

CARTAGO CASE STUDY: WASTE WATER MANAGEMENT IN RURAL AREAS OF COSTA RICA¹

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ACRONYMS:

ASADAs: Communal Associations Management of Rural Aqueducts.

AyA: National Institute of Aqueducts and Sewers

MinSalud: Ministry of Health of Costa Rica

GAM: Greater Metropolitan Area

SETENA: Environmental Impact Assessment National Secretary

MINAE: Ministry of Environment and Energy

TEC: Technological Institute of Costa Rica

BOD: Biological Oxygen Demand

COD: Chemical Oxygen Demand

INEC: National Institute of Statistics and Census

SMEs: Micro, small and medium-sized enterprises

NPD: Nitrogen-phosphorus detection

ECD: Electron capture detection

1. Background information

Costa Rica has prioritized the provision of drinking water to households in the past years. This attribution has greatly contributed with obtaining very good health indicators in the country. Thus, our country is in third place in the distribution of drinking water in Latin America, (Mora, La comparación en el acceso a saneamiento en Costa Rica con

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respecto a América Latina y Caribe en período 1960-2010, 2011) (Bank, 2017) reaching 98% of the national population.

The Cartago province has a mixture of both urban and rural housing. In the center of the district capitals 90% of the population is concentrated, but in some districts, such as San Isidro del Tejar del Guarco, the rural housing percentage reaches 43%, and in other extreme places like Peralta, Chirripó and Santa Cruz they reach a 100%. In the rural areas, the main productive activities are based on agriculture, livestock and small agroindustry. (INEC, 2016)

At the beginning of the last century, the cities were designed with their respective sanitary sewer systems, but only with only leaving the pipelines for the future connection to the treatment plants. As the cities grew, the use of septic tank as the sole individual treatment of excreta became common and very popular because the local governments stopped investing in wastewater treatment. According to national statistics, the use of septic tanks is estimated at 70,54%. (Silva, 2013)

It is interesting to note how the city of Cartago built the sanitary sewerage back in 1911 and it was later extended in 1962. The Cartago sewage treatment plant was built in 1943 but, these structures no longer exist (Angulo F., 2013). Therefore, at present, untreated wastewater goes directly into rivers and streams, therefore steadily increasing the production of pollution. (Fallas, 2012)

The priority of the country has been focused on the distribution and potabilization of water for human consumption. On the contrary, the management and treatment of wastewater has been neglected, showing serious problems of surface, groundwater and coastal pollution. (García, Acuña-González, Vargas-Zamora, & García-Céspedes, 2006) (Barrantes, Pardo, & Achí, 2004) (Mora, Calidad Sanitaria de las aguas de la playa Jacó, Costa Rica 1986-2008, 2009) This pollution despite there being legislation and regulations for the disposal of wastewater. (Poder Ejecutivo, Costa Rica, 2005)

The largest amount of untreated wastewater in the country is generated in the Greater Metropolitan Area (GAM) where the most important and populated cities of the country are located: San José, Alajuela, Heredia y Cartago (Hidalgo, y otros, 2012).

The Tárcoles and Virilla rivers that cross these cities have one of the most serious pollutions in Central America (Nación, 2007). In the country, 48% of the 27 water treatment plants are abandoned or in poor condition, which implies a direct discharge of untreated wastewater into the rivers. Although 21% of the country's population has access to sewage service, only 4% of the water collected is properly treated. In the country there are only four public sanitary sewerage networks in the center of the principal cities. Many of these networks flow the wastewater directly into the rivers. (Ministerio de Vivienda y Asentamientos Humanos, 2017) (Mora, La comparación en el acceso a saneamiento en Costa Rica con respecto a América Latina y Caribe en período 1960-2010, 2011) (Astorga, 2015),

In the rural areas of the Cartago Province, the volume of wastewaters produced is lower compared to that of the GAM, since there are individual sewage systems with septic tanks and drainage in these rural areas. These individual solutions have often been built in an empirical way. (Dallas, Scheffe, & Goen, 2004). Previous studies have identified high

levels of nitrates that exceed the maximum permissible concentrations in groundwater reaching levels to 10 mg/L in areas with a high density of population. (Reynolds-Vargas, Fraile-Merino, & Hirata, 2006). Moreover, the exact quantities and qualities of greywater discharged in rural areas of the country are unknown.

The National Institute of Aqueducts and Sewers (AyA) is executing the “San Jose Metropolitan Area Environmental Improvement Project”, with economical support from the Japan Government Cooperation, the Inter-American Development Bank, the National Bank of Costa Rica and funds of their own. This project aims to implement a wastewater treatment plant for one million people, (GobiernoCR, 2015), however, this infrastructure will only give service to the GAM.

Moreover, in the city of Cartago, the Municipality of the Central Canton began, in 2016, the construction of a sanitary sewerage with the goal to connect it at some point to a treatment plant. This sewerage system will only serve the wastewater of the southern parts of the city and a few central sectors. (SETENA, Ministerio de Ambiente y Energía, 2016) The construction of this Wastewater Treatment Plant has not started yet.

In 2016, the Government of Costa Rica, through the Ministries of Health, AyA y MINAE, (MINAE, 2017) generated the National Wastewater Sanitation Policy to improve sanitation conditions specifically in the management of wastewater. Different institutions are part of this policy due to the characteristics of the water resource in the country. These rise hope for the improvement in environmental sanitation, specifically in areas with a high density of population, leaving aside rural areas that are currently densifying, therefore, it is foreseen that pollution will rise in these areas.

Along with these, standing before the climate change scenarios foreseen for Costa Rica, the necessity of adaptation of the population in order to reduce the impact of the changes in rainfall and the increase of temperatures has to be envisioned. (Alvarado, Contreras, Alfaro, & Jimenez, 2012), Therefore, it is necessary to identify the state of waste water management in the country.

This article describes the current situation of sanitation in rural areas of the province of Cartago in Costa Rica. In the area studied, the population separates the wastewaters into toilet water, which is treated by septic tanks, and the greywaters, which are produced by activities like cleaning and food preparation at home and are discharged freely to the water bodies.

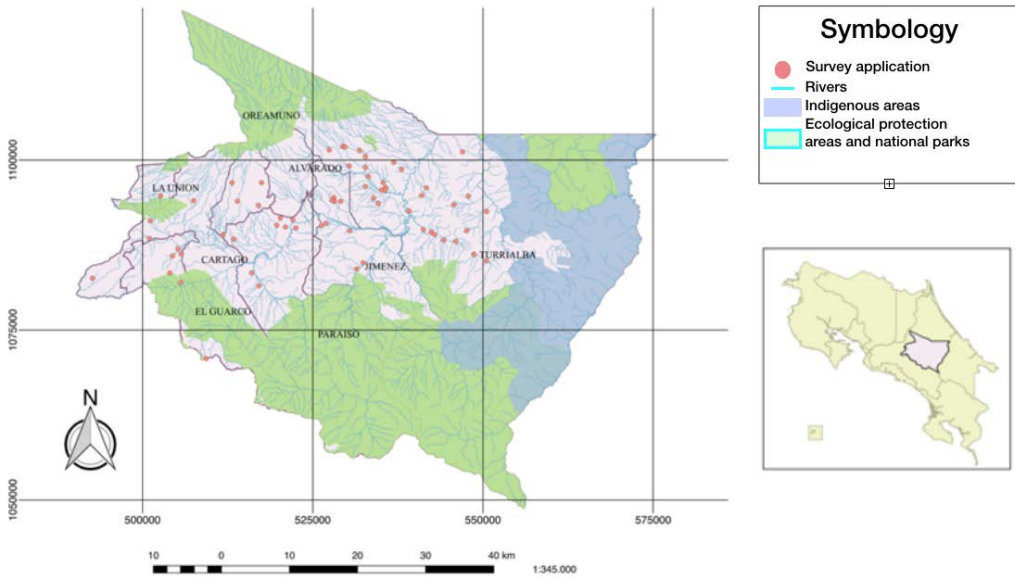
2. Methodology

2.1 Study area

Costa Rica is in the humid tropic. It has an important water supply due to the abundant rains that last nearly all year long. In the less rainy periods and in the drier zone of the country (North Pacific) the average rainfall reaches 1481 mm, meanwhile, in the extreme rainy events in the Central Pacific, it reaches 4537 mm. The province of Cartago is located in the central area of the country, has 8 cantons and 2 municipal district councils. It has a mountainous relief, formed by two ridges: The Central ridge

and the Talamanca ridge. The river system present in this province corresponds to the Caribbean and Pacific slopes. Its total population is of 490 903 inhabitants. (Instituto Nacional de Estadísticas y Censos, Costa Rica, 2011). The geographical location of the province is shown in Figure 1. Geo-referenced points in the map are also included in the places where the surveys were applied. (Section 2.2)

Figure 1. Cartago province map and its location within Costa Rican territory.



2.2 Sample selection

The sample of the study corresponds to the population supplied by the Aqueduct Management Associations (ASADAs) given that these entities are the main operators that provide water service for consumption in rural areas of the Cartago Province (Figure 1). The next areas were not incorporated in the sample: the Tapantití and Barbilla National Parks, the ecological protection areas and the indigenous populations, the former because of their isolation and low densification.

The rural population that was served by ASADAs in Cartago in 2014 was of 131 559 (Ministerio de Salud, Regional Este, 2014) inhabitants approximately, with a total 31 621 connections. In the province, 113 ASADAs were in operation, distributed mainly in the cantons (unit of administrative territorial division of second level, under the provinces) of Turrialba, Oreamuno, Paraiso, El Tejar del Guarco and Jiménez.

The researchers applied a survey in order to determine the water service and sanitation situation. The population sample was determined in the cantons mentioned above. The following selection characteristics were considered: belonging to the province, living in rural areas and having water supply service from ASADAs.

The statistical formula for sample size (Yamane 1967) equation 1 was used.

EQUATION 1

$$n = \frac{Z^2 * \sigma^2 * N}{(N - 1) * e^2 + \sigma^2 * Z^2}$$

N = Total size of population

n = Sample size

σ = Population standard deviation. In this case 0,5 was used

Z = Statistical confidence level, 95% of confidence was used

e = Acceptable sampling error limit. In this case 0,9 was used

The mathematical solution of the formula generated 387 total surveys to be carried out.

That number was increased by 60% to have a margin for no answers, because these places are difficult to access and, by previous experiences, it is known that some people are not at home during daytime.

2.3 Survey design

The community application questionnaire was developed using the criteria of experts; single, multiple and open selection questions were applied according to the methodology proposed by (Sampieri, Collado, & Lucio, 2002). The questionnaire was initially validated with a sample of 27 volunteers who responded an online form, and, as the responses were analysed, the interpretation errors were identified and corrected.

To avoid inducing biases in the captured information, 37 volunteer students of the Environmental Engineering major of the Technological Institute of Costa Rica (TEC) were trained to apply the survey. These students were taught the protocol to address the interviewees in cases of doubt and to explain the correct way of filling out the questionnaire. They were also trained to determine in site the existence of clandestine dumps, wastewater discharges, presence of smells and some other environmental problems. The group of students was subdivided into subgroups and each of these was led by one investigator, in order to cover most of the rural areas of the province.

The questionnaire was divided into five sections: 1) Section 1, General data: name of the surveyed, age, sex, schooling, location and name of ASADA; 2) Section 2, Management of Solid Waste: forms of waste collection, attitudes towards the recovery of materials, knowledge of the separation of valuable solid waste, 3) Section 3, quality and supply clean water, including the perception regarding to the quality considering presence of odour and colour, in addition to the existence of suspended solids, continuity and price of the service; 4) Section 4, Wastewater management: sewage and greywater treatment systems, water use habits and 5) Section 5, Environmental commitment: involvement in environmental protection activities in the community.

The survey results were typed into an excel spreadsheet and then analyzed using the program Mintab 17.

2.4 Field visits

Additional information was collected through field visits that were carried out after the survey, with the aim of deepening and corroborating the information. The role of the state institutions regarding the issue of environmental sanitation was verified. Table 1 shows the list of ASADAs chosen for the visits, the criteria for choosing this sample was based on the number of subscribers by ASADA and its respective geographical location in each canton.

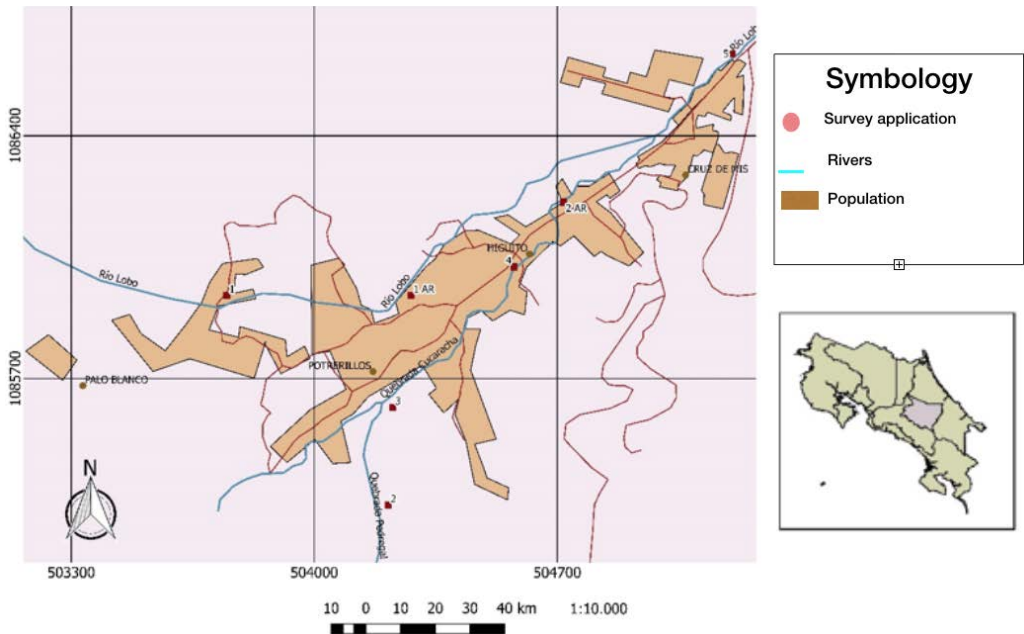
Table 1. ASADAs sectioned list for field visits.

Canton	ASADA Name	Nº suscribers	Height above mean sea level (AMSL)
Del Guarco	Higuito	570	1500
	San Isidro	567	1600
	Macho Gaff	335	2900
	Guatuso	230	1500
Oreamuno	Santa Rosa	850	2600
	Cot	2025	2200
	Potrero Cerrado	438	2600
	Paso Ancho y Boquerón	580	1750
	San Pablo	410	2500
La Unión	San Vicente	230	1450
Turrialba	Santa Cristina	35	1500
	Alto Varas	323	800
	Santa Cruz	906	1700
	Jicotea	85	900
Paraíso	Palomo	470	1300
	San Jerónimo	141	1250
	Santiago	733	1350
	El Yas	425	1400
	Río Macho	-	1300
Central	Quebradilla	1000	1600
	Coope-Rosales	154	2200
TOTAL		10507	

2.5 Physiochemical analysis

The Cucaracha Creek, Pedregal Creek and Lobo River that cross the town of Higuito were selected for this analysis. These bodies of water receive the untreated greywaters of approximately 2 565 inhabitants. These sources cross the center of population, they have an easy access for the sampling and are confined in three branches before they flow to the Central River Purires. The flow of these three streams is unknown and their location is shown in the following figure:

Figure 2. Sample points distribution.



The sampling points were selected along the streams in order to be able to establish a correlation between the pollution and the high population density along them.

Samples (1, 2, 3, 4, 5) of superficial water were taken in five points along the Pedregal, Cucaracha creeks and Lobo River. The samples AR-1 and AR-2 correspond to waste water samples from houses.

The following analyses were performed on surface waters: BOD, methylene blue active substances, total solids, pH, electrical conductivity as described in standardized method (APA-AWWA-WEF, 2012), fecal coliforms and *E. coli* according to the most probable number (APA-AWWA-WEF, 2012), and organochlorine organophosphorus pesticides (FDA, 1994). The sampling was done using solid phase (SPE) and the concentration was determined by gas chromatography with nitrogen-phosphorus detection NPD y electron capture detection ECD. Carbamate analyses were performed using the FDA method (FDA, 1994) using chromatography in HPLC with UV detector.

The composition analysis of the greywater discharged from the houses was carried out by taking samples from the water collection box discharge and COD, BOD, total solids, pH, active substances to the blue of methylene, fecal coliforms and *E. coli* were analyzed.

3. Discussion and study results

This article shows the results of the applied survey of sections 4 and 5, the field visits and the results of the physical-chemical analysis.

3.1 Field visits

Three types of wastewater to be discharged to surface waters were found:

a) 100% of the greywaters collected from households is discharged directly into land or into rainwater collectors and drain into surface water sources.

b) 100% of the waters from vegetable washing and food packaging activities from micro and small enterprises (SMEs) are mixed in rainwater collectors and discharged directly into rivers. Their volume is high due to the socio-economical characteristics of the area.

c) 6% of the toilet waste waters from houses are discharged directly into rivers, with the consequent risk of diseases related to fecal coliforms, mosquitoes and other vectors.

It is common that some families infiltrate greywaters into their courtyards or gardens. Such practices, in principle, don't bring serious problems to the environment or to human health, but as communities become denser, these practices are unsustainable. (Siegrist & Lowe, 2008).

If no attention is paid to the treatment of greywaters in these areas, soon there will be the same conditions that the GAM faces today in regards of superficial water resource pollution. (Angulo F., 2013)

As the population density increases, the quantity of residual waters increases as well. These greywaters cause the presence of foams downstream; there is also the appearance of solid waste in the rainwater collection systems. The most aggravated case was observed in the community of Cot, Canton Oreamuno, but similar cases were also observed in the community of San Isidro, Tejar del Guarco. All of the above is further aggravated by the culture of water wasting and the lack of awareness of what happens to the waste water generated once it leaves the house. The quantification of the water flows exceeded the scope of this research.

The forest cover on the rivers banks and the protection strips don't comply to the Forestry Law 7575 signed in April 16, 1996. According to the projections of the average increase of temperature associated with the climatic change in the area, a larger amount of evaporation of water is foreseen, therefore, implying a diminution in the flows of the water sources. On the other hand, given that these areas don't have forest protection, the risk of possible flooding is also increased. (Mander & Kuusemets, 2005).

3.2 Environmental Sanitation Survey

3.2.1 Survey Generalities

The survey was implemented during the months of October to December of 2014. A total of 614 people were interviewed, each one representing a household. The surveys were distributed in the following cantons: 23 surveys in Tejar del Guarco, 188 surveys in Oreamuno, 113 surveys in Paradise, 216 surveys in Turrialba and 73 surveys in Jiménez.

The rural populations are generally served by ASADAs. However, places like Higuito, San Isidro, and Cot have characteristics that tend to be on the urban side, such as high density of housing and jobs in the tertiary sector. In these cases, there is not only a mixture of rural and urban activities, but also different types of land usage and productive activities. (Gaviria- Montoya, Pino- Gómez, & Soto-Córdoba, 2016)

It was identified that the majority of the population only completed the primary level of studies (57%).

3.2.2 Excreta Treatments

The distribution of excreta treatment is 89% septic tank, followed by the use of sewerage with a small percentage contribution of 7%. The remainder use latrines, black wells and direct discharge. Sanitary sewerage was found only in some small sections of the community centers of Santiago (Paraíso), El Yas (Paraíso) and Cipreses (Oreamuno), but there doesn't exist a treatment plant at the end of these water collection systems. All of these practices contribute to the contamination of the surface water.

30% of the people surveyed don't know the type of building materials used in the septic tanks they use. The compliance of national regulations depends on the type of material used, therefore, making it of vital importance to know this information. There are PVC and fiberglass tanks with the appropriate dimensions depending on the size of each family being sold on the market, but only 7% of the households surveyed used them. Another 53% of the population use concrete tanks, the main problems with these being that they are constructed empirically and don't necessarily have the dimensions nor hydraulic requirements for their proper operation. Finally, 11% use sewer pipes as septic tanks due to their low cost, however, since they are not designed for this purpose, they become sources of soil and aquifer pollution.

The correct performance of a septic tank is directly related to the draining area, which must be suitable for the infiltration of the overflowing water. A 79% of the survey responses show that a draining area exists, however, it is important to note that about 17% of those surveyed don't know if they have draining in their homes. In addition, it is unknown whether this area is sufficient, if the system is built correctly, nor what the structure of these tanks is.

On the other hand, these terrains are not always the best in the infiltration of water. The students who applied the survey observed, in certain cases, problems of pollution due to water stagnation or leakage near homes, with a consequent risk to human health.

Although attempts were made to know about the state of maintenance of these tanks, people were uninformed about their situation.

Table 2 corresponds to the location of the septic tank in homes. About half of the people interviewed indicated that it is located at the backyard of the house. The high percentage of people who don't know where the septic tank system is located is also noteworthy.

Table 2. Localization of the septic tank in the lot

Location of septic tank	Response percentage
Don't know/ No response	17%
Backyard	42%
Next to the house	21%
In front of the house	8%
Don't use septic tank	6%
Underground of the house	6%

Approximately 80% of households report having a single toilet, this corresponds to the INEC classification (Instituto Nacional de Estadísticas y Censos, Costa Rica, 2011) of low socioeconomic levels in these areas. In addition, 86% of the toilets are of conventional size, which implies the consumption of 10 to 15 liters of water per discharge, with only 14% of the houses having a low-flow toilet.

3.2.3 Perception of environmental problems

The positive impact in the resolution of environmental problems is directly related to the knowledge and sensitivity of the population. For this reason, the study investigated the perception of the main environmental problems in each area. According to interview responses, 34% of people fail to identify their community's main environmental problem, 27% of respondents noted that there is inadequate solid waste management and 16% indicated that the main problem is inadequate wastewater management.

3.3 Results of the physical-chemical analysis on the river and waste water

As it can be seen from the results of the physical-chemical analysis carried out in the sampling points (Table 3), the series of parameters of the values obtained are consistent with the approach initially established. As the population is densified, these values increase, resulting in pollution. These results cannot be attributed to anthropogenic pollution, with the exception of data associated with active substances to methylene blue, which are indicative of the presence of surfactants. In relation to the analysis of wastewater from the confluence of dwellings, in both cases they exceeded the maximum permitted discharge limits for treatment plants on water surface bodies. No dissolved pesticides were found in the water, despite the existence of agricultural activities near

the river. It is recommended to deepen this study with a sediment analysis, given that it was beyond the scope of this study.

Table 3. Physical-chemical parameters results at sampling points for surface water and grey waste from the Higuito community.

Parameter	Point sample 1	Point sample 2	Point sample 3	Point sample 4	Point sample 5	AR-1	AR-2
COD (mg/l)	20 ± 6	20 ± 6	40 ± 7	30 ± 7	30 ± 7	200 ± 14	419 ± 26
BOD ₅ (mg/l)	< 10	10 ± 1	< 10	< 10	10 ± 1	120 ± 16	162 ± 16
Total solids (mg/l)	63 ± 3	91 ± 3	130 ± 3	129 ± 3	126 ± 3	527 ± 3	515 ± 3
pH (pH units)	6,81 ± 0,01	7,50 ± 0,01	6,97 ± 0,01	6,93 ± 0,01	7,01 ± 0,01	7,10 ± 0,01	6,78 ± 0,01
Methylene blue active substances (mg/l)	0,45 ± 0,05	0,85 ± 0,05	0,10 ± 0,05	0,45 ± 0,05	0,45 ± 0,05	1,50 ± 0,05	1,55 ± 0,05
Conductivity (°S/cm)	95 ± 10	104 ± 10	158 ± 10	169 ± 10	151 ± 10	NR	NR
Fecal Coliforms (NMP/100 ml)	4,6 × 10 ²	9,3 × 10 ¹	4,6 × 10 ²	9,3 × 10 ¹	1,1 × 10 ³	NR	1,1 × 10 ³
E. coli (NMP/100 ml)	4,3 × 10 ¹	2,3 × 10 ¹	9,3 × 10 ¹	9,3 × 10 ¹	4,6 × 10 ¹	NR	4,6 × 10 ²
Organochlorine pesticides	ND	ND	ND	ND	ND	NR	NR
Organophosphorus pesticides	ND	ND	ND	ND	ND	NR	NR
Carbamates	ND	ND	ND	ND	ND	NR	NR

ND = Not detected according to the detection methods used

NR = It was not done, it's residual water

Until now, the rivers in the area have had the capacity of self-purification, because of their high slopes, high levels of oxygenation, important rainfall regimes, high temperatures and the geomorphology of rivers promoting the rate of degradation of organic matter more easily (Umaña-Quiros, 2014), (Umaña-Villalobos & Springer, 2006), (Rodriguez, Mata, & B, 1984). This has allowed these bodies of water to show no serious problems of eutrophication or environmental degradation, despite the continuous discharge of grey wastewater. Previous studies on the Purires river basin show BOD values from 10, 8 to 14, 8 mg/L in the water stream. Using other parameters, it is classified as moderate pollution, showing a gradual degradation of the quality of its waters according to the months of the year, even reaching severe pollution values during the months of May and June which are drier than other months in Costa Rica (Calvo, 1990) (Leiva, 2007).

At present time, the population of these areas is supplied with water from springs or water captured in high mountain areas. The catchment systems of these is rudimentary and has little investment, however, as the population increases, water coming from the surface bodies will need to be used, water which every day is more altered by the effect of the discharge of greywaters.

The lands where the rural dwellings are located have enough unbuilt spaces to implement solutions for the treatment of grey and individual wastewaters around them.

Population densification is low in most areas, with the exception of Cot de Oreamuno, Higuito and San Isidro del Guarco and Cachí de Paraíso, where houses occupy most of the land with their biggest problem being garbage and wastewater accumulation.

The urban growth is increasing in the Cartago province; the land of the old farms is being subdivided into smaller lots which form part of urbanizations, commerce and industries. The new use of these lands will increase the problem of vulnerability associated with climate change, as natural areas where rain water infiltrates will gradually decrease, therefore, generating an additional pressure in the use of soil and the availability of water for human consumption. In general, there is a transformation of rural areas into urban areas characterized with disorderly growth and without the corresponding sanitary infrastructure to go along.

3.4 Institution responsibilities related to sanitation.

In Costa Rica, there is a diversity of institutions responsible for sanitation. In the case of greywaters, it was determined that the competence of each of them is limited in most cases to control protocols. The Health Ministry and AyA monitor the quality of drinking water received by the population, but do not intervene in regard to the communal sewage, only with private companies, in which case they simply request operational reports of their treatment plants and discharges. Municipalities are in charge of the collection and treatment of solid waste, acting when clandestine dumps arise, but do not carry out any action to control greywaters. (Soto-Cordoba, Pino-Gómez, & Gaviria-Montoya, 2016)

Of all the problems identified, the inadequate disposal of these waters is the most important, since no authority intervenes in these cases, unless they are of toilet water discharges.

In environmental matter there is a shared competition between the following institutions: Health Ministry (monitors water quality offered to the population), Ministry of Environment and Energy (water concession to public and private entities), Ministry of Agriculture and Livestock (triple washing program of agrochemical containers and irrigation), Ministry of Planning (environmental programs), Costa Rican Tourism Institute (concession of water for recreational purposes), National Institute of Housing and Urbanism (approves plans for the construction of housing projects), AyA (controls the ASADAs and gives technical support), Costa Rica Electricity Institute (cleans solid waste from water reservoirs for the production of electricity), National Irrigation and Drainage Service (responsible for issuing technical criteria for the use of groundwater), National Commission for Risk Prevention and Emergency Mitigation (acts in case of natural disasters), Regulatory Authority of Public Utilities (determines the rates for water service), Comptroller General of the Republic (authorizes the implementation of budgets according to compliance with environmental standards)

ASADAs do not perform any sort of environmental sanitation activity as they do not have the technical knowledge nor the proper budget. Even so, the law still gives them environmental responsibilities in this matter. The country has a general health law that specifies that any person or entity that threatens public health will be subject

to sanctions; it also specifies regulations for the discharge and re-use of wastewater. In the case large generating entities, such as industries, it is their responsibility to comply with these discharge regulations, but in the case of discharge from houses, there are no clear regulations, with the exception of toilet water discharge which is penalized by law.

4. Conclusions and recommendations

The rural area of the Cartago province doesn't currently present serious problems of environmental pollution, in part due to the low densification of the population living there, with the exception of the communities of Higuito and San Isidro de Tejar del Guarco, and Cot de Oreamuno. Despite this information, it is worrying that 100% of untreated grey wastewater is discharged directly into surface water sources. It is also worrying that septic tanks are massively used without proper controls for the treatment of excreta and that State control are insufficient.

According to this study, the potential pollution of water resources in the near future is very high, therefore, highly risking the environmental sustainability of rural areas. Despite of the historically favorable conditions of purification that the bodies of water in rural areas have had, considering the increase in population added to low investment in sanitation, the country will begin to feel the environmental consequences.

There are many reasons why wastewater treatment in Costa Rica is deficient, including: a) insufficient investment to ensure the growth of sanitation infrastructure, b) national policies focused on other objectives, c) Government plans that have not given priority to sanitation in the last 50 years and d) heavy rainfall regime that drags pollution from their origin sites, creating an apparent effect of clean environments, meanwhile the coastal sector is severely disrupted.

To reduce the risk associated with wastewater discharges, there are several options that the country could implement:

- a) Individual treatment solutions, which are developed with little economic investment, but with great investment in education and environmental awareness.
- b) Monitoring of the maintenance and operation of septic tanks
- c) Monitoring of new septic tank constructions, so as to ensure their efficiency and position them in a favorable place for future connections to sanitary sewers
- d) Construction of rural sanitary sewers
- e) Construction and operation of wastewater treatment plants. Institutions need to agree on a plan to improve environmental sanitation in rural areas of the country.

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Original Articles

CARTAGO CASE STUDY: WASTE WATER MANAGEMENT IN RURAL AREAS OF COSTA RICA

Abstract: This article provides information on the management of the grey and toilet water collected in rural areas of the province of Cartago, from the years 2014 to 2016. For this research, information was gathered from a survey applied to 614 households located in rural areas. Information was also obtained through field visits and a physical-chemical and microbiological analysis of surface and residual waters. It was found that 100% of greywater from houses in rural areas are thrown into their surrounding rivers and 87% of wastewaters are treated in septic tank systems. Pollution is observed in the surface water sources due to the increase of population density in rural areas and discharge without greywater treatment.

Keywords: Waste water, sanitation, sewage systems, septic tanks

Resumo: Este artigo compila informações sobre a gestão de águas cinzas e negras em áreas rurais da província de Cartago na Costa Rica, durante os anos de 2014 até 2016. Foram avaliadas 21 de um total de 135 comunidades. Os dados apresentados são referentes a 614 famílias localizadas nas áreas rurais da província. Foram realizadas visitas a campo para identificação do destino final dos efluentes e amostragem de águas superficiais para a respectiva análise físico-química e microbiológica. Verificou-se que em 100% das comunidades avaliadas, despejam, sem tratamento prévio, a água cinza diretamente em rios circundantes e que 87% das águas negras é tratada em sistemas de tanques sépticos.

A poluição é observada nas fontes superficiais devido ao aumento da densidade populacional nas áreas rurais e à descarga sem tratamento de água cinza.

Palavras-chave: águas residuais, o saneamento, as áreas rurais, fossas sépticas

Resumen: Este artículo brinda información recolectada en las zonas rurales de la Provincia de Cartago sobre la gestión de las aguas grises y negras, durante los años 2014 hasta el 2016. Se evaluaron 63 comunidades de la provincia. Para esto se recabó información a partir de una encuesta aplicada a 614 hogares ubicados en área rural. También se obtuvo información a través de visitas de campo y muestras de aguas superficiales y residuales para su respectivo análisis físicoquímico y microbiológico. Se encontró que el 100 % de las zonas rurales disponen sus aguas grises en los ríos circundantes y que el 87 % de las aguas negras son tratadas en sistemas de tanques sépticos. Se observa contaminación en las fuentes

superficiales debido al aumento de la densidad de la población en las zonas rurales y el vertimiento sin tratamiento de aguas grises.

Palabras Clave: Aguas residuales, saneamiento, zonas rurales, tanques sépticos
