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Design and Development of Sustainable Wastewater Treatment Plant for Sustainable Development Management of Wastewater

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Sustainable wastewater treatment plant is a kind of wastewater treatment plant that meets the needs of the present without compromising the ability and efficacy of future generations to meet their own wastewater treatment needs. Environmental and social impact assessment (EIA) process for the existing Publicly Owned Wastewater Treatment Plant (POTP) has been carried out. The present research study involves design and development of sustainable wastewater treatment plant that succeeds to sustainable development management (SDM) of wastewater. Sustainable wastewater treatment plants are designated as primary, secondary, and advanced nutrient treatment plants. The benefits of sustainable wastewater treatment plant are the removal of principal wastewater constituents such as about 90 percent of the biochemical oxygen demand (BOD), 90 percent of the suspended solids (SS), 90 percent of total nitrogen, and 90 percent total phosphorus in wastewater rather non-sustainable wastewater treatment (Iyer, 2011). Municipal wastewater is over 99.9 percent water. Composition of treated wastewater has been characterized and assessed from a Publicly Owned Wastewater Treatment Plant (POTP) in Koyambedu located at Chennai, India. American public health association (APHA) method has been followed (American Public Health Association, AWWA (American Water Works Association), & Water Environment Federation, 2012). The treatment plant treats wastewater having a capacity of about 60 million liters day (MLD). Primary treatment plants utilize physical unit operations. Secondary and tertiary treatment plants utilize biological unit processes. In POTP primary treatment removes only about 30 percent of the BOD and 70 percent of SS and secondary treatment provides additional BOD and suspended solid removal, beyond what is achievable by primary treatment. It has been observed that eutrophication is one of the major problems in receiving streams as POTP does not possess advanced or tertiary treatment plant. Some degree of safety is supplemented by chlorine disinfection. Odour of 45 unit has been found after secondary treatment. It has been investigated that the effluent has enough nutrients such as total nitrogen and total phosphorus, to accelerate eutrophication that means no more than quarter of the nitrogen and one-fifth of the phosphorus are removed during the secondary treatment. Since receiving body of water is sensitive to eutrophication, advanced treatment plant must be required in POTP for sustainable development. A model on sustainable wastewater treatment plant (SWTP) has been designed and developed to facilitate incorporation of such model in the existing POTP integrated with the advanced or tertiary de-nitrification, phosphorus, and sulphur removal processes. SWTP treated effluent reused for agricultural irrigation purpose and discharged into environment as per safe legislation requirement. The legislation act, in essence, requires advanced wastewater treatment facilities for all POTP by stimulating that such facilities

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provide at least 90 percent of total bod removal, which should translate into an effluent requirement of 10 mg/l for both 5-day BOD and SS, total nitrogen of 0.3 mg/l and total phosphorus of 0.02 mg/l. The SWTP design shall solve the existing environmental problems such as eutrophication and ground water pollution. Thus, it gives better performance in terms of techno-environment feasibility in wastewater treatment for SDM while incorporating mitigation measure with the conventional POTP. It is concluded that the existing POTP is considered as unsafe wastewater treatment plant in contextual to environmental and social problems of eutrophication, oxygen depletion, adverse fish toxicity, methemoglobin anemia poisoning, chlorine disinfection, and excessive odor due to high concentration of total nitrogen and total phosphorus in treated wastewater effluent. Further, it is suggested that modification and/or obsolescence of the conventional POTP should be required for sustainable development as POTP is inadequate.

Keywords: advanced, eutrophication, denitrification, nutrient, phosphorus, sustainability, treatment, wastewater

Introduction

Sustainable Development Management (SDM) of wastewater is a kind of development that meets the needs of the present without compromising the ability and efficacy of future generations to meet their own needs. Municipal wastewater is over 99.9 percent water (Masters & Ela, 2008). Remaining 0.1 percent contains sludge. The sludge contains solids and bio-solids such as bio-chemical oxygen demand, chemical oxygen demand, suspended solids, dissolved solids, and nitrogen and phosphorus including sulphur. Reservoirs, lakes, and up streams that accumulate silt and organic matter undergo natural eutrophication (well fed) process. Oligotrophic (feed food) streams and lakes gradually receive nutrients from Publicly Owned Wastewater Treatment Plant (POTP) causing aquatic growth while decaying organic matter thus contributing to oxygen depletion problem and groundwater pollution. POTP treated municipal wastewater discharged into lake that stimulates algal growth and degrades water quality such that it causes oxygen depletion, fish toxicity, blue baby syndrome, and other environmental health problems (Iyer, 2011). Existing POTP does not meet the acceptable BOD, SS, total nitrogen, and total phosphorus criteria that produce toxic organic pollution and vulnerable effects of sulphur and nitric acid. Therefore, it is necessary to obsolete the conventional POTP with the SWTPs for sustainable development as conventional POTP is inadequate.

Literature Review

Sustainable wastewater engineering is a branch of environmental engineering in which the basic principles of sustainability, science, and technology are applied to solve the issues associated with the treatment and reuse of wastewater (Iyer, 2017a). The goal of wastewater engineering is the protection of public health in manner commensurate with engineering, economics, environment, social, and sustainability concerns (Metcalf & Eddy, 2015). To protect public health and the environment, extensive literature survey is conducted that included the field survey of the constituents of concern in wastewater, impacts of these constituents when wastewater is dispersed into the environment, the transformation and long-term fate of these constituents in treatment processes through product life cycle analysis (Iyer, 2017c), sustainable treatment methods that need to be applied to remove or modify the constituents found in wastewater, and methods for beneficial use or disposal of solids generated by the treatment methods (Metcalf & Eddy, 2015). The literature survey addresses the final perspective on the field of sustainable wastewater engineering focused on developing countries that need to be addressed in the planning

and decision making process of wastewater management systems, and the status and innovation in wastewater treatment engineering (Iyer, 2017b). Environmental impact assessment in surface and ground water effects has been elaborated (Canter, 1996).

Materials and Methods

Wastewater characterization and assessment have been done for the existing POTP. American Public Health Association (APHA) method has been followed (American Public Health Association et al., 2012). Wastewater treatment plants are designated as providing primary, secondary, and advanced treatment as per the removal of principal constituents of concern in wastewater (Iyer, 2011). Primary treatment plants utilize physical unit operations such as screening and sedimentation to remove pollutants that are settleable or floatable solids. Secondary treatment plants utilize removal of bio-chemical oxygen demand and chemical oxygen demand from wastewater. Advanced wastewater treatment plants utilize removal of nutrients such as nitrogen, phosphorus, and sulphur.

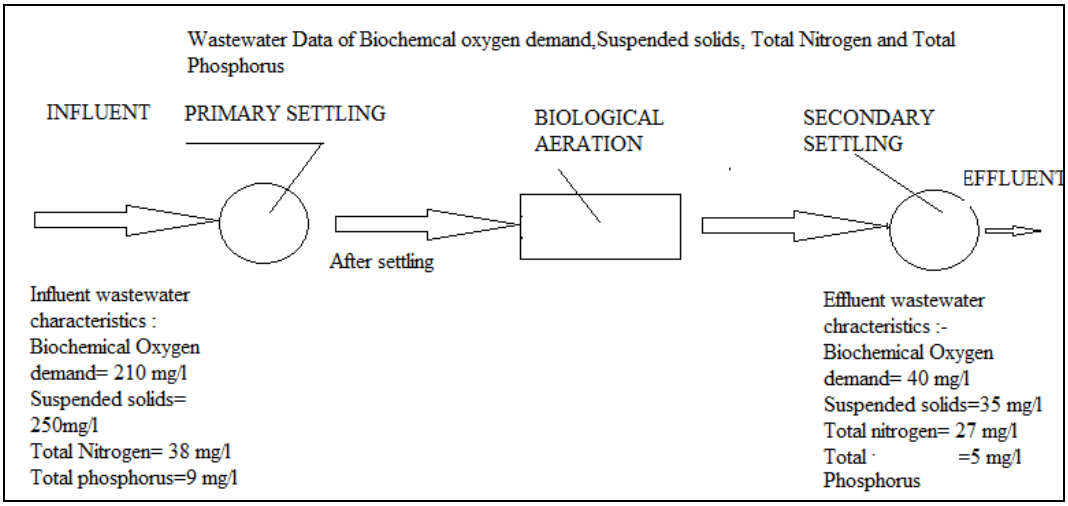

Figure 1. Schematic of Publicly Owned Wastewater Treatment Plant (POTP) providing primary and secondary treatment.

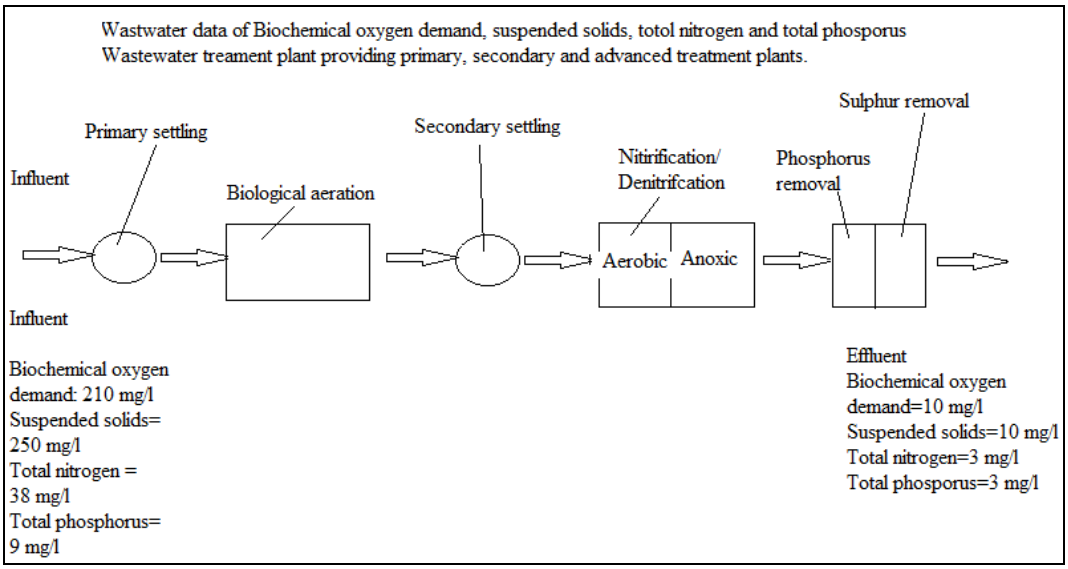

Figure 2. Schematic of sustainable wastewater treatment plant providing primary, secondary, and tertiary treatment.

Figure 1 represents the schematic of Publicly Owned Wastewater Treatment Plant (POTP) and shows representative values of biochemical oxygen demand, suspended solids, total nitrogen, and total phosphorus as waste water passes through primary treatment and secondary treatment.

Figure 2 represents the schematic of a proposed sustainable waste water treatment plant showing primary, secondary, and advanced treatment plants. The potential benefits of modified advanced wastewater treatment plant integrated with POTP are great in context to removal of nitrogen and phosphorus from wastewater, but the economic, social, cultural, and environmental costs of wide commercialization remain high. Environmental and social impact assessment process of the existing POTP has been provided (Iyer, 2014).

Results and Discussions

According to Sawyer and McCarty (1967), the total nitrogen available in treated wastewater of wastewater treatment plant (POTP) should be less than 0.3 mg/l. Stoichiometric analysis has been done for the carbonaceous bio-chemical oxygen demand and nitrogenous oxygen demand removal (Henry & Heinke, 2002). An oxidation pond or waste stabilization pond has been designed which has a surface area of 100 acres for wastewater treatment for 10,000 people (Iyer, 2007). The oxygen demand called nitrogenous biochemical oxygen demand (NBOD) is associated with the oxidation of ammonia nitrogen into nitrate nitrogen that is ultimate NBOD, approximately equal to 4.57 X TKN (Metcalf & Eddy, 2015).

It is experimented that publicly owned treatment effluent (POTE) contains considerable amount of oxygen demand in such a way due to the removal of total nitrogen for 30 mg/l found to be approximately 137 mg of oxygen (APHA, 2001). Treated effluent when discharged into lakes and streams causes eutrophication problem because of excessive nitrogen and phosphorus available in treated effluent. Oxidation reduction potential (ORP) has been measured and found out to be -80 milli volts in an anoxic environment. The amount of dissolved oxygen depleted by NBOD in wastewater is one of the indicator of a stream's health. As the dissolved oxygen drops below 3 mg/l, most higher forms of biological life are driven off because of noxious conditions that prevail in streams. Carbon source as methanol or acetate has been added as doze of 3.2 kg for 1 kg nitrate-nitrogen reduction that takes place during denitrification process. Removal of organic orthophosphate in wastewater has been experimented by adding optimum doze of alum as a coagulant such that aluminum phosphate settled as tertiary sludge from wastewater in tertiary clarifier. Nitrogen concentration of above 0.3 mg/l and phosphorus concentration of more than 0.020 mg/l in effluent wastewater have produced excessive algal blooms and poisoning eutrophic lake streams than oligotrophic lake steams. The rate of nitrification and denitrification in media fill from both anoxic and anaerobic biological film is found to be 19 mg of ammonia nitrogen removed per square meter in a day of media fill in movable bed biofilm reactor (MBBR) and submerged fixed film activated sludge process. Optimum doze of sodium bicarbonate has been added to destroy 7 mg of alkalinity per mg of ammonia nitrogen oxidized in advanced wastewater treatment because the POTE discharge effluent has acidic nature of pH 6.6 (Metcalf & Eddy, 2015). Nitrate is the hydrogen electron acceptor. As the algae production takes place in lake due to photosynthesis and therefore limited nutrients must be available for the control of eutrophication.

The concentration of total phosphorus found out from the point source 5 mg/l that could have been 250 times above than the permissible limit of 0.02 mg/l for total phosphorus to cause eutrophication in lake streams (Sawyer & McCarty, 1967). The concentration of total nitrogen found out from the point source 30 mg/l that can be 1,000 times above than the permissible limit of 0.3 mg/l for total nitrogen to cause eutrophication in lake (Sawyer & McCarty, 1967).

POTP is having the wastewater treatment capacity of about 60 million liters in a day (MLD). POTP only possesses primary and secondary wastewater treatment plants. POTP has only the degree of purification of about 50 to 60 percent which is against the safe permissible limits of 90 percent purification capacity for reusing and recycling applications and safe legislation requirements (Iyer, 2017a). It has been observed that the existing POTP is considered to be unsafe wastewater treatment plant in terms of environmental and social problems such as eutrophication, oxygen depletion, adverse fish toxicity, blue baby syndrome (methemoglobin anemia poisoning), chlorine disinfection, and excessive odor due to high concentration of total nitrogen and total phosphorus in effluent wastewater.

Conclusions

Sustainable development management (SDM) of wastewater is a kind of development that meets the needs of the present without compromising the ability and efficacy of the future generations to meet their own wastewater treatment needs. Municipal wastewater has over 99.9 percent water. The characterization and assessment of the remaining portion have been done from a wastewater treatment plant in Koyambedu located at Chennai, India. APHA method has been followed. A research study has been carried out Koyambedu Publicly Owned Wastewater Treatment Plant (POTP) having the wastewater treatment capacity of about 60 million liters' day. Primary treatment removes about 30 percent of the BOD and 70 percent of suspended solids and secondary treatment provides additional BOD and suspended solid removal, beyond what is achievable by primary clarification. Some degree of safety is provided by disinfection after secondary treatment although there is chlorine disinfection problem at high level of effluent nitrate concentration. It is mentioned that at present there are no advanced treatment processes available in Indian POTP. It has been investigated that the effluent has enough nutrients such as nitrogen and phosphorus to accelerate eutrophication that means no more than quarter of the nitrogen and one-fifth of the phosphorus are removed during the secondary treatment. The effluent has been found to be the major contributor to eutrophication problem. Since receiving body of water is sensitive to eutrophication problem, advanced treatment or tertiary nutrient removal process must be required in such Publicly Owned Wastewater Treatment Plant in India for SDM. It should be mentioned that all the Indian wastewater treatment plants utilize primary and secondary treatment plants, but the effluent still has enough BOD and nutrients such as nitrogen, phosphorus, and sulphur to cause ground water pollution and oxygen depletion problem. The degree of safety is against World Health Organization (WHO) standards even though the process is added by chlorine disinfection.

The benefits of sustainable wastewater treatment plant are the removal about 90 percent of the BOD, 90 percent of the suspended solids, 90 percent of the total nitrogen, 90 percent of the total phosphorus, and 90 percent of the total sulphur rather than non-sustainable wastewater treatment (Iyer, 2017a). A model of sustainable wastewater treatment plant has been designed and developed to incorporate in the existing POTE integrated with the tertiary or advanced treatments such as nitrification/de-nitrification, phosphorus, and sulphur removal processes. Outlet effluent water shall be reused for irrigation and discharged into environment as per safe legislation requirement. Environmental and social impact assessment process of existing POTP has been conducted (Iyer, 2007).

The legislation act, in essence, requires advanced wastewater treatment facilities for all POTP by stimulating that such facilities provide at least 90 percent of total BOD removal, which should translate into an effluent requirement of 10 mg/l for both 5-day BOD and SS, total nitrogen of 0.3 mg/l, and total phosphorus of

0.02 mg/l. The design shall solve the existing environmental problems such as eutrophication and ground water pollution. Thus, it gives better performance in terms of techno-environment feasibility in wastewater treatment for SDM while incorporating mitigation measure in the conventional POTP. It is concluded that the existing POTP is considered as unsafe wastewater treatment plant in contextual to environmental and social problems of eutrophication, oxygen depletion, adverse fish toxicity, blue baby syndrome (methemoglobin anemia poisoning), chlorine disinfection, and excessive odor due to high concentration of total nitrogen and total phosphorus in treated wastewater effluent. Further it is suggested that modification and/or obsolescence of the conventional POTP should be required for sustainable development as all conventional POTP in India is inadequate.

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