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Greenhouse gas inventory of a state water and wastewater utility in Northeast Brazil

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ABSTRACT

The growing concern about climate change and related greenhouse gas emissions (GHG) has been shared by many companies who are now involved in emission reduction efforts. In order to do this, it is necessary to first develop GHG emission inventories. The construction of inventories is not common practice in developing countries and among Brazilian water and wastewater companies, only four companies, among the top 25, have developed their GHG inventories, and none in the Northeast of the country. This paper aims to identify and estimate GHG emissions from the activities of a water utility, Empresa Baiana de Águas e Saneamento S.A (Embasa) in the State of Bahia during 2012. The method used for the inventory was the *GHG* Protocol proposed by World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI), the most widely adopted method worldwide. In addition, the guidelines of IPPC (Intergovernmental Panel on Climate Change) were used to calculate emissions from wastewater treatment plants. It was found that the emissions resulting from sewage treatment (mostly carried out by anaerobic processes) constitute the largest source of GHG at the sanitation company studied, when considering the activities defined in this work. The assessment of GHG sources and emissions identified in this research can support proposals for reduction targets and benchmarking. The results form the basis for the incorporation of GHG reduction measures in the company's strategic planning as well as for integrating its sustainability report. The findings of this work can also help other companies to undertake GHG reduction measures.

1. Introduction

Growing concern about climate change and its causes have led national governments to establish policies and strategies to control greenhouse gas emissions (GHG). As a result, many organizations are taking measures in this direction as part of their corporate sustainability objectives. A basic step is to identify and quantify the main sources of GHG in order to take effective measures for their reduction. These corporate activities are often referred to as the carbon accountability of an organization (Ascui and Lovell, 2012; Schaaltegger and Csutora, M, 2012; Stechemesser and Guenther, 2012).

Preparing an inventory is the most commonly used tool to quantify GHG emissions from an organization. A GHG inventory accounts for the emissions from all of the sources identified in the direct and indirect activities associated to a company. One of the most commonly used methods today is the GHG Protocol Corporate Accounting and Reporting Standard (WBCSD/WRI, 2004). This guide provides information on preparing GHG inventories, which is now widely used by many companies and environmental organizations around the world. The gases considered within its scope are those listed in the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride). The method is compatible with the ISO standards (ISO, 2006) and the Intergovernmental Panel on Climate Change (IPCC, 2006) methods.

Another method which could be used as a reference when preparing an inventory is ISO 14064-1, which guides the adoption

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of measures aiming to reducing or eliminating potential emission sources.

With a more wide-ranging vision, Galli et al. (2012) define the footprint family as a set of indicators which aim to track human pressure on the planet in accordance with specific aspects under analysis. They consider a joint analysis of the ecological, water and carbon footprints. The authors highlight that the carbon footprint measures the total GHG emissions originating directly and indirectly from an activity or stages of a product's life cycle.

Although Brazil does not have compulsory goals, in 2009 it voluntarily established a reduction in its emissions of between 36.1% and 38.9% by 2020, as contained in the *Plan and National Law for Climate Changes and Federal Law 12.187* of December 29, 2009. In a number of States in Brazil, such as São Paulo and Rio de Janeiro (Environmental Company of the State of São Paulo-CETESB, 2012; Institute for the Environment of Rio de Janeiro-INEA, 2012), a GHG inventory has now become a regulatory requirement for environmental permits, demonstrating the importance of this issue.

In other countries, various sectors are preparing inventories and proposing measures in order to contribute to reduction targets. Among the most active is the education sector, with several publications (Alvarez et al., 2014; Klein-Banai and Theis, 2013; Güereca et al., 2013; Larsen et al., 2013; Li, X et al., 2015; Ozawa-Meida et al., 2013) followed by others on the carbon footprints of nations (Hertwich and Peters, 2009; Wiedmann et al., 2010), cities (Larsen and Hertwich, 2010) and other sectors (Figueiredo et al., 2013; Vázquez- Rowe et al., 2013; Zakkour et al., 2014; Zhai et al., 2014).

Water and wastewater treatment produces a significant amount of methane and nitrous oxide, so reducing these emissions is one of the principal challenges for sanitation companies facing climate change issues (Gupta and Singh, 2012).

In developed countries, where the energy source is basically made up of fossil fuels, there is concern about the consumption of energy in the water sector, as it constitutes the largest emission source (Barber, 2009). A number of articles discuss the correlation between energy consumption and the carbon footprint (Boulos and Bros, 2010) that a significant percentage of this energy is used for pumping.

There are still very few articles in the literature on the carbon footprint of water and sanitation companies. The papers focusing on climate change and wastewater management are directed towards quantifying the emissions resulting from municipal wastewater collection systems (Guisasola et al., 2008), or from sludge treatment (Uggetti et al., 2012), emissions analysis according to the typology adopted (Cakir and Stenstrom, 2005; Shahabadi et al., 2009), modeling emissions at treatment plants, especially methane (Guisasola et al., 2009; Foley et al., 2009) and nitrous oxide (Foley et al., 2010; Law et al., 2012; Daelman et al., 2013) and measuring methane emissions (Wang et al., 2011). Very few articles include activities which are related to scope 3 (Frijns, 2011).

However, some companies are preparing and publishing their greenhouse gas inventories in Brazil. Twenty-two inventories were published in 2008, the first year that the Brazilian GHG Protocol program (GHG Protocol, 2010) was introduced. On consulting the GHG Protocol site, it can be seen that SANEPAR (the water and wastewater company of the State of Parana) is the only sanitation company that publishes an inventory in the Brazilian Public Emissions Register in 2012. As indicated by Perini (2011), Companhia de Agua e Esgoto de Ceará – CAGECE has also been developing initiatives related to climate change through measures directed towards mitigating greenhouse gas emissions. The practice of preparing inventories is still uncommon among water and wastewater companies in Brazil. At present, only 4 companies, Companhia Espírito Santense de Saneamento – CESAN (Girondolli, 2009), Companhia de Saneamento de Minas Gerais (Sanitation Company in the State of Minas Gerais) – COPASA (Rennó, 2011), Companhia de Saneamento do Paraná – SANEPAR (Sanepar, 2010) and Companhia de Saneamento Básico no Estado de São Paulo S.A (Basic Sanitation Company in the State of São Paulo), SABESP (Sabesp, 2007), which are among the top 25 water utilities in Brazil, have developed inventories. However, little information is given in their corporate reports about the implementation of strategies to mitigate their GHG emissions. In addition, none of these companies are from the northeast region of the country.

In his study about carbon footprint of the water sector in Holland, Frijns (2011) used the UK Water Industry Research (UKWIR) guidelines as a reference. UKWIR has been developing research to provide guidelines in order to aid in the quantification and publication of GHG emissions in companies in the water industry. This method used was also applied by Barber (2009) to evaluate the carbon footprint of sewage sludge digestion.

This paper aims to identify and evaluate GHG emissions generated from the activities of a water and wastewater company, Empresa Baiana de Águas e Saneamento S.A (Embasa) in the State of Bahia, during 2012. It also contributes with data to the few experiences in preparing GHG inventories and public reports in water utilities in Brazil.

2. Method

The inventory was carried out considering Embasa's area of coverage. The company comprises seven directorates: three Operation and Expansion Directorates (Metropolitan Region of Salvador (MRS), North and South), the Technical and Sustainability Directorate, Financial and Commercial Directorate, Corporate Management Directorate and the Presidency. The administration is decentralized: 13 regional units in the countryside and 6 in the Metropolitan Region of Salvador (Embasa, 2012). According to Embasa (2012), the company operates in 362 municipalities of the 417 located in the State of Bahia, resulting in 410 water supply systems (106 integrated and 304 local) and 73 sanitary waste systems. In the year that this inventory was carried out, the company had 5765 employees working in the various units. Fig. 1 shows Embasa's regional units.

The method selected for this inventory is based on the GHG protocol (WRI/WBCSD, 2004) and IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) on direct emissions from wastewater treatment.

2.1. Applying the greenhouse gas protocol (GHG protocol)

The GHG Protocol establishes three scopes for executing inventories. Scope 1 refers to direct emissions from the company's processes; scope 2 includes indirect emissions resulting from energy consumption and scope 3 includes emissions from activities over which the company has no control of the sources, such as transportation.

Following the definition of the emission sources to be analyzed, the gathering of data from the selected activities was carried out. The company's organizational structure was taken into consideration, with a view to identifying the offices responsible for collecting the required information on the emission source. Visits were made to the various company units between June 2012 and October 2013, where a wide range of documents were obtained (reports, database, etc.) and interviews were held with key personnel.

Then the macro processes carried out by the company were analyzed and following the guidelines for identifying potential

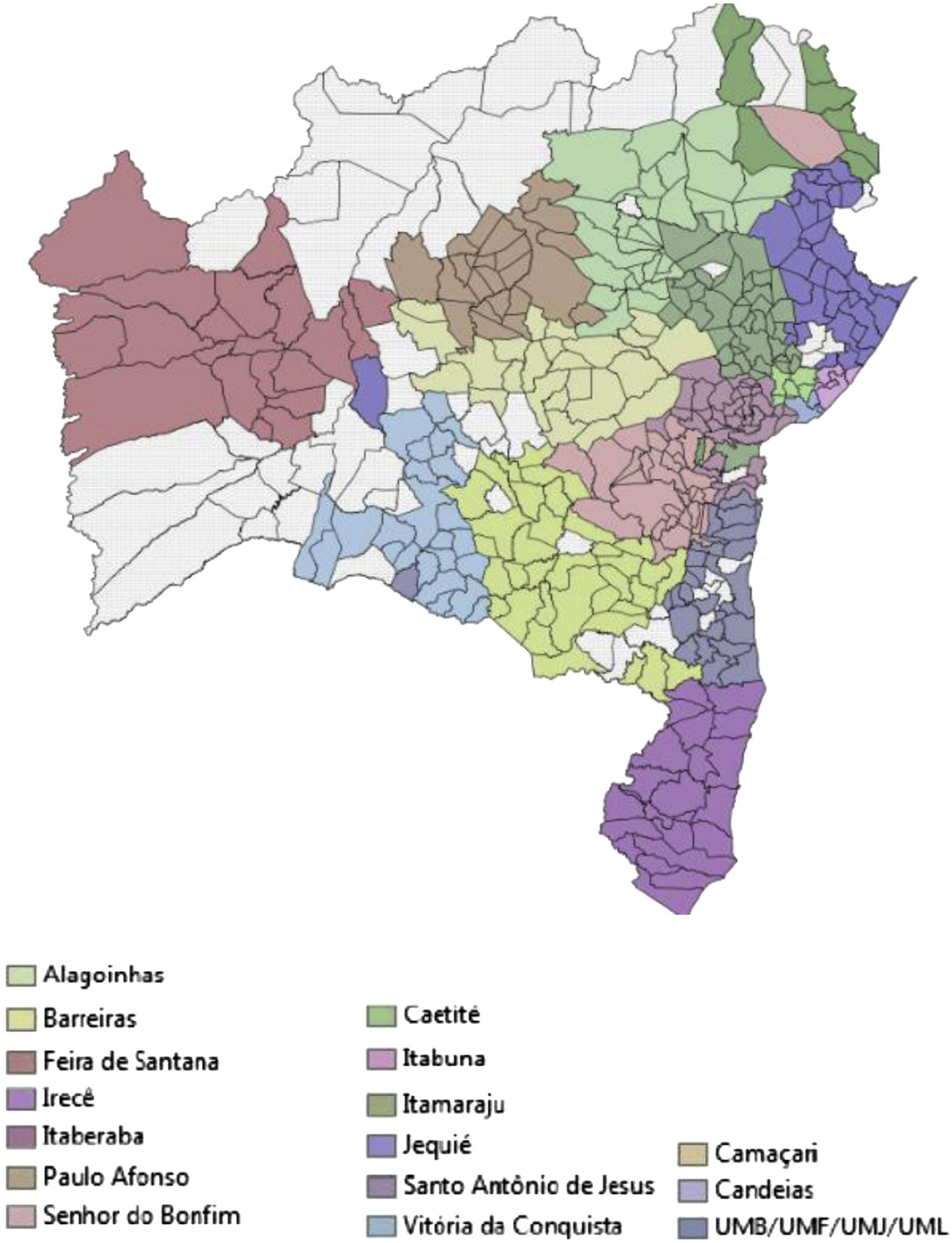

Fig. 1. Regional units.

sources of GHG emissions in the water and wastewater sector the following scope categories were defined and calculated (Table 1):

The emissions for a one year period (January 2012 to December 2012) were calculated for this paper.

Scope 1. ***Direct emissions from wastewater treatment plants (WWTP).***-The steps for calculating CH_4 emissions from wastewater treatment facilities followed the IPCC Guidelines for National Greenhouse Gas Inventories, 2006)

Step 1: An estimate of organically degradable material in domestic wastewater is shown in Table 2.

$$TOW = P \times BOD \times 0.001 \times 365$$

Table 1
Emission types and sources considered in the inventory.

Emission type	Activity	Description
Scope 1 Direct emissions	Wastewater treatment Direct mobile combustion	CH_4 emissions from WWTP and uncollected sewage
Scope 2 Indirect emissions	Energy consumption	Emissions from water catchment, pumping raw water; pumping treated water; pumping sewage and administrative activities
Scope 3 Indirect emissions	Employee travel Business travel	from home to work

where:

TOW = total organic load of wastewater in the year of the inventory, kg BOD/year.

P = population in the year of the inventory.

BOD (degradable organic component) = BOD per capita in the year of the inventory, g/person/day (the standard amount for Brazil according to the IPCC-2006 Guide is 50 (g/person/day)

0.001 = conversion factor (g to kg)

I = correction factor for industrial BOD disposal in the collection network (standard values: 1.25 for collected and 1 for uncollected).

Step 2: Organically degradable material entering the treatment plants was estimated based on the monitoring data listed in the Pollutant Load Declaration made available by the Department of Environmental Management of Embasa. Values for each month of 2012 were provided and the average annual BOD influent and effluent was therefore calculated. The BOD removed at the stations was calculated using the following equation:

$$BODr = (BOD\ entry - BOD\ exit) \times Q\left(\frac{l}{day}\right)$$

where:

BODr = BOD removed.

BOD entry = BOD in the influent of wastewater treatment plants.

BOD exit = BOD in the effluent of wastewater treatment plants.

The BOD discharged into the environment as raw sewage was calculated by subtracting the BOD entering the wastewater treatment plants (166,297,901.63 kgBOD/year) from the estimated total BOD produced by the served population (224,999,231.25 kgBOD/year). This results in 58,701,329.62 kgBOD/year discharged to natural receiving bodies.

This procedure resulted in the data presented in Table 3:

Step 3: The emission factor of a wastewater treatment system depends on its maximum potential of methane production and of the corrective factor, using the formula below:

$$EF = Bo \times MCf$$

where:

EF: Emission Factor ($kgCH_4/kgDBO$)

Bo: Maximum CH_4 production potential (0.6 $kgCH_4/kgDBO$)

MCF: CH_4 corrective factor (IPCC proposed standard for each treatment system)

After applying the formula, the emission factor for each treatment system was found. This factor was then multiplied by the removed BOD. The result is found in $kgCH_4$ then is converted in tCO_2eq. The Global Warming Power (GWP) for methane was 21.

Emissions from not removed BOD and the BOD discharged to the environment as raw sewage is considered in the estimate. Table 8 shows emission factors for each category.

Direct mobile combustion – Combustion emissions were estimated as follows:

$$\text{Combustion emissions } tCO_2eq = \text{fuel consumption} \times \text{emission factor}$$

Fuel consumption: Annual quantity of fuel consumed in 2012 in scope 1 activities, which was supplied by the Department of Transport of Embasa.

Emission factor for consumption by fuel type are based on the national land vehicle inventory prepared by the Ministry of the Environment in Brazil (MMA, 2011).

Scope 2. Energy consumption – indirect electricity emissions are estimated by multiplying the electricity consumption by the average electricity grid emission per month in Brazil.

$$\text{Electricity consumption emissions } tCO_2eq = \text{Energy consumption per month} \times \text{emission factor per month},$$

The emission factor for electrical energy is made available on a monthly basis by the Ministry of Science and Technology (Ministry of Science and Technology of Brazil, 2012).

Table 3
BOD values related to the WWTP in Bahia.

BOD	BOD removed (kg BOD/year)
Entry to the plants	166,297,901.63
Removed	158,919,116.95
Not removed	7,420,587.71

Table 2
Estimate of organically degradable material.

State	A	B	C	D
	Population	Degradable organic component (BOD) (kg BOD/cap/year)	Correction factor for industrial BOD discharged into sewers (I)2	Organically degradable material in wastewater (TOW) (kg BOD/year) D = AXBXC
Bahia	12.328.725[a]	18.25	1[b]	224,999,231.25

[a] Considering the municipalities which are served by Embasa.
[b] Embasa does not treat industrial wastewater, so the default value for uncollected = 1 is used for C.

Table 4
Emissions factor and energy consumption.

Month	Emission factor (tCO_2/Mwh)	Consumption (Mwh)
January	0.0294	111782.5
February	0.0322	109153.4
March	0.0405	118471.9
April	0.0642	105526.2
May	0.062	119266.0
June	0.0522	109888.8
July	0.0394	107616.6
August	0.046	112361.4
September	0.0783	109748.2
October	0.0984	114941.0
November	0.1636	105890.1
December	0.1168	104984.8

Table 5
Distance covered by employees and type of vehicle used (metropolitan area).

Vehicle	Distance (km)	Plus 15% for lunch (km)
Car	7,516,985	8,644,532
Motorbike	3,221,565	
Bus	6,368,000	

Table 6
Distance travelled by employees not using public transport (countryside units).

	Extra 15%	
Distance by car (60%)	3,229,866	3,714,345
Distance by motorbike (30%)	1,614,933	–
Distance on foot/by bicycle (10%)	538,311	–

Table 7
Emission factors.

Vehicle/Fuel				Source
Emission factors for employee and business travel				
Car/Alcohol		0.11780	kg CO_2/km	MMA (CO_2)/MCT (CH_4, N_2O)
		0.00001	kg CH_4/km	
		0.000004	kg N_2O/km	
Car/Gasoline		0.22690	kg CO_2/km	MMA (CO_2)/MCT (CH_4, N_2O)
		0.00001	kg CH_4/km	
		0.00001	kg N_2O/km	
Motorbike/Gasoline		0.22690	kg CO_2/km	MMA (CO_2, CH_4)
		0.00012	kg CH_4/km	
		–	kg N_2O/km	
Bus/Diesel		0.2671	kg CO_2/km	MMA (CO_2)/MCT (CH_4, N_2O)
		0.00002	kg CH_4/km	
		–	kg N_2O/km	
Emissions factors for type of fuel				
Gasoline		2.2690	kg CO_2/l	MMA (CO_2)/IPCC (CH_4, N_2O)
		0.0008	kg CH_4/l	
		0.00026	kg N_2O/l	
Diesel		2.6710	kg CO_2/l	MMA (CO_2)/IPCC (CH_4, N_2O)
		0.0001	kg CH_4/l	
		0.00014	kg N_2O/l	
Alcohol		1.1780	kg CO_2/l	MMA (CO_2)/IPCC (CH_4) (2006)
		0.0004	kg CH_4/l	
		–	kg N_2O/l	
Emissions factors for air travel				
Aereal distance	Increased to reflect the real route			
Long distance ($d \geq 3700$ km)	9%	0.1106	kg CO_2/passanger*km	DEFRA (CO_2)/(EPA, 2007) (CH_4, N_2O)
		0.00006	kg CH_4/passanger*km	
		0.000002	kg N_2O/passanger*km	
Average distance ($500 \leq d < 3700$ km)	9%	0.0983	kg CO_2/passanger*km	DEFRA (CO_2)/(EPA, 2007) (CH_4, N_2O)
		0.00006	kg CH_4/passanger*km	
		0.000002	kg N_2O/passanger*km	
Short distance ($d < 500$)	9%	0.1753	kg CO_2/passanger*km	DEFRA (CO_2)/(EPA, 2007) (CH_4, N_2O)
		0.00012	kg CH_4/passanger*km	
		0.000004	kg N_2O/passanger*km	

Table 8
Total emissions per source.

Category	Emissions (tCO_2eq)	%
Employee	5658.28	0.58
Energy consumption	90,402.78	9.35
Direct mobile	4970.86	0.51
Business travel by air	54.32	0.01
Business land travel	874	0.09
Wastewater management	865,426.92	89.46
Total	**967,387.16**	**100**

A calculation of the company's total consumption was made, based on both administrative and operational activities. Table 4 shows the emissions factor and consumption per month.

Scope 3. **Business travel** – An analysis of the distance covered during the year was required in order to estimate the emissions from business travel. Embasa does not register the distance travelled by employees on trips. Therefore, data from the daily control system, supplied by the financial execution division was used: information on the origin and destination of the journey, date and reason for the trip. The distance of each trip was then calculated using Google Maps, always considering the route covering the longest distance. The values obtained were then doubled to calculate the return journey. An estimate was made using the premise that the total distance covered was only made by one type of vehicle and also using the same type of fuel. The routes for air travel were classified as short, medium or long in order to apply the respective emission factors.

$$tCO_2e\ \text{emission} = \text{distance travelled} \times \text{emission factor}$$

where,

Distance travelled: estimated annual distance (either air or land travel);

Emission factors used in this study for air transport are based on the guidelines for Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting (Defra/DECC, 2012) and those for car passengers are based on the national inventory for road vehicles prepared by the Ministry of the Environment in Brazil (MMA, 2011).

Employee commuting – This concept corresponds to the distance covered during the house to work commute for each employee throughout the year. Emissions from employee commutes were estimated as follows:

$$\text{Emissions from employee commutes } tCO_2eq = \text{distance travelled} \times \text{emission factor}$$

Specific procedures were followed to estimate the distance travelled by employees as Embasa does not collect information regarding the route taken by its employees from their homes to work, nor does the company hold data regarding the type of transport and fuel used. Embasa registers the location of the home, the number of employees per business unit and if the employee receives transport benefits on its employee database. Embasa supplied data for 5765 registered employees through its Personnel Management Department, divided between the metropolitan region and the countryside. As the information provided was not sufficient for any calculations (no data on distance travelled and form of transport used), the following criteria was adopted:

1) employees who receive transport benefits: everyone uses the bus
2) employees who do not receive transport assistance in two groups:

Salvador and MRS (70% use cars, 30% use motorbikes)

Regional units (60% use cars, 30% use motorcycles and 10% bicycles or walk)

It was considered that cars and motorcycles run on gasoline, as the cost of alcohol in 2012 not was not advantageous; however, this assumption considers the worst emission setting.

Metropolitan area.-The route from the neighborhood in which the employee lives to the workplace was traced using Google Map, in order to estimate the distance travelled. For cases in which Google Maps provided two different routes, the longest one was used. It was considered that an employee commutes from house to work once a day, on 250 days, the number of working days per year. Therefore:

$$\text{Distance travelled} = \text{Distance from the neighborhood to the company}(\text{obtained from Google Maps}) \times 2 \times 250$$

In the case of employees using cars, a 15% increase in their commuting was considered in order to account for those employees who go home for lunch.

A more detailed analysis was carried out for the routes of 2692 employees in the Metropolitan Region of Salvador. The total for these journeys was 17,106,550 km. This was divided between employees who receive travel benefits (1,641, with 10,738,550 km) and therefore use the bus, and those who do not (1051 with 6,368,000 km). Table 5 summarizes the commuting data for the metropolitan area.

Regional units.-The data provided by Embasa's Personnel Management Department was used to calculate the GHG emissions for the 3073 employees from the business units outside the metropolitan area. The travel distance for each employee was calculated with Google Maps based on his/her home address and his/her respective workplace. As for the Metropolitan region, it was considered that an employee commuted once a day on 250 working days per year.

It should be emphasized that it was not possible to locate all of the addresses of Embasa's town offices or all of the employees' home addresses. In such cases an average distance was applied on the basis of those actually found. For the situations in which it was not possible to locate any of the addresses, it was considered that the employee's home address was in the city/town center and his work unit was the local office, thereby adopting the distance of 1 km. In all of the cases in which an employee lived in the city/town center, the Municipal Town Hall was adopted as the reference point for his home address.

Table 6 shows the distribution of employees that use their own means of transport to get to work in the countryside units.

The emission factors used for passenger transport are based on the national inventory of land vehicles prepared by the Ministry of the Environment in Brazil (MMA, 2011) and Second National Communication in Brazil (Ministry of Science and Technology of Brazil, 2010). Table 7 shows the emissions factor for type of fuel, for employee and business travel.

3. Results and discussion

The total GHG emissions of Embasa obtained with the above method are summarized in Fig. 2 and Table 8:

Scope 1. Wastewater management – The methane emissions from this activity came to a total of 865,462.92 tCO_2eq, constituting the most significant source (about 90%) of emissions among those analyzed. The removal of BOD by the sewage (anaerobic) treatment plants was responsible for the emission of 448,858.84 tCO_2eq/year, while the emissions from the untreated BOD that passed through the facilities and was discharged to the environment corresponded to 46,749.70 tCO_2eq. The emissions corresponding to the BOD which does not enter a treatment system was by far the highest in Scope 1: 369,818.38 tCO_2eq.

Gupta and Singh (2012) working with sewage treatment plants, found a more representative value for emissions in scope 2 (2863 tCO_2eq in a total of 3027.84 tCO_2eq), which refers to electricity consumption at the facilities. The main difference between the two studies is that these authors considered aerobic treatment plants and Embasa uses mainly anaerobic processes with no biogas burning. Therefore, in the first case, there is a lower production of methane but higher energy consumption. Moreover, the electricity mix in the Brazil is mainly clean (84.5% was hydroelectricity in 2012). This is one of the reasons why the emission of BOD removed by the plants was similar to the emission of BOD which is not removed. Table 9 shows the results.

Direct mobile combustion – The sanitation company consumed approximately 1,449,433 L of diesel, 647,960 L of gasoline, and 431,967 L of alcohol in 2012. The associated emissions

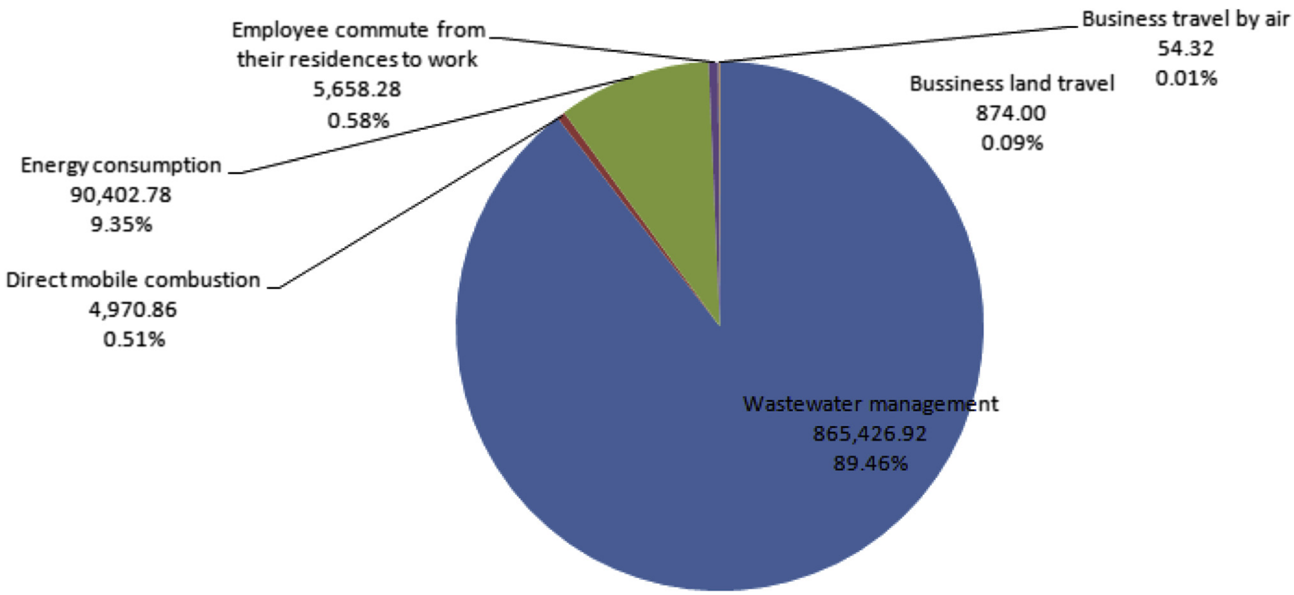

Fig. 2. Emissions results.

were 3741.00 tCO_2eq, 1226.37 tCO_2eq and 3.48 tCO_2eq respectively, producing a total of 4970.86 tCO_2eq.

It is suggested that the company began to gradually use a larger quantity of alcohol, with the aim of reducing diesel emissions. An additional option especially in the metropolitan area may be a carpooling program.

Scope 2. **Energy consumption** – The total emissions resulting from electrical energy consumption was 90,402.78 tCO_2eq/year. Of the total emissions relating to energy consumption, 89.62% refers to water supply, 9.6% to wastewater and 0.74% for administrative activities. Thus, the company should adopt energy efficiency measures in order to reduce consumption associated to these activities and, consequently, indirect emissions in scope 2.

Scope 3. **Business travel** – Trips made by air were divided into short, medium and long distances, in order to apply the proper emission factor. The resulting emissions were 0.662, 49.54 and 4.12 tCO_2eq respectively and 54.32 tCO_2eq as total emissions.

Regarding land travel, 5765 business trips accounted for a total of 3,796,748 km covered during 2012. The emission factors for two different fuels were used in order to obtain the highest value. If a car fueled by alcohol is considered the emissions are 452.8 tCO_2eq.

Therefore, it was assumed that all of the journeys were made by cars using gasoline, so 874 tCO_2eq, were produced.

Information regarding the type of vehicle used by employees for business land trips was not available. Generally, they are carried out using rental cars which are under the company's control. However, they may also be made by bus. We maintained the emission as scope 3, as the calculation related to business trips was lower than expected. Embasa has a significant number of service providers who work at their installations but control of their daily costs for business travel is dispersed throughout the human resource management for the various service providers. Therefore, a survey of the number of trips made by these workers was not possible, constituting a limitation to this study.

In order to improve the calculations for business trips, Embasa needs to create a database containing information on trips, such as the route and means of transport used. The service providers also need to report this information, which should also be entered into this database.

Employee commuting – The total emissions as a result of employees travelling within the metropolitan region was 4432.71 tCO_2eq. The emissions for commuting in the countryside were 1225.57 tCO_2eq.

As per the business trips, the emissions in this category were lower than the actual figures, considering that the personnel from the service companies were not included. To improve the inventory, it is suggested that the company gathers data on its service suppliers. As proposed for business trips, it is recommended that a database is created containing information on the employee's home address and the form of transport used. The transport information may be obtained by inserting this into the employee record controlled by the Personnel Management Department.

According to the Ministry of Science, Technology and Innovation (MCTI, 2013), Brazil emitted 1,246,677 Gg CO_2eq in 2010, with the waste sector being responsible for 4% of the country's total emissions. Despite this sector's low percentage within the country's emission profile, it was confirmed that emissions increased by 16.4% between 2005 and 2010. There was a 6.2% increase in sewage treatment in particular. Brazil emitted 9030 Gg CO_2eq) in 2010. With sewage coverage in Brazil reaching only 64.3% (Brazilian Institute of Geography and Statistics – IBGE, 2013), an increase in

Table 9
Emission Factor and carbon emissions from wastewater.

Category	Emissions factors (kg CH_4/kg BOD)	Methane emissions (t CH_4/year)	Carbon emissions (t CO_2eq/year)
BOD Removed	0.0950	21,374.23	488,858.84
BOD discharged	0.0782	17,610.39	369,818.38
BOD not removed	0.0098	2226.18	46,749.70
Total			865,426.92

emissions may take place depending on the technological option selected to treat this waste. 15 countries in the EU (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom) emitted 4999 Gg CO_2eq relating to methane from wastewater treatment (EEA, 2014) in 2012. Thus, the importance of Brazilian companies preparing greenhouse gas inventories and outlining strategies to reduce emissions is confirmed. A reference to SABESP is pertinent in this case. This is the largest sanitation company in Brazil, serving a population of 24.2 million, including 59% of the city of São Paulo, which is the most populous city in the country. SABESP emitted 1,163,054 t CO_2eq related to wastewater treatment systems, 57,327.99 t CO_2eq linked to discharge and wastewater collected and untreated and 110,968.94 t CO_2eq on indirect energy emissions (SABESP, 2013) in 2010. With regards to COPASA, which is the second largest sanitation company in Brazil, which serves 14 million people and is equivalent to 78% of the population in the State of Minas Gerais, it emitted 437,226.60 t CO_2eq related to methane emissions and 55,033.96 t CO_2eq on energy emissions (COPASA, 2013) during 2012. Embasa produced methane and energy emissions which were higher than those of COPASA. The high level of Embasa's emissions for wastewater treatment is related to a higher proportion of anaerobic treatment technologies, without burning methane or making use of it. COPASA, for example, is more advanced in this area, having reduced emissions by 13,713 t CO_2eq through using biogas. Embasa, one of the largest sanitation companies in Brazil, therefore has great scope to review its processes in the search for energy optimization and emission reduction.

4. Conclusion

It was found that the emissions resulting from sewage management constitute the largest source of GHG at the sanitation company studied, when considering the scopes defined in this work.

The main difficulty in preparing a GHG emission inventory at the company studied was data collection due to Embasa's extensive area of coverage and the absence of a central information system containing the data necessary to quantify GHG emissions. Furthermore, additional work to incorporate the supply chain (scope 3) into the inventory and an uncertainty analysis is necessary.

A number of actions are recommended in order to reduce GHG emissions at Embasa, based on the results of this study. Biogas capture and reuse in anaerobic reactors and the use of biodiesel (ethanol) for transportation could result in a reduction in GHG generation.

The amount and sources of GHG emissions calculated in this research could support proposals for reduction targets and to carry out benchmarking, which can be achieved through incorporating GHG reduction measures into the company's strategic planning and presenting this in its sustainability report. The results can also help other water companies to implement GHG reduction measures.

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