Efficiency of prefabricated biodigesters in the treatment of domestic wastewater in dispersed rural localities

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Abstract. In most developing nations, poor wastewater management continues to be a significant health and environmental concern. In this context, the research seeks to evaluate the efficiency of the biodigester treatment of domestic wastewater through monitoring and evaluation, based on physicochemical and bacterial parameters to reduce environmental pollution caused by excreta in the Chibaya Baja sector, Peru. Water sampling was done in the influent and effluent of the biodigester, taking samples periodically every 15 days, for 01 months, obtaining 03 samples for physicochemical and bacteriological analysis. According to the results obtained from the laboratory, the efficiency of the domestic wastewater treatment was 59.51% of the biochemical oxygen demand (BOD), 49.16% of the chemical oxygen demand (COD), in oils and fats 35.92%, in total suspended solids 52.78% and fecal coliforms (thermotolerant) 89.19%. A comparison of the parameters evaluated with the maximum permissible limits set by the Peruvian Ministry of the Environment reveals that the levels of BOD and COD exceed the limits. Therefore, this wastewater should not be discharged into water bodies.

1 Introduction

Rural sanitation is important because it prevents the generation of infection vectors and groundwater contamination [1,2]. In the world there is a tendency to improve rural household sanitation; however, this progress has been reduced [3]. Untreated wastewater from industrial, agricultural, and domestic sources has become one of the problems with the greatest impact on the environment and socioeconomic development of the country [4]. Wastewater treatment is a fundamental activity that contributes to the care of human health and the environment [5]. The inadequate disposal of wastewater and excreta are the most serious problems in rural areas [6]; in addition, in our country, there is a high incidence of diarrheal diseases and others related to the consumption of contaminated water and food, poor hygiene, and inadequately disposed of untreated wastewater [7].

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Within the framework of compliance with the sustainable development objectives, the adequate treatment of wastewater is discussed, in the context of recent investments made, mainly in rural areas [8,9].

In Peru, in recent years, rural sanitation infrastructure has been built based on a sanitary disposal system for excreta and domestic wastewater treatment with prefabricated biodigesters (improved septic tanks), without knowing the real efficiency of treatment in the environmental conditions of rural areas.

Ecotechnological solutions such as biodigesters must be integrated into the population so that they have greater acceptance as an alternative use [10]. An important mode of final disposal of excreta was studied by Saraz et al. [11] finding removals of 97.4%, 96.1%, and 95.1% for BOD, COD, and TSS, with the use of GTZ fixed dome biodigesters and a Taiwan type under cold weather conditions. Likewise, the management of cattle excreta can be carried out through the use of biodigesters [12].

This paper aims to determine the efficiency of the prefabricated biodigester through an evaluation of the treatment of domestic wastewater, in the town of Chibaya Baja, Peru.

2 Materials and Methods

2.1 Study area

The present investigation was carried out in the Chibaya Baja annex, Torata district, Moquegua region, whose geographical coordinates are 17°7'50" south latitude, 70°50' west longitude, at an altitude of 2020.0 masl (see Fig. 1). In this area, the system of basic sanitation units with prefabricated biodigesters have been implemented for the treatment of domestic wastewater typical of rural areas in the southern region of Peru. However, in recent years these have more frequently presented environmental problems, which could affect the activities of nearby populations and the local economy of the rural population.

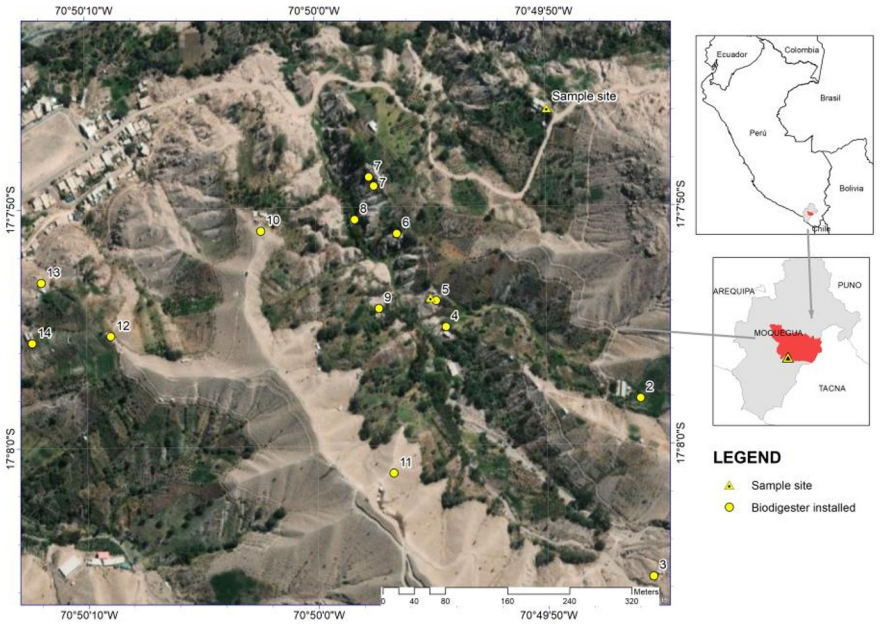

Fig. 1. Location of the research area.

2.2 Methodology

2.2.1 Information collection

To determine the treatment efficiency of the domestic wastewater, initially, samples were taken by the simple sampling method in the influent and effluent of the randomly selected biodigesters. That is, it has been considered that each individual in a population has the same possibility of being chosen [13], in which 06 samples were collected, 02 samples per sampling date in the influent and effluent every 15 days during a more critical month, where temperatures are lower during the year (Fig. 2).

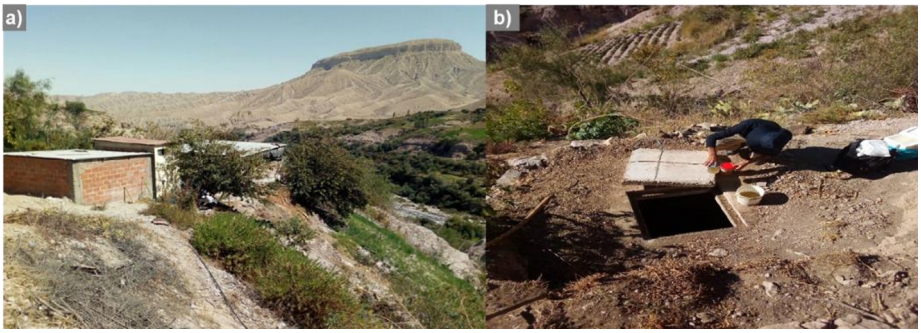

Fig. 2. a) General view of the house for sampling Chibaya Baja b) Sampling of residual water in biodigester tank.

The equipment and tools used for field work were: Garmin GPS, linear motorcycle, survey and observation data sheets, environmental thermometer, PET containers for collecting samples of domestic wastewater, laboratory supplies, and a cooler. Office materials such as computers, printers, and USB memory were used.

2.2.2 Wastewater characterization

The pH, temperature, electrical conductivity and total suspended solids were determined in situ with the Hanna Instruments model HI9829 multiparameter meter.

The concentration of fats and oils was determined by the Soxhlet extraction method, by gravimetrically determining the substances that were extracted with hexane from an acidified aqueous sample. The determination of BOD consisted of an initial and a final measurement of dissolved oxygen, after five days of incubation at 20ºC, and the result was expressed in milligrams of oxygen consumed per liter of sample, using the electrometric method. The COD was determined by the dichromate method, during digestion with chromic acid from the difference between the dichromate initially added and the dichromate found after oxidation of the organic load in the wastewater present in biodigesters. The presence of thermotolerant organisms was determined after incubating the tubes with EC broth or with re-seeded bright green bile lactose broth at a temperature of 44.5 °C ± 0.2 °C for 24 h ± 2 h and examining the gas production; these analyses were performed at the laboratory.

The physicochemical analysis was performed in the quality control laboratory of the Faculty of Chemical Engineering and the bacteriological analysis was performed in the microbiology laboratory of the Faculty of Biology of the Universidad Nacional del Altiplano. They were processed using the different techniques and standardized procedures adopted by these laboratories [14], then the data were processed using existing software once ordered, systematized, and classified for subsequent presentation in tables and figures, then proceed to analyze and describe.

The evaluation of the removal efficiency involves the percentage removal rate (%R) as the capacity of each test specimen to remove part of the concentration of a specific pollutant present in the wastewater. For the estimation of this %R the following equation was used [15]:

$$\%R = \frac{(Cont(i) - Cont(f))\ x\ 100}{Cont(i)} \quad (1)$$

where:
Cont(i) = Initial content
Cont(f)= Final content

The final results obtained through calculations have been compared with current regulations, which allowed for determining the efficiency of the treatment of domestic wastewater in rural areas.

To determine the level of correct operation and maintenance of the basic sanitation units, a survey has been applied to the beneficiaries about the knowledge of correct operation and maintenance of the treatment system.

3 Results and discussion

3.1 Physical, chemical, and biological analysis

The verification of the parameters of treated and untreated domestic wastewater was carried out for two brands of recognized manufacturing companies in the market, which they called trademark 1 and trademark 2, and compared the results of the wastewater treated by the biodigester with the efficiency offered. by the manufacturing companies of trademark 1, trademark 2, and standard OS.090 of the National Building Regulations (RNE) [16–18].

Table 1. Comparison of treatment efficiency in the Chibaya Baja sector

Parameter	Unit	Efficiency offered by trademark 1 (%)	Efficiency offered by trademark 2 (%)	Primary sedimentation (Standard OS.090) (%)	Efficiency of the Chibaya Baja biodigester (%)	Valuation
Oils and fats	mg/L	93.0	24.51	---	35.92	Satisfies with trademark 2
Biochemical oxygen demand (BOD)	mg/L	94.0	66.44	25 – 30	56.79	Satisfies with OS.090
Chemical oxygen demand (COD)	MgO_2/L	88.0	46.92	---	49.16	Satisfies with trademark 2
Potential of hydrogen (pH)	pH	---	---	---	---	---
Total suspended solids (TSS)	mg/L	98.0	49.30	40 – 70	52.78	Satisfies with OS.090 and trademark 2
Fecal coliforms (thermotolerant)	NMP/100mL	---	99.56	---	89.19	Does not satisfy with trademark 2
Temperature	°C	---	---	---	---	---

According to Table 1, in oils and fats, the biodigester treatment efficiency only complies with the efficiency offered by the company trademark 2 and does not comply with trademark 1.

For the BOD, the biodigester treatment efficiency complies with the OS.090 standard (primary sedimentation), being considered very good since it exceeds what is established in said standard. The level of treatment of the biodigester does not meet the efficiency offered by the companies that are in the market. While for the COD the biodigester treatment efficiency only complies with the efficiency offered by the trademark 2 company and the OS.090 standard does not indicate what value should be taken into account in the primary treatment. For total suspended solids, the treatment efficiency of the biodigester complies with the efficiency offered by the company trademark 2 and considers the efficiency of the biodigester to be good according to the Peruvian standard OS.090. For thermotolerant coliforms, the biodigester treatment efficiency does not meet the efficiency offered by the trademark 2 company, however, the trademark 1 company and the OS.090 standard do not mention a referential value; likewise, for pH and temperature, the companies that offer their products and the Peruvian standard OS.090 do not establish a referential value.

3.2 Comparison of physical-chemical and bacteriological parameters with maximum permissible limits

Table 2 shows a comparison of the effluent with D.S. 003-2010-MINAM, showing that the BOD and COD parameters do not comply with the Maximum Permissible Limits (LMP). Therefore, the domestic wastewater treated by the biodigester cannot be discharged directly into bodies of water (rivers, lakes, groundwater, etc.) in the Chibaya Baja sector. However, parameters such as oil and grease, hydrogen potential, total suspended solids, thermotolerant coliforms, and temperature comply with the maximum permissible limits.

Table 2. Evaluation of compliance with physical-chemical and bacteriological parameters

Parameter	Unit	Influent	Effluent	D.S. 003-2010-MINAM	LMP Compliance
Oils and fats	mg/L	11.60	7.43	20.00	Yes
Biochemical oxygen demand (BOD)	mg/L	379.60	164.03	100.00	No
Chemical oxygen demand (COD)	MgO_2/L	810.33	412.00	200.00	No
Potential of hydrogen (pH)	pH	7.87	7.4	6.5-8.5	Yes
Total suspended solids (TSS)	mg/L	179.30	84.67	150.00	Yes
Fecal coliforms (thermotolerant)	NMP/100 mL	1233.33	133.33	10000.00	Yes
Temperature	°C	21.67	21.33	<35	Yes

The results could be attributed to several variability factors, such as geography, altitude, environmental conditions, installation, materials used in the installation, as well as the characterization of existing domestic wastewater in homes.

3.3 Operation and maintenance of biodigesters

The results of the survey of the beneficiary heads of household, on the correct operation and maintenance of biodigesters, are shown in Table 3.

Table 3. Correct operation and maintenance of your biodigester in the Chibaya Baja sector.

Response	Number of respondents	Percentage (%)
Yes	0	0.0
No	12	100.0
Total	12	100.0

That, 100% of the respondents indicate that they do not know to perform the correct operation and maintenance of the biodigesters, it could be deduced that at least the heads of household did not receive the training or those who executed the project did not carry out the training. According to Zuin et al. [3], a change in the behavior of the population is required to generate demand and use of sanitation facilities. The State seeks the participation of the beneficiary population at the community level in operation and maintenance, because water and sanitation management in rural areas has failed [19], and sustainability problems are a central point of social concern due to the deterioration of water, air and soil quality due to contamination [20].

3.4 Discussion of analyzed data

The results obtained from the treatment of domestic wastewater with biodigesters in the sector of Chibaya Baja at 2020 m.a.s.l. do not comply with the Maximum Permissible Limits, in the parameters of BOD and COD, and at higher altitudes (4560 m.a.s.l.) the efficiency is much lower. Therefore, the domestic wastewater treated by the biodigester is not suitable for discharge into water bodies (rivers, lakes, groundwater, etc.).), if discharged, these waters would increase the contamination of these bodies [21], thus being the main challenge to be faced, more serious than other socioeconomic problems [22], threatening water security, food security, and human health [23], presenting a higher risk of contracting diarrheal disease in people who have frequent contact with contaminated water [24,25].

The results are in agreement with those of other researchers [26], [27], and [28], where they indicate that the wastewater treated by the biodigester does not comply with the Maximum Permissible Limits for effluents in BOD and COD, so it should not be discharged into water bodies according to the results of this paper.

Our research does not agree with the results of Nina [29], who mentions that the removal efficiency of the wastewater treatment system in biodigesters adding biofilters is high for the primary phase, with 71% removal for BOD, 69% COD, 76% of TSS and 87% in fecal coliforms, being above the maximum permissible limits according to D. S. 003-2009-MINAM [30,31], this would be attributed to the operation and maintenance problems of the biodigesters [29].

4 Conclusion

The efficiency of domestic wastewater treatment with biodigesters is determined by the physical, chemical, and bacteriological parameters established by MINAM. The results of the analysis of the wastewater treated by the biodigester in the Chibaya Baja sector were below the manufacturer's specifications; it is also revealed that the parameters studied, such as BOD and COD, do not meet the Maximum Permissible Limits established by MINAM.

Inadequate conduct in the operation and maintenance of the biodigesters could affect the results to reach 100% efficiency, mainly due to a lack of knowledge of the correct operation and maintenance of the biodigester.

More exhaustive studies should be carried out regarding the treatment of domestic wastewater with biodigesters and experimental biodigesters should be installed in different regions of Peru, to evaluate the different parameters that influence the process of domestic wastewater treatment with biodigesters, since at present there is very little information, it is important to take into consideration the altitude above sea level, to have an optimal operation of the biodigester.

Acknowledgments

To the educational fund for the university development of the Universidad Nacional del Altiplano de Puno, for financing the execution of the research.

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