Alternative for an environmental improvement in domestic waste water treatment: The Case of the oxidation ponds at the Universidad de Piura - Perú

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Summary

The purpose of the research was to compare the improvement of water quality from an effluent by applying a phytodepuration system such as the floating macrophytes filter (FMF) with respect to a facultative system (conventional). For the purpose of facing environmental and health issues that suffer neighboring populations to waste water treatment plants in the north of Peru due to their low efficiency in the treatment (under minimum quality standards). The results show substantial improvements on the efficiency in waste water treatment by the FMF system.

Introduction

Currently in Peru, the quality of different water bodies has been reduced by different factors, among them the low level of sanitation. This low level can be characterized by a poor development of hydraulic infrastructure or deficiencies in the operation and maintenance of treatment plants (PTAR). A report from SUNASS by 2009 made known as an approximate volume of waste water in Peru the amount of 786’379,599 m^3, been treated water only 35%, many times with a deficient operation and maintenance (SUNASS, 2009). The other 65% was discharged to the water bodies (sea, rivers, lakes), filtrated in the ground or was used secretly for agricultural purpose (FONAM, 2010).

In the Piura region, at the north of Peru, where the oxidation ponds from the Universidad de Piura (UDEP) are located (marked in red in Pic. 1), and where this research is carried out, there are 26 PTARs, a 74% has the agricultural use as final disposition.

Figure 1 shows 6 of the 26 PTAR, located around the city of Piura. We see that their location is within the urban city. Picture 1 and 2 show clearly how the population is very close to two ponds (< 100 m) despite the Peruvian regulation indicates that the facultative ponds most be located at no less than 200 m (RNE 2006). The proximity of the waste water treatment ponds to the population, together with the low efficiency in the treatment of those waters, constitutes a danger for the public health of those populations (risk from parasite, viral and bacterial infection). Table 1 shows some of the health problems these populations suffer with, and which are directly related to the low efficiency in treating water from the effluents from the ponds.

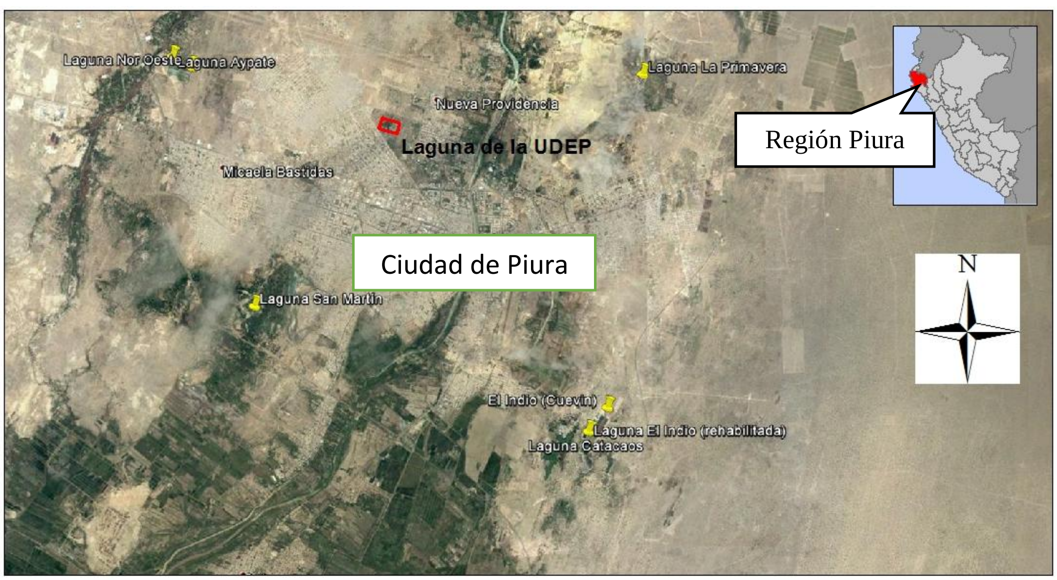


Fig. 1 Location map of the 6 PTAR in the Piura Region.

Picture 1 and 2: The populations has settled very close to the oxidation ponds.

Table 1 Morbidity causes in general population by external consultation by two health care facilities at nearby locations to oxidation ponds.

	Epidemiological profile	**Nva Esperanza**	**El Indio**
Nº	**MORBIDITY CAUSES**	**Cases**	**Cases**
1	Upper respiratory pathways infections	2540	3562
2	Oral cavity diseases from the salivary glands and from the jaws	1089	1574
3	Other diseases from the urinary system	592	808
4	Intestinal infectious diseases	493	892

Source: Self-made from health care facilities from El Indio and Nueva Esperanza

The Agency for Environmental Assessment and Enforcement (OEFA) is an specialized technical public agency attached to the Ministry of Environment. Figure 2. In January 2016, a supervision was performed considering complaints submitted by citizens from the department of Piura, and verified that nine oxidation ponds, in charge by the Provincial Municipality of Piura and managed by the Entidad Prestadora de Servicios de Saneamiento Grau – EPS GRAU (Sanitation Service Provider Grau – EPS GRAU) do not receive an appropriate maintenance, producing a high environmental and health risk for the nearby populations.

Fig. 2: Press release

For the purpose of finding a solution to the problem of low efficiency in treating current waste water treatment ponds allowing reducing environmental and health problems generated by that efficiency, this research was performed, whose purpose was comparing quality improvement of water from an effluent by applying a phytodepuration system such as the floating macrophytes filter (FMF) with respect to a facultative system (conventional).
This research is located within the project “Optimization in wastewater treatment of household, to reduce environmental health problems of community nearby; gaps caused by oxidation in the Piura region, through a phytodepuration process, with a macrophytes filtering system”, which was financed by FONDECYT-Perú and Grand Challenges Canadá according to the Grant Agreement Nº 045-2014.

The study was performed at the existing oxidation pond at the Universidad de Piura (UDEP), Perú.

Objective

The purpose of this research is the assessment of including a macrophytes system (FMF) in ponds currently with efficiency problems, such as is the case of the secondary pond of the UDEP, and to know the improvements generated in the water quality and the environment (environmental and health). The interest is to be able to obtain an alternative that may be replicated in PTAR from the region to help improving environmental and health problems currently affecting the neighboring population to those systems.

Methodology

The methodology developed in this research consists on the installation of a macrophytes filtering system (FMF) in the second oxidation pond of the Universidad de Piura.

a. The treatment system at the Universidad de Piura

The UDEP treatment system occupies an area of approximately 3.5 ha from the UDEP campus, and currently is comprised by two facultative ponds placed in series. The effluent that enters into the system, pumped by the Vicus Chamber managed by EPS GRAU, is prepared through a pretreatment unit that has a sand removal and an inclined grille that acts as a screening

Dimensions and pond operation data are shown in Tables 2 and 3. The operation data are from 2004. Also, with respect to operation levels, in 2014 a topographic survey was carried out where the level of the primary pond of 2.3m and the secondary of 1.5 m were indicated.

Table 2. Dimensions of the ponds.

Pond	Larger area m^2	Smaller area m^2	Depth m	Slope inclination (v : h)
Primary	74.80 x 72.60	59.20 x 57.00	2.60	1:3
Secondary	85.20 x 84.30	73.20 x 72.30	2.00	1:3

Source: (Silva Burga, 2004)

Table 3. Operation data from the ponds.

Pond	Average volume m^3	Average depth m
Primary	9494	2.25
Secondary	9975	1.65

Source: (Silva Burga, 2004)

The UDEP stabilization ponds are surrounded in U shape by a natural curtain comprised by a population of approximately 496 Tamarix (*Tamarix gallica*) trees. This living fence has a strategic location with regards to the winds acting as a tramp for eolic sand which obeys the direction of trade winds (from southeast to northwest). This way, we avoid the waiving of the water mirror and therefore the erosion of the slopes. Also, the fence helps preventing the proliferation of bad odors if there was the case.

The system effluent is reused for irrigation of a high stalk tree forest. Among the tree ecosystem present, currently there are approximately 550 Nim trees (*Azaderachta indica*), 132 Tamarind trees (*Tamarindus indica*) and in tiny proportions other species such as Palo verde (green stick) (*Parkinsonia aculeata)*, Charán

(*Caesalpinea paipai)*, Sapote (Sapota) (*Capparis angulata)*, Aromo (*Acacia macrocantha)* y cactus trees.

b. The FMF system at UDEP ponds

The phytoremediation or phytopurification can be defined as the set of methods to break down, assimilate, metabolize or detoxify heavy metals and organic compounds by using the plants.

The phytodepuration with aquatic plants occurs naturally in ecosystems that get poluted wáter and, together with the so called self-depuration of waters, has been the classic procedure for recovering water quality. This process occurs both in natural wetlands as in artificial (created by men). The most generalized definition for the phytodepuration refers to the phytodepuration of polluted waters by superior plants (macrophytes) (Fernández et al. 2010). This purifying system allows performing efficient, ecological and low cost of realization and minimum maintenance purification for any population size, without energy consumption, mud management nor bad odors generation (Rey Quintana et al. 2010).

In the phytodepuration, the oxygen necessary for phytodepuration of water is provided by the plants themselves.

For the implementation of this system, it has been necessary to perform previous activities allowing later inclusion of the FMF systems. These activities are briefly described as follows:

a. **Division of the pond:** For the purpose of comparing the improvements in water quality between a conventional system and a system where the FMF system has been implemented, we divided the secondary pond in two sectors. In the first sector, we kept the same conditions of the facultative pond and in the second one, we provided the conditions of the system proposed with the FMF. We observe in Pic. 3a the two sectors. In the FMF sector, the macrophytes system covered 16% of the water mirror (green color area).

b. **Flow homogenization:** The purpose was to obtain that the two sectors in which the secondary pond has been divided work under a similar hydraulic regime. The flow homogenization as achieved by installing 10 4" diameter PVC pipping and the entrance and exit of the second pond (Pic. 3b). For regulating the flow in each of the entry pipping, at the end of these pipes elbow pipes were installed tan when turning them allowed achieving a same flow in all of them. With respect to the exit, the pipes pour their flow into a cannel excavated and covered with a geomembrane which is conected to the exit structure by a 4" PVC pipe. Just like the entry, the exit piping were connected with elbow pipes at the end of these to regulate their flows.

c. **Perimeter step:** Its purpose was to raise the depth level at the FMF sector (green color area), so that the roots of the macrophytes are in contact with all the step of water. This way, the flows finds resistance when flowing through the roots obtaining a greater phytodepuration in that sector (Figure 3a).

d. **Implementation of the macrophytes system (FMF):** For the implementation of this system, three activities were performed: 1) Selection and gathering of the species *Typha angustifolia* species, native from the region. 2) Planting and growth of that plant in a nurse close to the pond where this study is carried out. When the pants reached 20 to 25 cm of height (aprox. 90 days), they were transplanted to the filter supports. 3) Assembling of the FMF system. For the assembling, we worked with pieces of low density polypropylene (Figure 4). These pieces presented a weight of 600 gr/und, a density of 0.9 gr/cm3 and measuring 72cm*60cm*10 cm. These pieces were getting together until obtaining a mesh that covered the sector proposed for the implementation of the FMF system. Inside each piece, a plant was transplanted (*Typha angustifolia).*

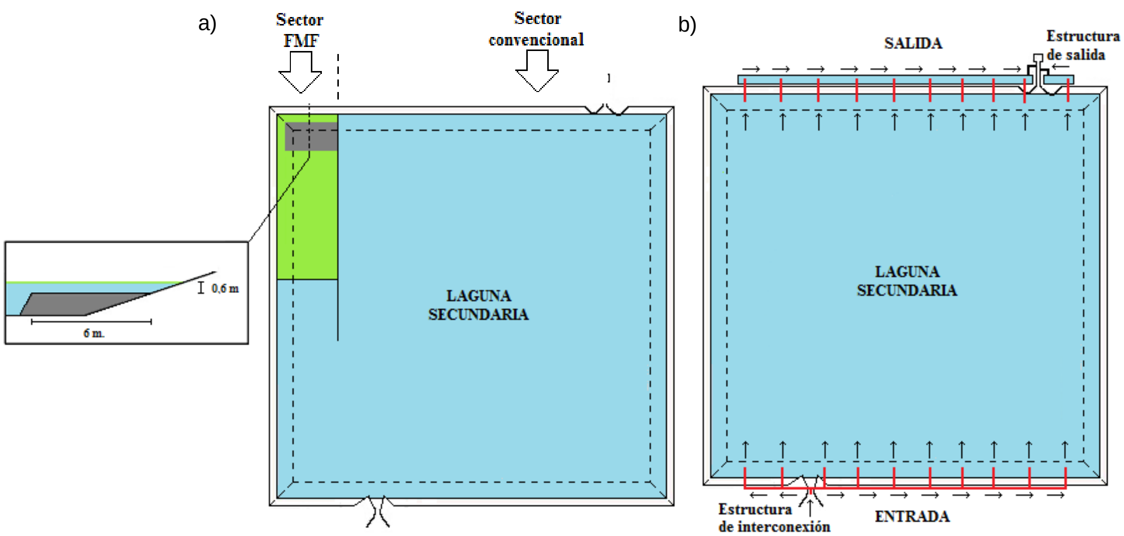


fig. 3. The Picture on the left (a) shows the division of the secondary pond in two sectors, as well as the perimeter step. The Picture on the right (b) shows the homogenization of the flow
Source: Self-made

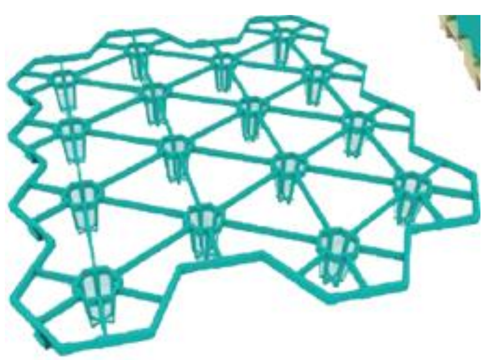


Fig. 4. Picture of the plastic piece

e. **Selecting the parameters to be evaluated:** For the purpose of been able to compare the improvements in applying an FMF system with respect to a conventional system, 8 parameters were selected to assess in the water quality: total suspended solids (STS), biochemical demand of oxygen after 5 days (DBO5), chemical demand of oxygen (DQ5), total nitrogen, total phosphorus and fecal coliforms, conductivity and pH.
To compare the values of these 8 parameters, both in the conventional system as well as in the sector where the FMF system has been installed, 3 sampling points were defined. The first one corresponds to the affluent that enters into the secondary pond (M1); the second corresponds to the effluent coming from the water that leaves from the conventional system (M2), and the third point at the effluent coming from the water that leaves from the system with macrophytes (FMF) (M3) (Figure 5).
The measuring of these parameters was performed every 15 days at the three sampling points for five months.

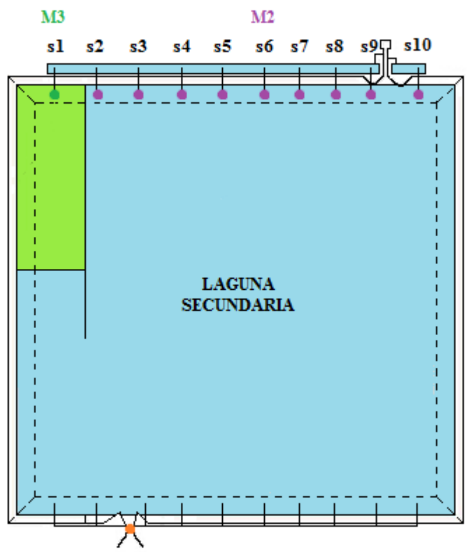
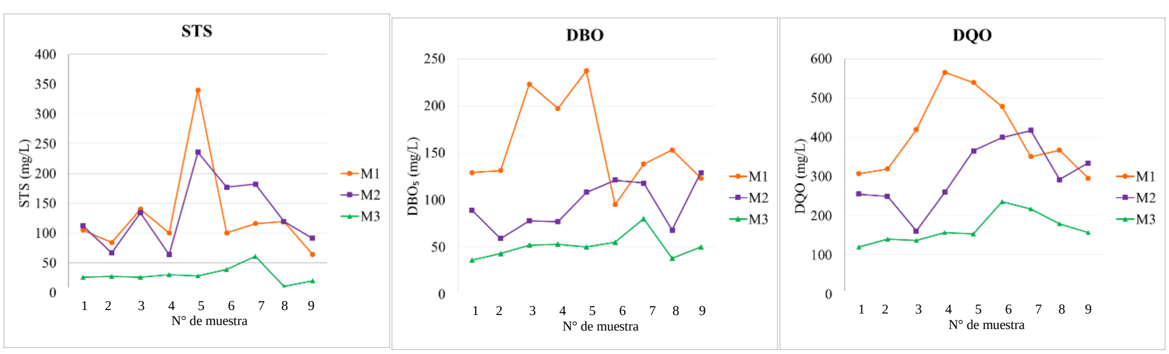


Fig 5. Denomination of exits and sampling points
Source: Self-made

Results and Discussion

The results obtained once the different activities mentioned in the methodology were applied are shown in Figure 6. The results shown correspond to 9 tests performed every fifteen days, during five months.

We observe that the entrance of the organic load into the secondary pond undergoes great variations (M1). Facing this variation in the load, the conventional system (M2) also shows great variations especially under the parameters STS, DBO, DQO and total nitrogen. This behavior generates an effluent with very variable features. To the contrary, we see that under the macrophytes system (FMF) (M3) we obtain a balance facing these variations of the loads, thanks to the filtration process the plants carry out. The results for the ninth sample allow seeing that for the greater number of parameters monitored, the FMF (M3) system allows obtaining much lower values than under the conventional system (M2).
The improvements reached with the FMF (assessment of 8 parameters) system allow obtaining a significant improvement in the water quality of the effluent. This improvement would allow the improvement of three significant aspects today for the population established around these PTAR.
First, we would reduce pollution of different water bodies by receiving effluents with better quality, taking as a baseline the maximum permissible limits from the effluents from PTAR approved by the Peruvian Government, Table 2 (MINAM, 2010). In that table, we see that the five parameters monitored from the seven mentioned in the LMP table are met by the FMF system (M3), which does not happen with the conventional system (M2).
Secondly, we would open the possibility of being able to reforest the surrounding areas to the pond with the effluents, improving landscape aspect of the affected area by the PTAR. In Picture 3, we see the panoramic view of the surroundings from the UDEP pond after years of reforestation. When seeing Figure 1 and Picture 1 y 2, we observe that the surrounding to those ponds are characterized by being surrounded of Sandy soils, having a scarce vegetation.



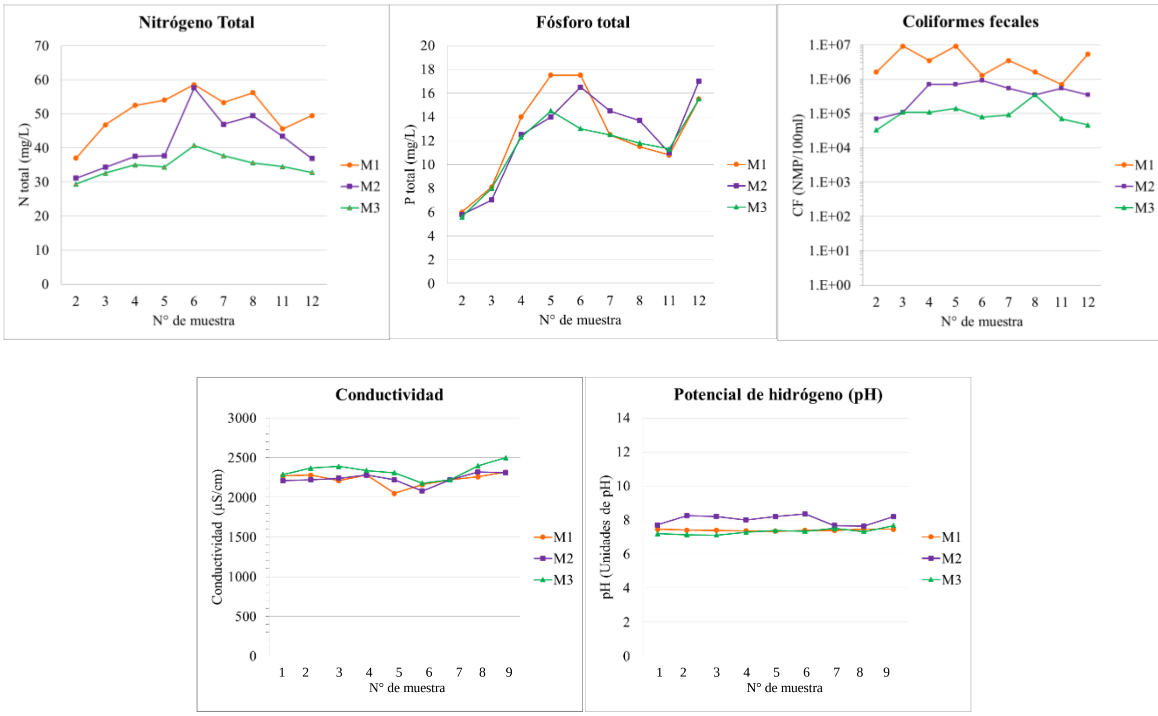


Figure 6. Value of the samplings from the 8 parameters selected at the three sampling points.M1 is the point at the entry of the secondary pond. M2 is the point at the exit of the conventional system. M3 is the sampling point at the exit of the FMF system.
Source: Self-made

Third, pollution reduction from the soil around the PTAR due to the waters from the secondary pond. Currently, it is frequent the pollution of the soils from around the PTAR either by the use of the waters from the PTAR to irrigate neighboring areas, and in other cases, due to the overflowing of them. The pollution of these soils has generated the surrounding populations to breathe these pollutants, and therefore, to suffer from serious problems from the respiratory, stomach and skin system. The reduction on the pollution of the soil, due to having less polluted waters, as well as the aide the reforestation from the area provides, would provide means to reducing these diseases that impact negatively the health and development of the surrounding populations to those infrastructures.

Table 2 Maximum Permissible Limits (LMP) for the effluents of the PTAR poured into water bodies

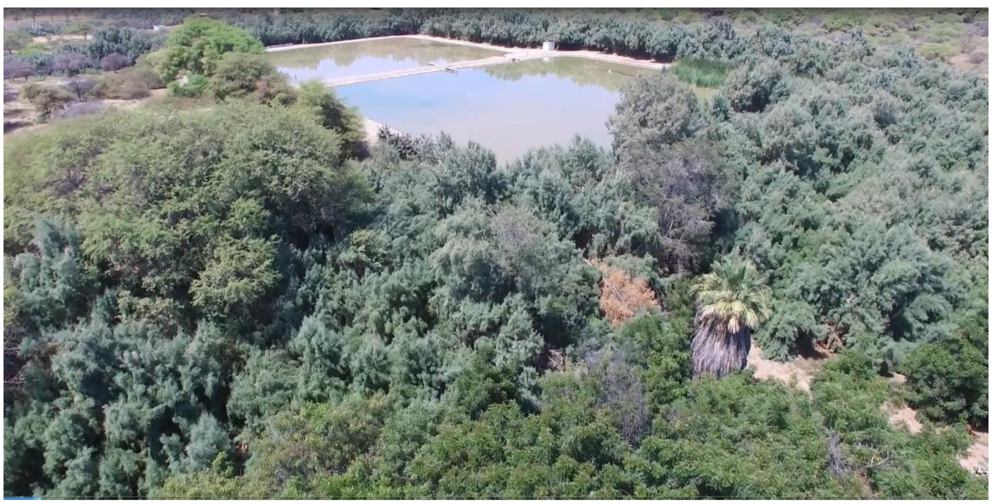
Parameter	Unit	LMP	M2	M3
Oils and fats	mg/L	20	-	-
Thermotolerant Coliforms	NMP/100 mL	10,000	350,000	46,000
Biochemical demand of oxygen	mg/L	100	129	48
Chemical demand of oxygen	mg/L	200	334	157
Ph	unit	6.5-8.5	8.2	7.7
Total solids in suspension	mg/L	150	91	20
Temperature	°C	<35	-	-

Source: MINAM 2010

Complimentary results to the shown that have been able to be obtained from this investigation are the reduction of odors, reduction of mosquitoes, and the creation of a habitat to shelter birds. With regards to the reduction of the odors with respect to a conventional system, even though, they have not been monitored they have been able to be verified when performing the daily field inspections. This is a significant improvement from the social and health standpoint for neighboring populations.

Under the FMF system, we saw a substantial reduction of mosquitoes with regards to the conventional system. The reduction of those insects, especially mosquitoes, is based on the free water mirror of plants. As the pond has greater coverage of plants, mosquitoes would have less place to incubate their eggs. This would positively impact in the population, because disease transmission issues such as a dengue fever, zika would be better contained.

Finally, with regards to the creation of a habitat to shelter birds. When the FMF system was installed and as the macrophytes were growing, we saw the coming of birds to nest. This constitutes a positive point in the landscape improvement.



Picture 3: Panoramic view of the oxidation ponds from the Universidad de Piura (UDEP)

Facing the results, the FMF system would allow improving the efficiency in treatment plants already collapsed from the Piura Region, and would help expanding their lifespan and to reduce environmental pollution and negative effects in the health of the population. An excellent and economic alternative – without electric energy consumption- to improve the adaptability of stabilization ponds before variations of organic load, as well as keeping quality trustworthiness of their effluents. Also, it would transform a conventional pond into a wetland of extraordinary landscape value. However, these results would not be relevant in developing countries such as Peru, if parallel to the investigation policies were not proposed where populations around those ponds work together. The implementation of awareness policies would allow not only the care of those plants by the neighboring populations to those infrastructures, but also to stimulate activities for economic, environmental and health improvement of those populations.

Conclusions

The results from the investigation confirm the substantial improvements on the efficiency of the waste water treatment by the floating macrophytes filtering system (FMF) compared to the minimum improvements obtained with the conventional treatment.

Added to the improvements obtained by the FMF is the simplicity for the implementation of this system, offering social and environmental advantages, allowing with that being replicated in the different treatment plants from the Piura Region.

For the period of 5 months of testing performed, the FMF system was able to present greater removal efficiency in the parameters analyzed of STS, DBO5, DQO, fecal coliforms, total nitrogen and total phosphorus in relation to the conventional treatment system. Also, we saw that the FMF system provides greater resilience capacity. Under this aspect, we conclude that the phytodepuration system is presented as an excellent and economic alternative –without electrical energy consumption- to improve the adaptation of stabilization ponds before the variations of organic load which may end up been harmful to keep their lifespan as well as also keeping quality trustworthiness of their effluents.

From the results obtained with the FMF system, we conclude that they are a valid system that can be designed to improve efficiently the domestic waste water treatment in active stabilization ponds, this way generating effluents that meet with the quality established of the maximum permissible limits avoiding that way environmental and epidemiological pollution.

It is important highlight that the improvements obtained by the FMF system were performed despite the reduced area used (approximately 7% of the area from the second pond) by the system compared to the conventional system. We expect to continue doing studies where the research period allows a greater number of samplings, as well as the application of the FMF in a greater area, with the purpose of observing improvements that may be reached.

Also, we have been able to observe complimentary results such as the reduction of odors, reduction of mosquitoes, and the creation of a habitat to shelter birds. This will allow improving the living conditions of the populations close to the ponds, as well as creating an area of an extraordinary landscaping value.

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