Modern Environmental Science and Engineering (ISSN 2333-2581)
April 2022, Volume 8, No. 4, pp. 252-256
Doi: 10.15341/mese(2333-2581)/04.08.2022/006
Academic Star Publishing Company, 2022
www.academicstar.us

Feasibility Analysis of the Utilization of Constructed Wetlands in Small High-Andean Urban Agglomerations

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Abstract: This article shows the results of bibliographic and documentary research and an in-situ visit to the treatment plants of small populations around the circunlacustrine ring of Lake Titicaca; with the aim of carrying out a feasibility analysis of the utilization and exploitation of artificial wetlands (wetlands) as an alternative for the domestic wastewater treatment of small urban agglomerations in high-Andean areas. From the visit to the thirteen localities and fourteen treatment plants, it was observed that in six of them, they just have stabilization ponds, and without maintenance, and eight have biological filter treatments and from these, just three have some maintenance, that is why the great majority is practically abandoned. In addition, they do not have an energy supply and they have sloping orographic conditions, as far as there is a great potential of eleven treatment plants, for the extensive technologies implementation (artificial wetlands), thereby reducing the discharge of wastewater without any treatment to the Lake Titicaca.

Key words: constructed wetlands (CW), artificial wetlands, wastewater

1. Introduction

Constructed Wetlands (CW) are man-made wetlands that treat organic, inorganic pollutants and excess nutrient in surface water, municipal wastewater, domestic wastewater, refinery effluent, uranium acid mine drainage, or landfill leachate [1], using biological processes that involve wetland vegetation, soils and their associated microbiota [2]. The CW for wastewater treatment can be classified according to the dominant vascular plant life forms and the water flow regime (Fig. 1) [3]. CW can still be classified according to the dominant macrophyte life form into floating macrophytes, floating leaves, emergent, and submerged. CW with emerging macrophytes is the most widely used system [4].

Surface flow systems are those where water preferentially circulates through the plants' stems and are directly exposed to the atmosphere (Fig. 2). This type of wetlands is a modification to the conventional lagoon system. Unlike these, they are shallower (no more than 0.6 m) and have plants [5].

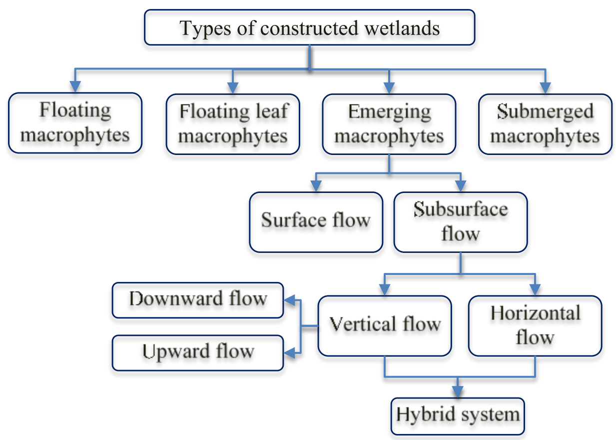

Fig. 1 Constructed wetlands classification for wastewater treatment based on dominant vascular plant life forms and water flow regime [17]. Types of constructed wetlands for wastewater treatment: their potential for nutrient removal. Transformations of nutrients in constructed natural and constructed wetlands.

In constructed subsurface flow wetlands, wastewater flows horizontally (vertically in some applications) through a porous medium consisting of a bed of washed gravel (characteristic gravel dimension: 2-10

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mm; bed height: 0.60-0.90 m) with a topsoil cover (Fig. 3). The bottom of the gravel bed slopes slightly (about 1-3%) in the direction of flow to facilitate water flow, while the water level is kept 0.05-0.10 m below the top of the bed. gravel. The incoming wastewater is distributed in the porous medium as evenly as possible. The treatment is based on both physical (filtration and sedimentation) and biochemical principles [6].

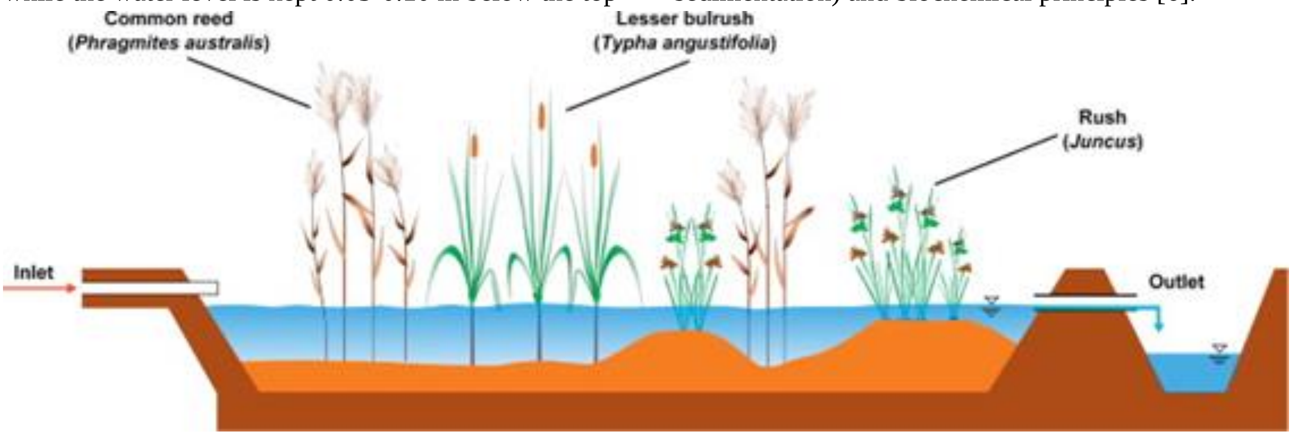

Fig. 2 Surface flow artificial wetland of free-water using rooted emergent macrophytes [18].

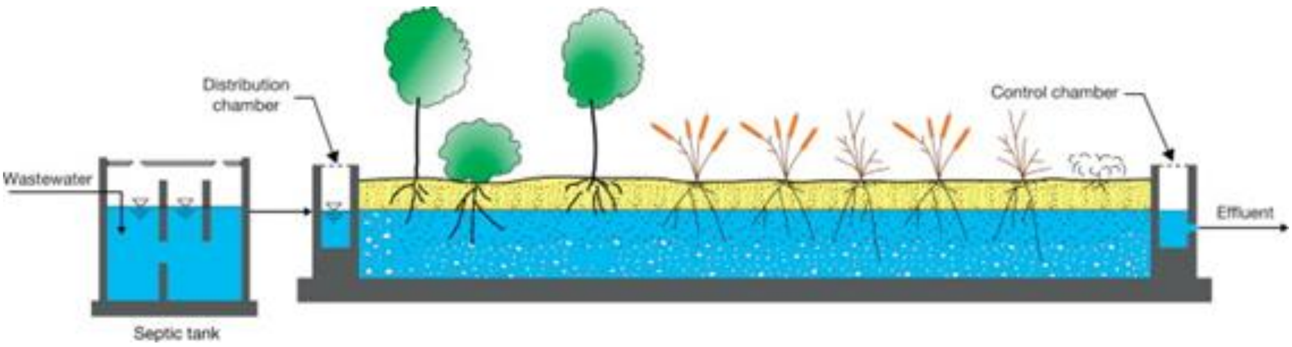

Fig. 3 Artificial subsurface flow wetland [18].

Constructed wetland application is more appropriate and beneficial in decentralized wastewater treatment in cities and small rural areas, as well as for slightly polluted waters of rivers and lakes due to the low costs of construction, operation, and maintenance [7].

Lake Titicaca is the largest freshwater lake in South America and the highest commercially navigable body of water in the world [8]. This large water mirror is within an endorheic basin and receives effluents from 25 rivers, the principal it is being the Ramis river of 14,700 km^2, on the other hand, Desaguadero river of 29,843 km^2 as an outward flow from the Lake Titicaca [9]. Unfortunately, the human activities development has generated a little-studied pollution process for some time, but that, without doubts, is causing some type of decrease in the water quality in the basin (rivers and the lake itself), this due to the discharge of its wastewater [10]. Because of the water contamination of the Titicaca basin, the Peruvian state with the help of private investment will launch the execution of the design, construction, expansion, rehabilitation, operation, and maintenance of six new treatment plants and the operation and maintenance of four plants already installed in the Titicaca basin [11]. These plants do not consider small urban agglomerations, whereof it is necessary the intervention through technologies that do not require more investment from the state. That is why, the review and updating of the technology called “artificial wetlands” were seen pertinent to be applied in small urban agglomerations near Lake Titicaca, in addition to identifying the potentialities of its implementation in conditions such as those found in the highlands of Puno.

2. Methodology

The research has a quantitative approach, inductive method, non-experimental design. It is transectional. Basic investigation. Descriptive. The population is the same as the sample. It was done next Protocol where the following activities are carried out: First phase: Documentary compilation, (1) Investigations carried out that demonstrate the pollution of Lake Titicaca (2) Investigations on Wastewater Treatment Plants. (3) Coordination with authorities for technical field visits and interviews with Operators/Technicians in charge of the Domestic Wastewater Treatment Plants (DWWTP). (4) Preparation of the instrument, formulary. (5) List of Plants. (6) Control sheets of the number of plants visited. (7) Daily tour schedule. (8) Record of photos and filming of the state of the PTARD. The population is the 14 Domestic Wastewater Treatment Plants, and the sample is equal to the population, as it requires the investigation of the total universe, in order to, individually specify the problems of each one of the DWWTP.

3. Results and Discussion

The obtained results are the summary of the in-situ observation of the fourteen treatment plants belonging to thirteen localities (Huata, Capachica, Samán, Taraco, Chupa, Zepita, Juli, Acora, Laraqueri, Chucuito, Pomata, Tilali, and Conima), located in the circunlacustrine ring of Lake Titicaca and they are outside the project of “Wastewater Treatment System PTAR Titicaca”.

In the access to the treatment plants, it is observed that 9 of them are near the urban area, so they can be accessed on foot and 5 of them require the use of a vehicle as they are far from the urban area.

In the treatment system that they have, it was observed that 8 treatment plants have small biological filter plants, and 6 only have stabilization ponds.

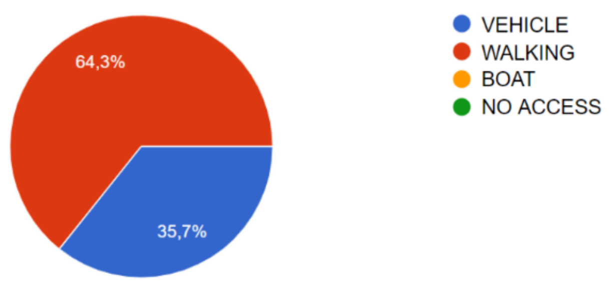

Fig. 4 Access to treatment plants.

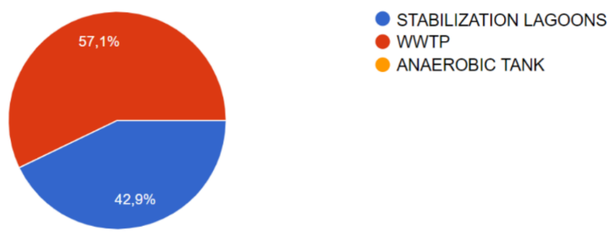

Fig. 5 Current treatment system

For the current conditions of the treatment plants, 3 were valued as “good”, 3 as “regular”, 6 as “deficient” and 2 as “inoperative”. It evidenced to more than 79.6% require immediate intervention.

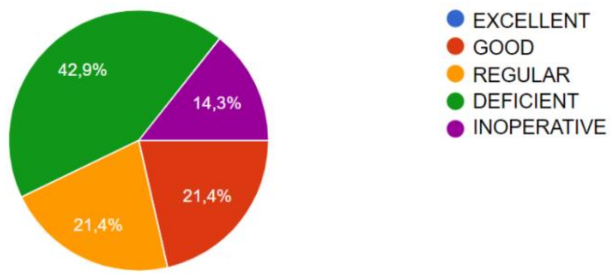

Fig. 6 Conditions of the treatment system.

The final discharge after the treatment of these waters, in 12 they are discharged to bodies of water such as rivers and lakes, and only in 2, the discharge is on the ground.

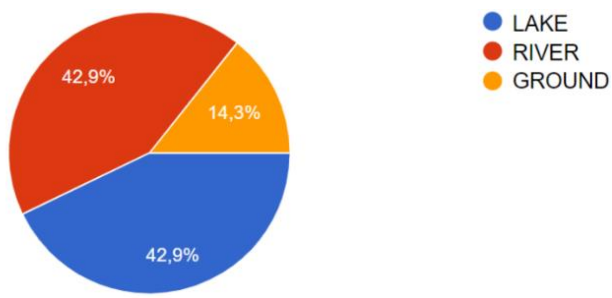

Fig. 7 Final discharge of wastewater.

Regarding the orography where the treatment plants are located, in 10 of them, they were valued as having a good and regular slope, and only in 4 as unfavorable.

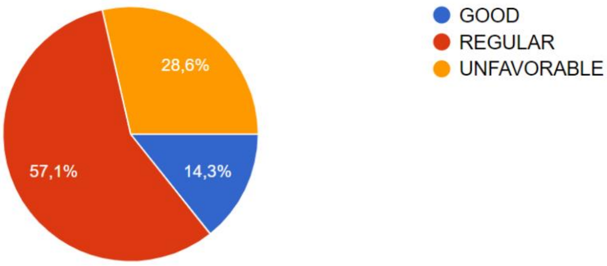

Fig. 8 The orography of the location of the treatment plants.

In 10 treatment plants they do not have an energy supply, and only in 4 treatment plants have an energy supply. All shows that implement conventional treatment plants, would have greater difficulty.

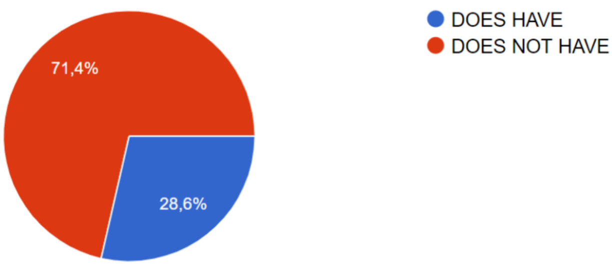

Fig. 9 The orography of the location of the treatment plants.

According to these results observed in these visits, they show us that it very likely the implementation of technologies such as "artificial wetlands", since artificial wetlands are an eco-technological alternative for the treatment of all types of water. They are designed to overcome the disadvantages of the natural wetlands and enhance their qualities since they can treat several types of pollutants simultaneously to satisfactory levels compared to other conventional treatment systems [12, 13].

Even though there are many discrepancies regarding the wetlands functioning of different aspects: dimensioning, operation, etc., including the purification capacity of the implanted species. Several authors affirm that the obtained results with the use of photosystems are better than those obtained with the same system, but without plants. Stearman et al. (2003) [14] report a reduction of pollutants in general, furthermore 20% in implanted wetlands compared to non-implanted ones. Additionally, the purifying potential of wetlands varies seasonally. This can be explained both by simple meteorological variations and by changes in the physiology of plants. Soto et al. (1999) [15] report that the activity of the plant increases in summer, therefore its capacity to treat various factors (removal of phosphorus, phosphates, and nitrogen). Zúñiga et al. (2004) [16] also reported a strong variation in the removal of ammonia and phosphorus between spring and winter, with better results in planted wetlands than in wetlands without plants.

4. Conclusions

This investigation identified 13 localities with 14 wastewater treatment systems, located in the circunlacustrine ring of Lake Titicaca, who are not considered in the Project of "Wastewater Treatment System PTAR Titicaca". localities whose water treatment systems wastewater shows deficiency because only 21.4% have adequate operating conditions for wastewater treatment, and more than 78% of the identified wastewater treatment systems need of immediate intervention; likewise, it was identified that the 86% of the final discharge from wastewater treatment reaches to the Lake Titicaca, directly or indirectly. Therefore, it is concluded that 11 of the 14 Wastewater Treatment Systems can implement Artificial Wetland Systems for Wastewater Treatment.

Wetlands are an alternative for the treatment of domestic wastewater for small urban agglomerations, where economic conditions are decisive when launching the type of wastewater treatment, therefore the design models must be adapted to local conditions and analyze the behavior of the different design and operating factors involved, among the most outstanding, are temperature, slope, terrain, vegetation.

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