world population is rising, more and more people are growing richer (thus demanding more water) and global warming is increasing aridity and reducing water supply in many regions. *Eichhornia crassipes* and other aquatic weeds in the lake act as to prevent global warming. This Velachery lake should be properly maintained by thoroughly monitoring in future for Aquaculture and Tourism

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