REVIEW OF WASTEWATER TREATMENT TECHNOLOGIES FOR APPLICATION IN COMMUNITIES IN THE AMAZONIAN VARZEA

REVISÃO DE TECNOLOGIAS DE TRATAMENTO DE ESGOTO PARA APLICAÇÃO EM COMUNIDADES NA VÁRZEA AMAZÔNICA

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KEYWORDS

Wastewater treatment;
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ABSTRACT

The riverine communities of the Amazon varzea are almost devoid of environmental sanitation. This situation exposes the population to risks of diseases. One of the most serious problems is related to the lack of treatment of human waste and sewage, which causes environmental, aesthetic and health problems. Given these findings, this study is a literature review that aims to evaluate domestic effluents treatment systems that are compatible with the reality of the Amazonian varzea and thus establish a social technology that enables the promotion of basic sanitation for the riverine populations. We surveyed information on the treatment technologies most commonly used in the country, discussing the particularities of each and the limitations of the varzea ecosystems, such as the presence of wetlands and the lack of electricity. From the discussion we concluded that the set septic tank + anaerobic filter and constructed wetlands were more suitable for wastewater treatment in the varzea, because theirs building materials can be adapted to the humidity, do not require electricity and can be installed individually by residents. We recommend further studies on the adaptations of these technologies to meet the regional needs.

PALAVRAS-CHAVES:

Tratamento de esgoto;
Várzea;
Amazônia;
Áreas rurais.

RESUMO

As comunidades ribeirinhas da região de várzea da Amazônia são praticamente destituídas de saneamento ambiental. Esta situação expõe a população a riscos de doenças. Um dos problemas mais graves relaciona-se à ausência do tratamento dos dejetos humanos e esgotos, os quais oferecem problemas ambientais, estéticos e de saúde. Diante desta constatação, este estudo é uma revisão bibliográfica que tem por objetivo avaliar sistemas de tratamento de efluentes domésticos compatíveis com a realidade da várzea amazônica e desta forma estabelecer uma tecnologia social que possibilite a promoção do saneamento básico para as populações ribeirinhas. Foram pesquisadas informações sobre as tecnologias de tratamento mais aplicadas no país, discutindo-se as particularidades de cada uma com as limitações existentes nos ecossistemas de várzea, como a presença de áreas alagadas e falta de energia. A partir da discussão, concluiu-se que o conjunto tanque séptico + filtro anaeróbio mostrou-se mais adequado para o tratamento de esgotos na várzea, pois seus materiais construtivos podem ser adaptados para a umidade, não demandam energia e podem ser instalados individualmente por residência. Recomenda-se mais estudos sobre as adaptações da tecnologia pra atender às características regionais.

INTRODUCTION

This work presents information on wastewater treatment technologies and provides a discussion regarding their applicability in communities of the Amazonian varzea.

The varzea represents a small fraction of Amazonia (about 3%), however it encompasses the largest portion of floodplain forest, with approximately 200,000km^2 (AYRES, 1993). Its' main characteristics are fertile soils and rivers with a great abundance of fish.

The Sustainable Development Reserve of Mamiraua (Reserva de Desenvolvimento Sustentável Mamirauá - RDSM) is the largest existing reserve dedicated exclusively to the protection of the Amazonian varzea. It is located in the confluence of the Solimões, Auati-Paraná and Japurá rivers, extending throughout approximately 1,124,000 ha (PLANO de Gestão RDSM, 2010) and has a population of approximately 10 thousand inhabitants distributed in 200 rural localities. It is considered a flooded area of international importance, and is one of the Brazilian sites in the Ramsar Convention, of the United Nations (QUEIROZ, 2005).

The most striking environmental characteristic of RDSM is the great variation of annual water levels of its rivers. Seasonal flooding varies from ten to twelve meters between the dry and wet seasons, and is caused mainly by increased rains in the headwaters of the rivers of the region, associated with the annual thaw of the Andean summer. The flood brings along a large quantity of sediments from the hillsides of the Andes, which provides an enormous concentration of nutrients associated with clays in suspension. This accounts for the enormous productivity of the Amazonian varzeas, verified in its aquatic as well as terrestrial components. (QUEIROZ, 2005).

Control of water use that is consumed by families in RDSM occurs considering its different uses, in accordance with Moura (2006): drinking water, cooking water and bathing water.

In riverine communities of the varzea region, domestic activities are mainly executed using river water. In recent years water pumping and distribution systems, with a faucet in each residence, have been installed in RDSM communities. These systems have effectively reduced the physical effort and discomfort of manual water transport and domestic activities carried out on riverbanks, such as the washing of dishes and clothes, and personal hygiene.

In addition to the collective solution for water supply (the supply system), the riverine inhabitants have been encouraged to collect and save rainwater for nobler uses, such as drinking and cooking.

There are many benefits to the use of water at home, and on properties. However, the use of water in a household has a drawback: the production of liquid effluents. The domestic effluents are usually composed of water containing residues from the kitchen, from laundering, cleaning, bathing, and eventually from the toilet.

The main inconvenience related to sewage (domestic effluents), that characterizes water pollution, beyond aesthetical problems, is the presence of pathogenic organisms, nutrients (mainly nitrogen and phosphorus), and organic matter, indirectly represented by the Biochemical Oxygen Demand - BOD. According to Fundação Nacional de Saúde (National Health Foundation) (BRASIL, 2006) diseases such as cholera, dengue, schistosomiasis, leptospirosis, which result from the absence or inadequacy of sanitation, have increased epidemiological occurrences in Brazil. In order to promote the health of the riverine populations and prevent them from the possibility of contracting diseases related to the lack of proper sanitation, it is essential to seek solutions for the disposal of human waste.

A few institutions have made efforts to improve investments in pumping and water distribution systems, based on systems that have already been installed in the communities. Given this, the challenge of wastewater treatment, which is already significant in some communities, will be greater as the efforts of improving the quality of life through the water supply are expand.

Thus, the purpose of this article is to gather information on wastewater treatment processes that are compatible with the reality of the Amazonian varzea, and in this way to establish a social technology that enables the promotion of basic sanitation for the riverine communities.

METHODOLOGY

A literature review was conducted , consulting books, articles, and specific publications on wastewater treatment. The existing technologies of treatment were assessed, and we gathered information on their configurations, characteristics, and the advantages and disadvantages of their use. By comparing this information, we were able to recommend a few wastewater treatment technologies most appropriate for the Amazonian varzea.

RESULTS

This article does not present all existing forms of biological treatment of domestic wastewater, but it shows, in general terms, those most commonly discussed in academic circles, and which most commonly used in Brazil.

The treatment technologies were grouped in five broad categories: stabilization ponds, effluent disposal in soil, anaerobic reactors, aerobic reactors with suspended biomass, and aerobic reactors with biofilm.

Stabilization ponds

Jordão and Pessôa (2009) define stabilization ponds as biological systems of wastewater treatment characterized by natural or constructed ponds, with proper technical conditions for the enabling of autodepuration.

Stabilization ponds are classified as anaerobic, facultative, aerated, maturation, polishing, high rate, and macrophyte ponds, according to the predominant type of biological process.

In general, wastewater treatment by stabilization ponds presents elevated efficiency in the removal of organic matter and pathogenic organisms. There is also the possibility of agricultural reuse of the treated effluent. On the other hand, some disadvantages can be identified, such as the need for large areas to construction ponds, the presence of algae in the final effluent, weather dependence, the possibility of vegetation and insect proliferation, and high energy consumption (in the case of aerated ponds).

Effluent disposal in soil

The disposal of effluents in the soil surface, considered a type of final treatment and disposal, is characterized by the controlled application of wastewater in the soil, when enables physical, chemical and biological mechanisms to decompose and remove pollutants (VON SPERLING, 2005). The main variations of this type of treatment are: slow rate infiltration, rapid infiltration or subsurface infiltration, overland flow, and constructed wetlands.

Depending on soil and plat management, and of the wastewater disposal rate in the soil surface, four processes concur in this type of treatment: wastewater depuration, fertilization of vegetable cultures, aquifer recharge or final disposal of effluents.

Constructed wetlands, or artificial wetlands, are defined as a complex of saturated substrates, designed and built by man, of emergent and submerged vegetation, animal life and water that simulates natural wetlands for human use and benefit (HAMMER, 1989). In practical terms, they are planted macrophyte filters that contribute to treatment by means of soil-water-plant interaction. Wetlands differ from other types of soil disposal because their environment is constructed and can be built with impermeable walls. Thus, there is no direct contact with the soil and contamination hazards are reduced.

Anaerobic reactors

Anaerobic processes have many positive aspects in wastewater treatment, however they present one major disadvantage related to the low removal rate of nutrients and pathogens, and as a result they must be followed by post-treatment. In general terms, the treatment of domestic wastewater by anaerobic reactors can be presented in three configurations, which are the septic tanks, the anaerobic filters and the UASB reactors (Upflow Anaerobic Sludge Blanket).

Septic tanks are defined by Hartmann (2009) as units where processes of sedimentation, flotation and digestion occur. They can receive input from one or from dozens of residences. The only maintenance required for septic tanks consists of sludge removal and pipe unclogging when necessary.

Anaerobic filters are reactors with biofilm attached to a support medium that promotes the biological depuration of the effluent. Combined with a septic tank, the removal efficiency rate of organic matter is around 85%. By presenting relatively simple maintenance requirements and lower costs, this technology is widely used in places where there is no access to sewerage systems, especially in rural areas and isolated communities.

UASB are anaerobic reactors that promote biological depuration of the effluent without the need of filler, through the formation of a biomass composed of suspended granules (KATO et al., 1999). Among the anaerobic treatments this has shown better results in both technical and economic terms. In these reactors several simultaneous functions occur: sedimentation of suspended solids forming a blanket of sludge; anaerobic digestion of the more clarified liquid; and separation of the gases that are generated during the process.

Aerobic reactors with suspended biomass

The treatment of wastewater by suspended biomass involves variants of the traditional treatment system by activated sludge (GONÇALVES et al., 2001). These variants are selected depending on the purpose of the final effluent and the desired level of treatment. They are versatile processes that occur by constant contact of the wastewater with a volume of biologically active sludge. This mixture is kept in suspension by mechanical aeration, converting the biodegradable material into inorganic matter and sludge (biomass), which is then separated by decantation and is re-circulated towards the beginning of the process.

The major disadvantages of this type of treatment are the high costs of aeration and the difficulty in controlling the process.

Aerobic reactors with biofilms

In aerobic reactors with biofilms, or fixed biomass reactors, the biomass grows attached to a fixed or mobile support medium that promotes the depuration of the wastewater. There are several configurations for this type of treatment, such as: low load trickling filters; high load trickling filters; submerged aerated biofilters; and biodiscs.

Among the benefits of aerobic reactors are the reduced size, the absence of clogging of the filtering media, and the efficiency in nutrient removal. The advantages include: the high consumption energy associated with mechanical aeration, and the sophistication of the process that requires specialized operation (GONÇALVES et al., 2001).

DISCUSSION

The collective wastewater treatment generally is carried out in more than one stage, using also more than one treatment technology. Thus, they are combined systems or technological arragements of united or alternating aerobic and anaerobic processes, that seeking to improve the quality of the treated effluent, using the potential of each treatment unit. Thus, some of the technologies we presented require the application of preliminary or posterior treatments.

In discussing this work we emphasized decentralized treatment technologies, as oppossed to centralized systems. The centralization of wastewater treatment is common in cities, where the municipal government is responsible for the construction of an underground sewerage system to which homes are connected to collecting channels through piping. The collected wastewater is then sent to a treatment system that is usually located in the periphery of the city and combines two or more technologies, in order to achieve satisfactory results.

Individual and decentralized systems seek to treat wastewater near the origin, thus avoiding the expense of transport to and construction of large treatment plants. Two other points are relevant regarding decentralization. The first is related to the administration of technologies, carried out by users. The second refers to the technologies themselves, which sometimes allow nutrient recycling and the reuse of treated water, promoting waste recovery and energy savings.

Table 1 gathers information on the technologies we discussed, in terms of removal efficiency of the major pollutants present in domestic wastewater.

Table 1 – Average efficiency of removal of pollutants from domestic wastewater according to treatment technologies

Treatment technology	Average efficiency of removal of pollutants, in %						
	BOD	**COD**	**SS** [1]	**Ammonia-N** [2]	**Total N** [3]	**Total P** [4]	**FC (Log unit)** [5]
Anaerobic ponds – facultative pond	75 -85	65-80	70-80	<50	<60	<35	1-2
Facultative ponds	75-85	65-80	70-80	<50	<60	<35	1-2
Aerated ponds	75-85	65-80	70-80	<30	<30	<35	1-2
Ponds in series [6]	80-85	70-83	73-83	50-65	50-65	>50	3-5
Slow rate infiltration	90-99	85-95	>93	>80	>75	>85	3-5
Rapid rate infiltration	85-98	80-93	>93	>65	>65	>50	4-5
Overland flow	80-90	75-85	80-93	35-65	<65	<35	2-3
Constructec wetlands	80-90	75-85	87-93	<50	<60	<35	3-4
Septic tanks + Anaerobic Filters	80-85	70-80	80-90	<45	<60	<35	1-2
UASB reactors	60-75	55-70	65-80	<50	<60	<35	▯1
Aerobic reactors with suspended biomass	85-93	80-90	87-93	>80	<60	<35	1-2
Biological trickling filter – low load	85-93	80-90	87-93	65-85	<60	<35	1-2
Biological trickling filter – high load	80-90	70-87	87-93	<50	<60	<35	1-2
Aerobic reactors with attached biomass – Submerged Aerated Biofilter [7]	88-95	83-90	87-93	>80	<60	<35	1-2
Aerobic reactors with attached biomass - Biodiscs	88-95	83-90	87-93	65-85	<60	<35	1-2

Source: Adapted from Von Sperling (2005)

Notes: 1 Suspended solids. 2 Ammonia nitrogen. 3 Total nitrogen. 4 Total phosphorus. 5 Fecal coliforms in logarithmic units. 6 Maturation pond combined with anaerobic and facultative pond. 7 Submerged aerated biofilter with nitrification.

These efficiency values should not be used a sole information source when evaluating the performance of each type of treatment; they are however useful for a more simplified analysis.

In order to select the treatment technology most appropriate to rural communities of the varzea, it is necessary to consider the boundaries imposed by the hydrographic dynamics of the region. One most also weigh socioeconomic + cultural factors, mainly related to financial resources, availability of materials and specialized work force. Construction costs, acquisition of proper equipment, operation and maintenance of the treatment systems, as well as availability of electricity for these purposes and the education level of residents, for equipment operation.

Among the various characteristics of the varzea ecosystem, probably the most significant is the annual flooding of lands. This factor is important because most technologies demand a dry area for construction. The natural cycle of flooding causes waterlogging and soil instability, rendering difficult the installation of piping for wastewater collection interconnecting residences. Furthermore, the piping that carries the effluent should not remain submerged, because of the risk of contamination of river water with wastewater. Further risks include the possibility of wastewater dilution from water infiltrating the collecting network and compromising treatment. For these reasons, we conclude that collective system of wastewater treatment is scarcely suitable for use in floodable areas.

However, adaptations to the original conception of these technologies may be executed, such as the case of treatment reactors commonly buried in dry soil, built with impermeable walls and additional piping protection. Thus, these systems can be set up in a way to be only partially submerged. However, the proper precautions must be taken, such as the sealing of entrances and exits, to prevent water infiltration or wastewater leakage.

In Chart 1 we summarize the limiting factors of the Amazonian varzea regarding wastewater treatment technologies.

As is shown on Table 1, wastewater treatment by soil infiltration and surface runoff remove all the pollutants mentioned above with great efficiency, and are appropriate in almost every respect. However, as reported on Chart 1, these technologies demand relatively large areas, both stable and at a distance from the water table, which renders their use infeasible in the varzea, due to its fluviometric regime. The same applies for stabilization ponds, that could be rendered appropriate if not for the need for dry areas.

Most wastewater treatment technologies present barriers for the use in communities of the Amazonian varzea. Biological filters, in spite of not requiring sophisticated equipments or electricity, demand dry areas, qualified workforce and also have high implementation costs.

Treatment by activated sludge and submerged aerated biofilter, which has high efficiency and is widely used internationally, has greater restrictions for use in the varzea: it presents all the limiting characteristics, and thus is inappropriate.

The process of treatment by biodiscs, despite being relatively simple, presents high costs for implantation, mainly related to the acquisition of the discs, which are provided by specialized companies.

Among the alternatives presented in Chart 1, those which demonstrated fewer limitations, and thus which are most suited, are the UASB type reactors and septic tanks + anaerobic filters. Because they are anaerobic, both systems have the advantage of presenting low costs for implantation

Treatment technology	Limiting characteristics of the wastewater treatment technologies						
	Applicable to collective treatment	Demands dry area for construction	Need for sophisticated equipments	Need for electricity	Qualified workforce for operation	Need for full treatment of sludge	High implantation cost
Facultative ponds							
Anaerobic ponds							
Aerated ponds							
Ponds in series							
Slow rate infiltration							
Rate rapid rate infiltration							
Overland flow							
Constructed Wetlands							
Septic tanks + Anaerobic reactors							
UASB reactors							
Aerobic reactors with suspended biomass							
Biological filter – low load							
Biological filter – high load							
Aerobic reactors with attached biomass – Submerged aerobic filter							
Aerobic reactors with attached biomass – Biodiscs							

Chart 1 – Limiting characteristics of wastewater treatment technologies for the Amazonas' varzea

and operation, tolerating effluents concentrated in organic matter and generating small amounts of sludge. The wetlands can also be used for complementary treatment of effluents from anaerobic reactors. The combination of septic tank + wetland is an alternative for the treatment of wastewater from single families, a set of residences or small communities that have large areas for the implantation of the system, according to Philippi et al. (2007).

Between septic tanks combined with anaerobic filters and UASB type reactors, the first should be prioritized, given their practicality in terms of installation and on account of being widespread in areas deprived of wastewater collecting systems or with relatively low outflow. The UASB type reactors, despite being constantly efficient and compact in size, are sensitive to the variations in organic loads.

In addition, the correct functioning of the UASB type reactor depends on its affluent flow, because the flow speed through the biological sludge is responsible for keeping it in suspension (CHERNICHARO et at., 2006). Therefore, the reactor would not have a good performance in single-family wastewater treatment, because the water consumption in these households is not constant, as it suffers great variations over the couse of the day. In order to ease the flow variation it would be necessary to build an equalizing unit, which would increase the costs and the complexity of the treatment.

Septic tanks and anaerobic filters, being very traditional and widespread across the country, have very specific rules for their construction (ABNT NBR 7229/1993 and ABNT NBR 13969/1997). These regulations include recommendations on minimal sizes, input and output devices, and so on. We show a schematic drawing of a combined system of septic tank and anaerobic filter in diagram 1.

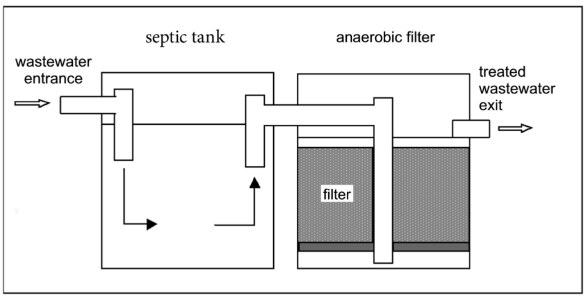

Diagram 1 – Schematic drawing of a wastewater treatment system with septic tank and anaerobic filter.

To comply with all items of the regulations, however, presents entails many construction difficulties in a floodable environment. The main issues are the requirement of at least 1.25 m^3 for the usable volume of the septic tank, and 1.0 m^3 for the filter bed. Considering the need for floating or aerial (suspended) platforms for the installation of treatment units (as well as for the construction of residences), the greater the volume of these units, the greater the difficulties and costs. In order to adapt the system to the characteristics of the varzea, we suggest a reduction in size of treatment units to values that do not hinder the biological process and the hydraulic detention time.

Furthermore, in the case of aerial structures, it is necessary to predict the highest level that the water may reach during the river flood for a period of 10 years or more, thus preventing the total submersion of the treatment system, be it a septic tank + anaerobic filter or a wetland arrangement. The choice of construction site for the treatment facilities must also consider the risk of landslides, locally called “fallen land” (ALENCAR, 2002).

Regarding the choice of media for the anaerobic filter, the support materials of the wetland and its planted vegetable species, one should prioritize those available within the region, considering the desirable characteristics, that are specified in the literature.

For the anaerobic filter, for instance, the filtering material should have low reactivity, uniform granulometry and a size between 38 and 76 mm. The regulations recommend the use of gravel no. 4, which is difficult to acquire in the region. The use of other viable options, such as taboca (which includes several species of regional bamboo), broken brick, waste construction materials and pebble, are sugested to provided the aforementioned characteristics.

In addition to the adoption of wastewater treatment technologies, it is necessary to give special attention to maintaining of these systems. Only under appropriate conditions of use these technologies will provide the desired efficiency.

CONCLUSIONS

In the use of wastewater treatment technologies we must consider the realities and conditions of a region, taking into account criteria such as the complexity of construction of the technology, the type of system operation, the costs of implantation, maintenance and operation. Due to the need for dry area + stable soil, most wastewater treatment systems can not be implemented in the varzea. This is the main limiting factor for this environment.

After analyzing the limiting factors of the varzea regarding the application of the technologies we discussed, we conclude that the arrangements Septic Tank + Anaerobic Filter and Septic Tank + Wetland are most appropriate to perform the depuration of domestic wastewater in areas of the Amazonas' varzea. In addition to wastewater treatment systems with these technologies, we must seek a method of reducing the pathogenic organisms (disinfection) prior to the discharge of effluents into the natural environment.
Given this, we recommended further studies on these technologies in order to promote the necessary adaptations for this specific environment and to evaluate in detail their performance, considering the noted regional characteristics.

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