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Review Paper

Towards Embracing sewage Stabilization ponds for Sewage effluent Treatment for small communities: A review

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Abstract

One of the biggest challenges facing the world today is management of waste water particularly due to pressures imposed by population growth and rapid urbanization. In most countries, the few sewerage systems that are present serve only the formal urban population while in the informal settings and areas that are far flung from the cities, raw sewage is left to run in the open most often joining the natural waterways. In order to address this challenge, other sewage water treatment options must be developed and adopted for protection of the environment. Sewage stabilization ponds (SSPs) are artificially constructed ponds or wetlands that use natural purification processes to purify sewage water. They are simple to construct and maintain and have low capital investment and annual running costs. The SSPs are used to retain sewage waters can become stabilized before being discharged into receiving water bodies. The main aim of this review paper was to assess scientific knowledge of SSPs in treatment of sewage in order to evaluate their applicability in treatment of sewage in the informal settlements and for small communities. This document does not provide the actual design of these ponds but rather is a review that can be useful to public works engineers and researchers to assess the feasibility of SSPs especially for stabilization of sewage effluents in areas that are far-flung from the central conventional sewage treatment systems.

Keywords: Environmental protection, pollution, sewage stabilization ponds, sewage treatment.

Introduction

It is the immediate need of every community to combat and avert pollution of surface water bodies with sewage that is the norm rather than the exception in many countries worldwide. In developing countries, surface water bodies are threatened because of discharge of untreated or poorly treated industrial and sewage effluents[1]. Untreated wastewater discharged into natural water ways causes deterioration of aquatic environments[2]. Pollution of surface water bodies with untreated sewage also constitutes health hazards both to users and to aquatic life.

In many developing countries, a majority of the populations are not sewered[3]. For example, only about 10- 15% of the urban population in Africa is sewered[4]. With many of these developing countries struggling financially, consideration of alternative methods of low-cost sewage water treatment technologies is both timely and useful. Untreated discharges pollute surface water bodies and contribute to increased BOD and nutrient loads thereby destabilizing the aquatic ecosystems[5].

The major objective of sewage treatment is normally to provide for a means of stabilization of effluents before discharging them into the receiving environments thus enhancing environmental sustainability. According to Mara D.D. et.al.[6], sewage treatment plants are normally designed to reduce organic load and suspended solids so as to limit environmental pollution. To control these waterborne diseases, wastewater treatment systems must be highly efficient in microbial reduction. Various treatment processes including SSPs have been shown to be very efficient in reduction of bacteria that are present in sewage water. In fact, SSPs have been reported to be one of the most economical processes to remove pathogens and fecal bioindicators from wastewater[2].

Description of Sewage Stabilization Ponds: A sewage stabilization pond can be described as a shallow pond into which sewage water is introduced and retained for a period of time to allow for a natural degradation or purification process[7,8]. Sewage Stabilization Ponds are also often referred to as oxidation ponds, lagoons, constructed wetlands or artificial wetlands. In these basins or ponds, treatment of sewage water (sewage effluents) occurs by natural/biological decomposition of organic matter.

Sewage Stabilization Ponds have also been described as shallow bodies of sewage water contained in earthen man-made basins that are meant for treatment of the sewage before disposal. Louisiana Administrative Code[9] also defines a SSP as a shallow excavation that is meant to naturally treat sewage under the influence of prevailing environmental conditions. To prevent leaching, the ponds are normally lined with impervious material such as asphalt or compacted earth and berms are erected around the ponds using the excavated material to assist in protection of the ponds against runoffs and soil erosion. The sewage effluents are introduced into a pond from one end and released at the opposite end of the pond after being treated naturally during the retention period. The degree of treatment provided depends on the type and number of ponds used.

Sewage stabilization pond treatment technology has been used for removal of organic matter[10], pathogenic organisms[11] and nutrients[12]. This technology can be used for treatment of wastewater from domestic, industrial and agricultural sources[13]. Waste stabilization ponds are largely used in tropical climates [14] although their application in temperate climatic region with temperatures as low as 7^0C is not uncommon[12].

The Self- Purification Mechanisms of Sewage Stabilization Ponds: The activities in SSPs are a combination of complex processes of bacteria and algae the result of which is reduction of the organic content of the effluents and production of a more stable effluent.

According to Imhoff and Fair[15], microorganisms constitute an essential part of the sewage purification system in SSPs as a result of their metabolic activities that bring about changes to the physical and chemical composition of the sewage. In these ponds, biodegradable organic matter is broken down by aerobic bacteria into simple and stable inorganic materials such as carbon dioxide, water, sulfates and phosphates[16] which are then utilized by algae to produce complex organic materials that make up the algal cells. During this process algal cells generate oxygen which is utilized by bacteria[6]. These processes all lead to the efficient mineralization of organic matter translating into lowered BOD and inactivation of microorganisms[17]. The use of SSPs has therefore been considered as the ideal way of improving effluent quality by purely natural processes[18]. Botkin and Keller[19] reported that apart from pathogenic microorganisms, organic chemicals, heavy metals, phosphates and nitrates are also reduced significantly in effluents treated by SSPs.

Sunlight is an important factor in the elimination of microorganisms in SSPs[20]. Normally, the SSPs are constructed in series of between 3 and 5 with the effluents from the first pond being transferred into the next pond and so on and so forth. The first pond is normally anaerobic while the second pond is facultative. The facultative pond is usually followed by one or more aerobic ponds. The general overview of processes involved in removal or reduction of pollutants and microorganisms in SSPs is provided in table-1.

Self-Purification in the Anaerobic Pond: The anaerobic pond is usually a pre-treatment pond that serves to reduce the suspended solids and the BOD by up to 60%. Anaerobic ponds are moderately deep (2-5m) and the sewage effluents are retained only for a short period of time (1-7 days). The anaerobic bacteria in these ponds break down the organic content of sewage water into methane thereby contributing to reduction of BOD. Many authors have reported that anaerobic ponds are capable of treating strong sewage waters[2,6]. The sewage effluent from the anaerobic pond is channeled to the facultative pond. It has been reported that removal of BOD_5 in anaerobic ponds increase with increased retention time of the effluents in these ponds. The percent removal of BOD_5 in anaerobic ponds based on retention time is provided in table-2.

Table-1
Overview of pollutant removal mechanisms

Pollutant	Removal processes
Organic material (BOD)	Biological degradation, sedimentation, microbial uptake
Suspended solids	Sedimentation, filtration
Nitrogen	Sedimentation, nitrification/denitrification, microbial uptake, volatilization
Phosphorous	Sedimentation, filtration, adsorption, microbial uptake
Pathogens	Natural die off, sedimentation, filtration, predation, UV degradation, adsorption

Table-2
Biochemical Oxygen Demand removal in anaerobic ponds

Retention time (days)	BOD_5 removal (%)
1	50
2.5	60
5	70

Self Purification in The Facultative Pond: In a facultative pond, both aerobic and anaerobic processes occur. The upper sewage water is provided with oxygen from the atmosphere and from photosynthetic algae present in the pond and is therefore aerobic. The sewage water at the bottom of the pond lacks oxygen and is therefore anaerobic. Suspended solids settle to the bottom of the pond and are digested by the anaerobic bacteria present there. In these ponds, BOD can further be reduced by 75%. The facultative ponds are usually shallower than the aerobic ponds (1-2.5 m) but the sewage water is retained for a longer period of time in these ponds (up to 30 days) [1, 18]. Sewage water from the facultative pond is normally channeled to the aerobic pond to further stabilize the sewage.

Self Purification in the Aerobic Ponds: Aerobic ponds are also known as maturation, finishing or polishing ponds. This is because they serve as the final level of treatment in a series of SSPs. They are usually the shallowest of all ponds (0.5-1.5m) to ensure the penetration of sunlight for photosynthesis. The main purpose of these ponds is the elimination of pathogens from sewage water[21]. The DO in aerobic ponds comes from the atmosphere and from the photosynthetic algae present in the ponds. Such ponds can be used for fish farming to enable further reduction of nutrients[18].

The Pros for Sewage Stabilization Ponds: Sewage stabilization pond systems are reliable, less costly and require less maintenance when compared with the conventional sewage treatment options. Because of this, they can be useful in areas that are out of reach of Municipal sewage treatment plants such as the informal settlements and rural areas.

Many authors have reiterated the fact they the low costs involved in erection of these ponds plus the low maintenance costs both make the SSPs attractive for use in areas where the sewage treatment facilities are out of reach. Operation and maintenance only involve pond construction, maintaining the pond site, draining the ponds and removing sludge[22]. The SSPs have shown high level of performance in organic load reduction especially in the tropics and sub-tropics because the climatic conditions are condusive[2]. The SSPs have been reported to be suitable for the treatment of both domestic and industrial effluents under different weather conditions[18]. Other authors have reiterated the same. In fact, Mtethiwa *et al.*, [18] reported that many characteristics make SSPs substantially better than other sewage water treatment techniques. These include simplicity in design and operation and cost effectiveness in addition to low energy and maintenance requirements.

The other major advantages of SSPs technology include removal of pathogenic organisms without addition of chemicals, low sensitivity to hydraulic and organic shock load and the fact that minimum or no mechanical equipment is required for their operation. These ponds also function well with no requirement of external sources of energy unlike the conventional sewage treatment processes[22].

Apart from the major uses of sewage treatment and stabilization, SSPs can also have other uses such as to provision of habitat for birds and waterfowls thereby providing ecological benefits especially in areas where wetlands have been degraded. These SSPs can also provide areas for public education, outdoor recreation activities such as jogging and bird-watching.

The Cons of Sewage Stabilization Ponds: Everything good under the sun does not lack the bad side. Sewage stabilization ponds also have disadvantages in that they require extensive land area for construction and are therefore only feasible in areas where there is a lot of land. These ponds also have seasonal odors associated with organic material decomposition and there is the potential of these ponds to attract and provide habitat for dangerous wildlife such as snakes and alligators since they have limited vegetation and have a lot of space for resting, watering and feeding. Sewage stabilization ponds retain water for a long period of time and can act as mosquito breeding grounds thereby leading to mosquito and malaria menace where they are constructed. The sewage treatment process in SSPs is rather slow compared to the conventional methods of sewage treatment and there is little control over the effectiveness of the treatment process.

Other disadvantages of SSPs would include the possibility of seepage of effluents and metals into soil which may also lead to ground water pollution and the possibility of bioaccumulation and biomagnifications of pollutants in the wildlife that they harbor and subsequently, in the entire food chain of ecosystems. The use of SSPs has been reported to be more effective in warm tropical climates of the world. For efficiency of these pond systems in cold climates, wastewater has to be applied at very low organic loading rates of less than 60 $kgBOD_5$/ha/day[33] and wastewater may be retained for a duration of up to one year before they can be stabilized[24]. Pond technology also suffers stability problems with effluent concentrations because of large amount of biomass in the effluent and large land requirement[18].

The Present and the Future of Sewage Stabilization Ponds: Sewage Stabilization Ponds are now recognized as a suitable method for sewage water treatment in many parts of the world[3]. They are especially common in the developing world where they are employed to treat sewage effluents from large populations. In fact, it is one of the methods used extensively in the tropical areas of the world for treating wastewater[25]. Other authors have also reported that sewage treatment using SSPs is widely used all over the world especially in tropical and subtropical countries[27].

In Europe, SSPs serve small communities in rural areas with populations of about 2000[28]. However, in the United States the SSPs are used for larger populations of up to 5000 people[29]. In warmer climates such as the Middle East, Africa, Asia and Latin America, the SSPs are used for extremely large populations of up to 1 million people. In many developing countries, the SSPs are employed as an ideal way to improve sewage effluent quality at low costs and with minimum mainatance[6]. France has over 2500 and Germany has more than 1100 SSPs. In Kenya, sewage stabilization ponds exist in places such as Dandora in Nairobi (serving a population of approximately 1 million[2].

An appropriate sewage treatment method is one which provides effluents of good quality at low costs and with minimum maintenance requirements. Adopting such a low cost and simple method of sewage treatment is desirable especially in developing countries where there can be difficulties even in the operation of complex systems reliably. Of late, urbanization, industrialization and technology have lead to the enrichment of various pollutants, which may affect the treatment efficiency of stabilization ponds. The concern with these SSPs is that pollutants can get accumulated in the sediments of ponds and become toxic to the entire oxidation pond community. The SSPs can also be very offensive and provide breeding places for mosquitoes if not maintained well so proper maintenance is necessary.

Other efforts have been made towards improving nutrient removal and reducing land requirements with regard to the use of SSPs. These include introduction of attachment sites for algae and bacteria such as duckweed and water hyacinths[30].

Conclusion

Sewage stabilization ponds can ideally and effectively reduce large amounts of organic pollutants and pathogens in sewage water for small communities worldwide and help a great deal in environmental sustainability and protection. This technology can be and should be embraced worldwide to help in the achievement of the Millennium Development Goals worldwide. The use SSPs should be advocated for to enable Public Health Engineers use them confidently as simple and reliable means of treatment of sewage at a fraction of the cost of conventional sewage treatment plants.

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