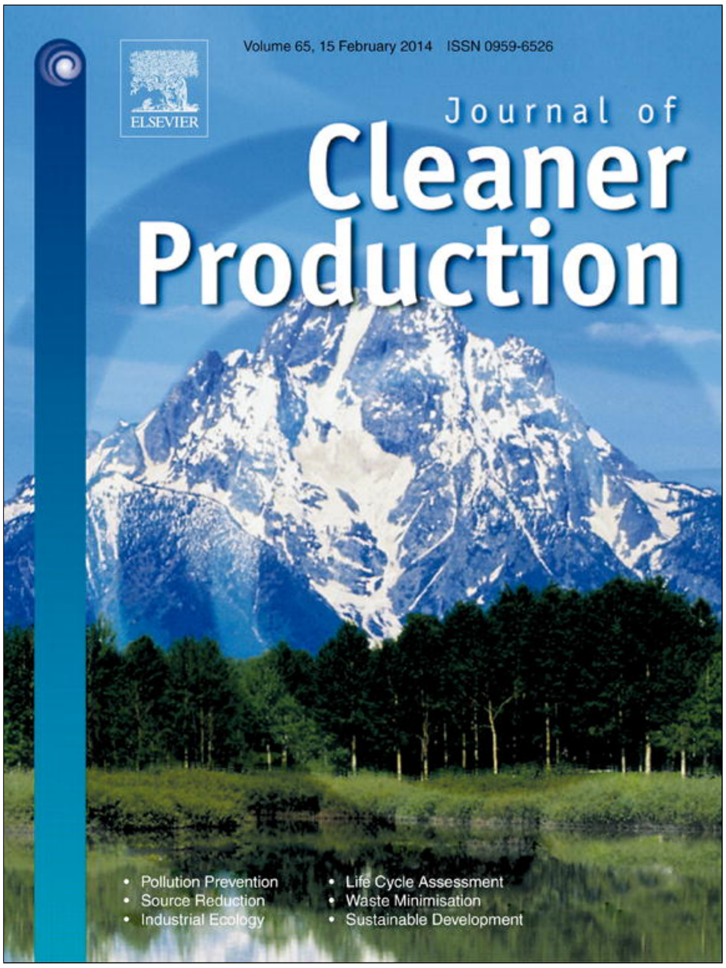
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Assessment of the viability and sustainability of an integrated waste management system for the city of Campinas (Brazil), by means of ecological cost accounting

Kely Cristina Passarini, Maria Aparecida Pereira, Thiago Michel de Brito Farias, Felipe Araújo Calarge, Carlos Curvelo Santana*

Industrial Engineering Post Graduation Program, Nine July University, UNINOVE, Av. Francisco Matarazzo, 612, Água Branca, 05001-100 São Paulo, SP, Brazil

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A B S T R A C T

The population growth of cities increases the generation of construction building waste (CBW) and wastewater and, respectively, their environmental impacts. The present study shows a new technology to manage of the sewage and construction wastes from Campinas city, Brazil, based on the ecological cost accounting theory. In this way, the treatment of the crude sewage from Anhumas Wastewater Treatment Plant was made by decantation using the construction building waste. The organic amendment was obtained from the decanted sludge, which has been used in the recovery of a poor soil. From the supernatant liquid was obtained the reusing water, which has been tested in irrigation process. The efficiencies of the organic amendment and reusing water have been assessed by the quantity of the germinated bean seeds on the poor soil. Results show that the best condition to organic amendment production was the one in which a total soil layer of 2 cm and 100 mL/L of CBW were used, which yielded a gain in soil fertility of 11.11%. It was verified that 85% of bean seeds have been germinated on soil, when it irrigated these seeds with the reusing water, being 6% larger than control water. All parameters of lower water quality were reduced above of 90%, keeping the water in according to Brazilian standards. The cost evaluation of reusing water and organic amendment production shows a saving of US$ 81.1 million, indicating the social, ecological and economical viabilities of the new technology developed and demonstrated in this work. In that sense, this work provided a possible environmental solver based on the ecological cost accounting theory for the city of Campinas, Brazil.

1. Introduction

In accordance to Leonidou and Leonidou (2011), the interaction of companies with natural environmental has been an issue of interest for researchers from various fields for a long time; it was not until the late 1960s that it was included in the research agendas of marketing and management scholars. Stricter environment regulations, stakeholder pollution concerns, and growing public pressure were among the forces that contributed to the emergence of a new line of academic inquiry, focusing on the effects that producing practices exercise on the environment, and how this in turn influences them.

According to Ronnenberg et al. (2011), corporate environmentalism is an essential component of corporate social responsibility and it can take several forms: waste minimization and prevention, demand-side management, design for the environment, product stewardship, and full-cost accounting. The collaboration between different sectors companies is essential for better practices and efficiencies (Mc Donald and Young, 2012).

Boons et al. (2013) describe that any significant alteration of the dominant economic logic involves, or may be even necessarily starts from, the application of new business models by social actors seeking to promote more sustainable ideas, which may also lead to different types of practices and sustainable innovations. If our wellbeing is served by leaving the path of economic growth, then each of the dimensions of business models as identified above needs to be altered: value propositions need to reflect the true needs of citizens, and the distribution of revenues needs to be defined in categories other than purely economic ones. This will also require that the way through which firms connect to each other and wider society requires a fundamental change.

Unfortunately, in accordance with Giraçol et al. (2011), these practices are not common in Brazilian sanitation companies, which

* Corresponding author.
E-mail addresses: kelly_passarini@yahoo.com.br (K.C. Passarini), mapereira@fmr.edu.br (M.A. Pereira), tfarias@uninove.br (T.M.B. Farias), fcalarge@uninove.br (F.A. Calarge), jccurvelo@yahoo.com.br (C.C. Santana).

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just implement the minimum conditions for their plants, in order to avoid the pressures of environmental regulation. However, in Brazil there are few aware companies that have a corporate environmental thinking.

In this study was conducted in one Brazil's large urban concentration with a strong water demand, causing critical conditions of sustainability due to their extremely high loads of domestic and industrial pollution, as well as the occurrence of urban flooding that contaminates fresh water sources. On the other hand, recycling of construction waste in Brazil is still incipient and few adequate techniques are employed.

The aim of the present study was to reuse of construction building waste (CBW) and sewage from Campinas city, in order to produce humus and reusing water. The CBW was used in decantation of sludge from sewage and to obtain the humus. The sewage water was filtered in a membrane of microfiltration and used in irrigation. Bean seeds were used in germination on a degraded soil mixed with CBW humus and irrigated with reusing water. In that sense, this work provided a possible environmental solution for CBW and sewage based on the theory of ecological cost accounting for the city of Campinas, Brazil.

1.1. Ecological cost accounting: paradigms and concepts

Given the current need of organizations to obtain and provide information to its stakeholders, managers have struggled to formulate and implement strategies and information systems while also addressing the environmental focus. In this sense, management systems and accounting information plays an important role for the hierarchical control of information flow within an organizational context (Cavalett and Ortega, 2010; Dillard et al., 2005).

The need for information on how environmental activities can affect the financial performance of the organization, has contributed to the further development of accounting tools for use in corporate sustainability practices (Schaltegger and Burritt, 2010).

In that sense, economic performance results from improvements in environmental performance, and therefore the managers should be aware of the importance of integrating environmental issues in management control systems, focusing in the eco-style control over financial control and strategic management methods (Henri and Journeault, 2010).

According to Burritt and Saka (2006), Giraçol et al. (2011) and Labodová (2004), the discussion regarding sustainable companies does not only relate to large companies, which are pressured by their shareholders to demonstrate that their businesses are not running the risk of being devalued due to improper social and environmental attitudes. Small businesses are also now seen by society as offering possible risks to the environment in which they operate.

Nowadays, different environmental solutions to reduce production processes impacts have been investigated in wide industrial areas, for example in the case of cleaner cars in the automotive industry (Zapata and Nieuwenhuis, 2010), companies are developing sustainable technologies to achieve feasibility of the ethanol produced from sugarcane of a large-scale production (Delivand et al., 2012; Ometto and Roma, 2010; Pereira and Ortega, 2010); the reuse of beef tallow in biodiesel production (Pereira et al., 2012) or in food industry after treatment by ultrasound (Sivakumar et al., 2012) to be used as collagen, jam and jelly products (Almeida et al., 2012a,b,c) to avoid the problem of freezer industries instead of been dispensed at unsuitable site, allowing cost reduction in packing industry by its waste reuse (da Cruz et al., 2012).

The companies, at implementing the new and efficient system of effluent treatment, show a proactive and compromised posture facing the environmental problems by measuring and eliminating its negative externalities, not causing impacts coming from its production process becoming sustainable, reducing water consumption and discharge of polluting effluent (Fresner and Engelhardt, 2004).

The Ecological Costs Accounting (ECA) approach seeks to establish an analysis that allows integrating the internal costs with the external costs, including the environmental and social impacts of the activities, operations, products and/or services from the organization (Criado-Jimenez et al., 2008; Fernandez-Chulian and Larrinaga-Gonzalez, 2005; Burritt and Saka, 2006; Fresner and Engelhardt, 2004).

In that sense, the ECA has a different approach considering the Traditional Costs Accounting (TCA), which presents limitations regarding environmental aspects, exempting the intangible benefits and social impacts of the environmental actions. In addition, the TCA is restricted to the internal costs and environmental investments of the organization, mainly related to the prevention, mitigation and remediation of environmental impacts (Criado-Jimenez et al., 2008; Ronnenberg et al., 2011).

According to ECA approach, one of the major constraints of the TCA lies in not considering the concept of "externality", that can be understood as the social and/or environmental impact coming from the organization's activities, which can affect in a favorable or unfavorable way other activities during the organization's productive process. The externalities may be considered in a positive or negative way, being these situations one of the crucial points toward the success in the ECA implementation (Fernandez-Chulian and Larrinaga-Gonzalez, 2005; Criado-Jimenez et al., 2008; Labodová, 2004).

However, the utilization and dissemination of the ECA approach throughout the industrial organizations is still on preliminary stages, despite the discussion of this subject has begun about two decades ago (Huizing and Carel Dekker, 1992; Bennett and James, 1997).

The literatures list ECA such initiatives have proven to offer adequate quality and efficiency and help maintain a company's good image in the eyes of society.

Upon achieving self-sufficiency, such companies can be rewarded for their practices with ISO 9001, ISO 14001 and OSHAS 18001 certifications in a separated or integrated way. Therefore are accounted costs for changes in the processes so that they become sustainable and these costs are discounted with the reduction in spending on the purchase of raw material, water, energy and the reduction of costs derived from fines for discharges outside environmental standards. In addition to the environmental and economic benefits, companies gain generates social benefits, not impacting on the health of the workers and the surrounding population, improving the image, which also generates benefits as better acceptance of the products, which are viewed as environmentally friendly (Burritt and Saka, 2006; Fresner and Engelhardt, 2004; Giraçol et al., 2011; Rosa et al., 2013).

The ECA stages suggested for an eco-friendly solution for discarding wastes are presented below (Burritt and Saka, 2006; Fresner and Engelhardt, 2004; Giraçol et al., 2011; Labodová, 2004):

Stage 1 – the current unsustainable position of the company: most of the environmental impacts result from process feedstock and waste production.
Stage 2 – a more sustainable position in which a company is taking steps to reduce its impact on the environment.
Stage 3 – a position in which operations should have no impact on the environment.
Stage 4 – a position in which a company is self-sustainable, whereby the environmental accounting balance of its operations results in credits for the company.

1.2. Management of sewage in Brazil

Currently, fresh water to address the basic needs of the population is becoming scarce due to wasting activities, population grow and contamination of natural sources. Furthermore there is a lack of implementation of water resource management policies in order to minimize the impacts produced by human activities. In a global perspective, available water resources are no longer sufficient to adequately supply the population. In the current period there are today approximately 26 countries that shelter 262 million people, which represent areas under water shortage. Corroborating with this, several studies have reported an increased and unrestricted exploitation and pollution of water bodies reducing its quality and quantity, restricting thus the possibility of multiple uses (Andrade Filho et al., 2013).

Large concentrations in Brazilian urban areas exhibit critical unsustainability conditions due to excessive domestic and industrial pollution loads, and frequent urban flooding contaminating water sources, besides the strong demand for water and climate change (Passarini, 2011) and changes climate. The National Agency of Water or *Agência Nacional de Águas* as called in Portuguese (ANA, 2003) have data that indicate the existence of several rivers in the country in which demand has already reached 40% of the offer, which becomes even more serious when the availability is restricted, since the index pollution that many of those present. Faganello (2007) complements the context citing that around 70% of the fresh water in Brazil is located in the Amazon Basin, home to only 7% of the population, leaving only 30% distributed in other regions of the country, which concentrates 93% the population. However since 2007 users of water services and sewage have a number of rights guaranteed by the Law of Sanitation. Besides Federal law provides for the universalization of water and treatment of sewage system to ensure the health of Brazilians.

With regard to the treatment of sewage, Brazil is a step behind with respect to developed and developing countries. In Brazil, more than 90% of cities haven't wastewater treatment stations, however, population areas with treatment processes correspond to 47% of the population. To the present, in case of fresh water supply, considering the urban and rural areas of the country, the distribution of water reaches more than 80% of the population. However, according to the plan of the federal government, it is predicted that by 2025 the entire Brazilian population is benefited from the treatment of sewage (TRATA BRASIL INSTITUTE, 2013).

Water consumption per inhabitant in Brazil grew 7.1% in 2010 compared to 2009: the daily consumption per capita reached 159 L. The region with the lowest consumption is the Northeast, with 117 L per capita per day, whereas the region with the highest consumption is the Southeast, with 186 L per capita per day. Thus, between 2009 and 2010, there was an increase in piping extension of 2.2 million and 2.4 million, respectively for water and sewer distribution networks, of the country, which generated revenues of US$ 36 billion. Also, Brazilian Government increased the investment to US$ 4.5 billion, demonstrating that the country is interested in investing in this area (TRATA BRASIL INSTITUTE, 2013).

The most commons equipment set used in Brazil are: facultative pond combined with anaerobic pond, facultative aerated lagoon, sedimentation lagoon and stabilization pond; low rate infiltration, rapid infiltration overland flow and constructed wetlands; UASB reactor combined with aerated biofilter, active sludge, maturation ponds and conventional active sludge extended aeration and tertiary filtration. Amongst cities that are treating their sanitary effluents, Oliveira and Von Sperling (2005, 2007) and Von Sperling and Oliveira (2009) were evaluated 166 wastewater treatment stations and had realized that none of these stations reached the indices with established by national standards. There were a large gap between real concentrations and those limits necessaries to meet the national legislation. However, it appeared that the stations that use activated sludge lagoons showed satisfactory results with respect to the targets set in their projects. This shows that Brazil is in a worrying situation, since only half of the treated sewage is reaching national standards.

Von Sperling and Chernicharo (2002) appointed the implementation sanitation and sewage treatment depends largely on the political will and, even when this is present, financial constraints are the final barriers to undermine the necessary steps toward environmental restoration and public health maintenance. Brazil's situation is that cities that have implemented its policy of treating sewage are not concerned with achieving the indices established by CONAMA 357 legislation, instead only fulfill the established by the law of sanitization: collect and treat, instead of treat with CONAMA's (2005) rules.

Currently, the usage of wastewater has been proposed primarily for irrigation purposes in agricultural field (Faganello, 2007). As Sousa et al. (2006) which have been reused the sanitary wastewater treated with chlorine in the production of chili (*Annuum* L.); which showed satisfactory results of about 80% of seed germinated with respect to plants grown with treated water. Mazen et al. (2010) have been studied the soil recovery from desert using the sanitary wastewater and its potential impacts on wheat and jews mallow plants. The nutrient contents gradually increased as the ratio of sewage sludge increased. About 70% of variously treated test plants were increased to add of the sewage sludge levels in the soil. However, Batista et al. (2010) have observed the bacterial biofilm into pipe in micro-irrigation of coffee plants with crud sewage. This problem was solved to add a 550 mesh membrane in feeding of the pipe line. Souza et al. (2011) had verified the microbiological contamination of soil by irrigation with untreated sewage Results show that the contamination of soil surface by fecal coli forms increased with decreasing soil depth. It has been also verified by Herpin et al. (2007) in irrigation of coffee crops.

1.3. Management of construction building waste

The construction building waste (CBW) constitutes one of the groups of solid waste that causes more environmental impact. In most municipalities there is a place for the reception of such residues that occupy large areas and can mostly hide unwanted animals and contaminate water bodies and soil. There are certain emergency to seek the reuse of CBW, as well as their insertion in the production chain. ABRELPE (2013) emphasized that this mass of CBW in total solid waste generated in Brazilian cities is around 150 tons. It is estimated that this chain of actions is responsible for consuming 20–50% of all natural resources, renewable and non-renewable.

In Brazil, Levy (2007) and Passarini (2011) found that construction wastes are composed mainly of bricks, mortar and sand (around 80%). In a still smaller proportion were found concrete debris (9%), stones (6%), ceramics (3%), gypsum (2%) and timber (1%).

The main health and environmental impacts related to CBW, or spoil as it is known, could be those associated with irregular depositions, a conjunction of detrimental effects on the local environment: commitment landscape, pedestrian traffic and vehicles and urban drainage, soil compaction, degradation and contamination by the accumulation of garbage dumps in their surroundings, attracting non-inert waste, proliferation of disease vectors and other effects (Passarini, 2011). However the reuse of these wastes has been done in countries such as the Netherlands getting a reuse of construction waste around 80 and 90%, in the same level as Belgium, Germany, Austria, Switzerland and the Province of

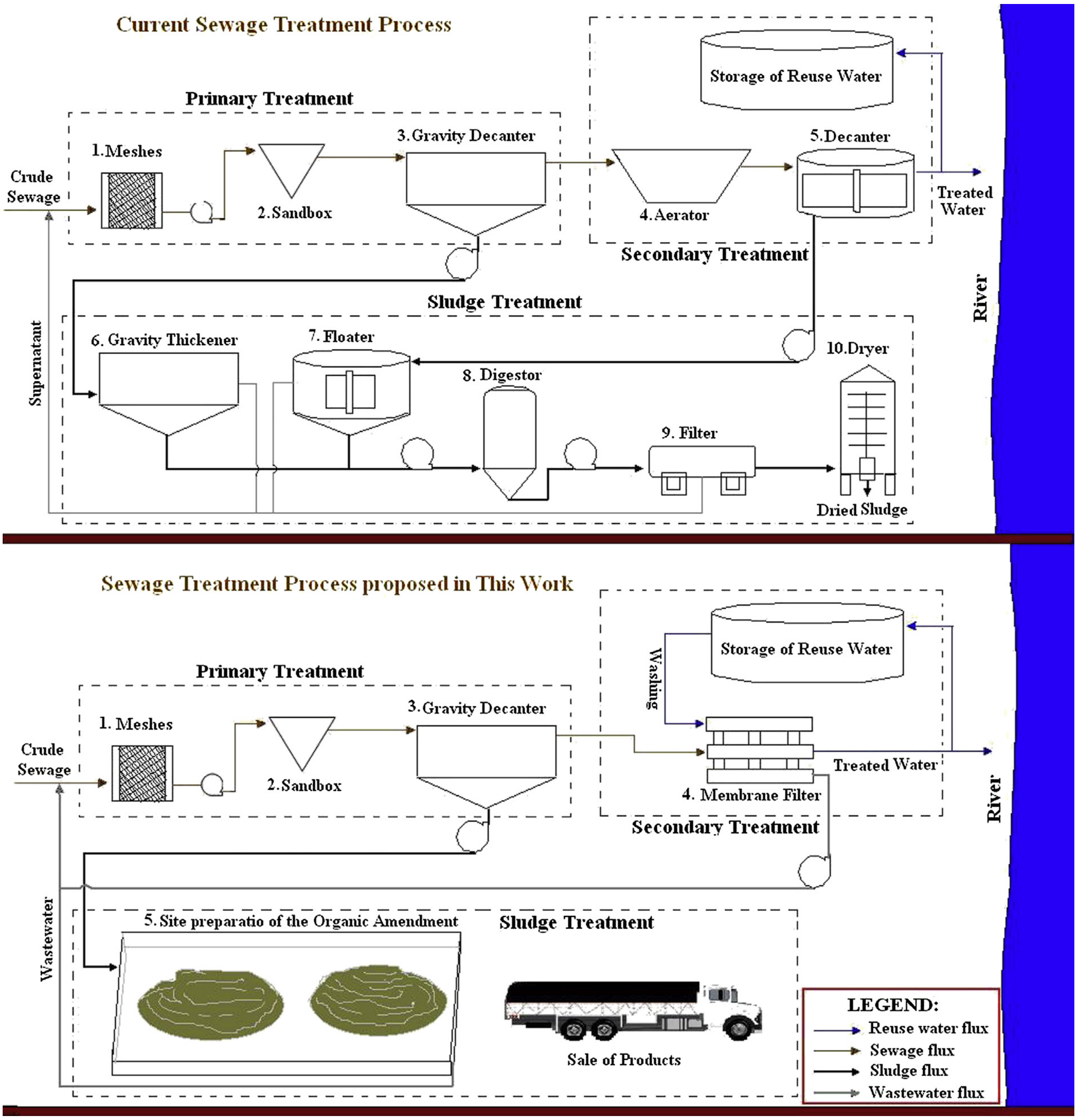

Fig. 1. Current stage of sewage treatment process and new sewage treatment process proposed in this work.

Bolzano, Italy. About 90% of all natural stone, sand and gravel from heavy engineering construction are reused and about 60% of the asphalt and 80% of wood are converted into energy (Passarini, 2011; Silva et al., 2010). According to Levy (2007), in Brazil, this practice of reuse began in the 80s.

The CONAMA Resolution 307 (CONAMA, 2002) establishes criteria for correct segregation, classification and allocation, as well as recycling and rationalization of wastes from the construction industry processes. And, the current National Policy on Solid Waste (BRAZIL, 2010) establishes the legal instruments of reverse logistics and shared responsibility in order to ensure movement in this direction involving all actors responsible for the life cycle of the product to its final destination.

According to Levy (2007), the quantity of wastes generated by construction in cities is such that, if this material were completely reused, all the needs of new street pavement or even the construction of low-income housing, for instance, could be fully met. Some forms of reuse of construction waste have been shown in research studies as of de Castro and de Brito (2013), Lopes (2010), and Levy and Helene (2004).

2. Material and methods

2.1. Process description

Current stage of sewage treatment process is shown in Fig. 1, composed of following steps: 1) the crude sewage from the city enters in the sewage treatment plant and feeds a tank containing meshes separating coarse material; 2) then the liquid flows into another tank where is retained the sand; 3) immediately after the liquid enters a primary decanter where the solids are retained, 4) then to be aerated and 5) finally the liquid will feed a decanter which 90% of the total solids retained. A part of the treated wastewater is discharged into the river and other part is stored to market as a water reuse. The sludge from decanters passes for following steps: 6) it is compressed and 7) floated to then pass by 8) a biological treatment in a digester; 9) immediately after this material is filtered and 10) dried to follow to landfills. It is also seen in Fig. 1 the sewage treatment process proposed in this work, which is composed of steps 1, 2 and 3 and the liquid leaves of decanter 4) feeds the membrane filter, which can treat the effluent converting water got a product of high quality of according Brazilian Law. The sludge from decanters passes for following steps: 5) it is put in a resting place on at home conditions, it is mixed with grass and turned over from time to time to transform in organic amendment.

2.1.1. Decantation

The crude sewage was supplied by the Sewage Treatment Plant of Anhumas (STP Anhumas) from Campinas, SP, Brazil, which is operated by the water and sewage utility SANASA. It is located on the right side to São Paulo Campinas of SP-065 Dom Pedro highway, coordinates 22°50′43″S 47°1′48″W. The sewage was collected at the outlet of the incoming bar screen, the only path for the piped wastewater to enter the treatment plant.

The CBW was provided by Poli-technique School of State University of São Paulo (USP) and treated and characterized of according to Levy and Helene (2004) and Levy (2007). The average composition of CBW used in this work was 43.75% (±9.24%) of concrete, 28.18% (±10.99%) of grout, 22.95% (±11.34%) of stone and 3.89% (±3.75%) of ceramic. These values are an average of the samples provided by various companies in the state of São Paulo, Brazil to USP.

Different volumes of CBW were mixed with 2 L of domestic sewage in decanters with a useful volume of 3 L, on a laboratory scale. The mixtures were allowed to rest until decantation was completed, in order to separate the supernatant liquid and sludge. The complete process took 15 h. This supernatant was stored separately for subsequent irrigation of bean seeds. The sludge was used to obtain the organic amendment (Biazus et al., 2009; Severo Jr. et al., 2007).

2.1.2. Organic amendment preparation

Soil used in this work had a red-yellow clay soil field surrounding the STP Anhumas. The grasses were collected from a public garden after mowing in the same city (surrounding the STP Anhumas) and were not treated in any way in order to simulate their incorporation into the soil as naturally as possible (Mazen et al., 2010; Yamanishi et al., 2004).

The sludge and grasses were added to the degraded soil and left for 15 days, to obtain of the organic amendment. Factors influencing fertility were evaluated, thereby varied the layer of total soil (TSL) (2–4 cm) used in germination cubes and the volumetric content (100–200 mL/L) of the organic amendment obtained after decantation of sludge with CBW. As a response, was measured the increasing of soil fertility due to the application of the amendment to measure the efficiency of this step, as showed in Equation (1) (Mazen et al., 2010; Silva et al., 2006; Yamanishi et al., 2004). Calculation of the increasing of soil fertility is showed in Equation (1) (Mazen et al., 2010; Santos and Paula, 2009; Sousa et al., 2006).

$$\text{Increasing Soil Fertility (\%)} = \left(\frac{SG_{OA} - SG_{Control}}{SG_{Control}}\right) * 100 \quad (1)$$

where $SG_{Control}$ and SG_{OA} are the total of seeds germinated in soil without and with organic amendment, respectively.

2.1.3. Germination

The selected bean seeds of good quality, which came from the state of Paraná, were purchased at the city's municipal market. The organic amendment was put into germination cubes with dimension 30 × 20 × 5 cm, in which 20 bean seeds were planted and germinated under the following conditions: a photoperiod of 12 h at 25 °C ± 3 °C and irrigated daily with 50 mL of reuse and control water, according to the standards in Brazil and showed by Santos and Paula (2009), Silva et al. (2006) and Sousa et al. (2006). The growth of the seeds was accompanied for up to twenty-one days. Each growth assay from Table 1 was performed in triplicate, a total of 60 seeds were grown and from these the average and deviation were calculated for each assay. As used two irrigations source (control and reuse water) was necessary to make another triplicate for each growth assay. For each assay was also used two control assay containing the seeds planted in the soil control, both with 20 seeds and without organic amendment, however, one was irrigated with control water and the other with the reuse water.

2.1.4. Water reuse

The experiments were conducted in a membrane module composed of a polyvinyl acetate membrane (TECH-SEP-6501 model) with an area of 707 mm^2 and a pore size equal to 0.4 μm. The flow fed was tangential to the membrane surface, with a discontinuous operation and a concentrate recirculation (Lopes et al., 2009, 2012; Severo Jr. et al., 2007; Zarragoitia et al., 2009). In this experiment, the water from water supply network has been used as a control water. Water reuse efficiency was calculated based on Sousa et al. (2006) and Mazen et al. (2010), as is shown in Equations (2) and (3).

$$\text{Water Reuse Efficiency (\%)} = \left(\frac{SG_{\text{Water Reuse}}}{SG_{\text{Control Water}}}\right) * 100 \quad (2)$$

$$\%\text{Germination} = \left(\frac{SG_{\text{Sample}}}{TSP}\right) * 100 \quad (3)$$

where $SG_{\text{Control Water}}$, $SG_{\text{Water Reuse}}$ and SG_{Sample} are the total of seeds germinated on action of control and reusing water and total of seeds germinated in anyone samples; TSP is total of seed planted on the soil. All statistical analyzes of data was performed based on Farias et al. (2012).

2.1.5. Analysis of samples

The metal composition of soil, CBW and organic amendment was analyzed by mass spectrometry (Watanabe et al., 2007) and showed in Table 2. Water quality parameters as DQO, pH, turbidity, total solids, turbidity and microorganisms have been measured of according to standard methods for the examination of water and wastewater (Eaton et al., 1995) and have been capered to CONAMA 357/05 Brazilian Laws, such as showed in Table 3.

2.2. Strategies for the ecological cost accounting

Calculation of costs, purchases and savings were made accordance to Giraçol et al. (2011), Lopes et al. (2012), Novaes (2007) and Rosa et al. (2013); and some data provided by sites ANHUMUS (2011) and SANASA (2011). The steps suggested for an eco-friendly solution for discarding wastes are presented below.

- Conduct assessment of current conditions in the city with respect to its situation of pollution of rivers and water sources and the soil and surrounding environment;
- Obtaining the city record for environmental liabilities, fines and contamination of soil and water;
- Assessing people's thinking about the pollution generated by CBW and the disposal of sewage treated badly in rivers;

- Assessing people's thinking on good practices that reduce or eliminate pollution from CBW and the disposal of sewage treated badly in rivers;
- Evaluating people's thinking about companies that are environmentally friendly;
- Determine the amount of sewage treated daily in the sewage treatment station and obtain the maximum amount of reused water for month of according to Equation (4) (SANASA, 2011). Of according to SANASA the average sewage flow is 66,960 m^3/day (2,008,800 m^3/month).

$$\text{Reuse Water Amount}\left(m^3\right) = \left(\text{Sewage Flow}\left(m^3/\text{month}\right) - 0.0035\right) \bullet \text{OperationTime}\,(\text{month}) \quad (4)$$

where 0.0035 is the total solid for each m^3 of sewage (showed in Table 3).

- Obtain the CBW amount required for the wastewater treatment for best condition, while had been determined by Passarini (2011) and its value was 0.248 ton of CBW for each m^3 of crude sewage.
- and calculate the maximum amount of organic amendment can be obtained at the end of decantation process by the use of Equation (5);

$$\text{Organic Amendment Amount (ton)} = (0.248 + 0.0035) \bullet \text{Treated Sewage}\left(m^3\right) \quad (5)$$

where 0.248 is CBW amount (ton) and 0.0035 is total solid (ton) for each m^3 of sewage.

- Presents the potential profit for each product, demonstrating its advantages compared to others that are being marketed. These purchases can be obtained by the use of Equation (6) (Almeida et al., 2013). According to ANHUMUS (2011) the average selling price of the organic amendment is US$ 161.36 for ton and according to SANASA (2011) the selling price of reuse water is US$ 7.06 for each m^3 of liquid.

$$\text{Product Profit (US\$)} = \sum_{j=1}^{m} \text{Selling Price}_i \bullet \text{Product Amount}_i \quad (6)$$

- Therefore, calculate the cost of acquisition of CBW was made of according to Equation (8) (Almeida et al., 2013). Before this calculation must be made to calculate the CBW amount used in decantation process by Equation (7). The unit cost provided by a CBW supplier placed in Barueri, SP, Brazil, is US$ 14.70 for each ton (Passarini, 2011).

$$\text{CBW Amount (ton)} = 0.248 \bullet \text{Treated Sewage}\left(m^3\right) \quad (7)$$

$$\text{Material Costs (US\$)} = \sum_{i=1}^{n} \text{Unit Cost}_i \bullet \text{Material Amount}_i \quad (8)$$

- Compare the price reduction with respect to the purchase of chemicals (current treatment) (SANASA, 2011);

Table 1
Experiments and results obtained for seed growth assay.

Assays	Organic amendment (mL/L)	TSL (cm)	Increasing of soil fertility (%)
1	100	2	11.11[a]
2	200	2	11.11[a]
3	100	4	5.56[b]
4	200	4	0[c]

TSL = total soil layer (cm). a, b, c = different letters indicate that there are significant differences at 95% of level confidence.

- Determine a market logistic and calculate of transport cost according Equation (9). In this study a distribution zone of 50 km radius has been considered (Almeida et al., 2013; Lopes et al., 2012; Novaes, 2007).

$$\text{Transport Cost (US\$)} = (14.41 + 0.28 \bullet \text{Distance Traveled (km)}) \bullet \left(\frac{\text{Total Volume Transported}\,(m^3)}{\text{Truck Capacity}\,(m^3)}\right) \quad (9)$$

- Calculate the profit from the sale of reuse water and organic amendment of according to Equation (10) (Almeida et al., 2013);

$$\text{Profit (US\$)} = \text{Product Profit} - \text{Material Costs} - \text{Transport Cost} \quad (10)$$

- Reposition the company after checking each phase completed. Questionnaires should be used to check the progress of the company and acceptance noticed by the people (Burritt and Saka, 2006; Giraçol et al., 2011; Rosa et al., 2013).

3. Results and discussions

After adding CBW to the domestic sewage, the color of the sewage changed from black to yellow. This is because the material that makes up CBW exerts electrostatic attraction, causing particles of organic matter to adhere to it. Floccules were formed in the medium, which favored their precipitation, clarifying the effluent. As the organic amendment production time proceeded, it was found that the soil, which originally was red, took on a darker color, likely due to the incorporation of organic matter. In the trials with humus, the bean seeds began sprouting two days after planting. After three days in the germination vats, the seeds germinated uniformly and grew fast in the vat containing humus than in control soil.

Table 1 shows the results obtained to ascertain the improvement in soil fertility. As can be seen, the best results were obtained with the smallest total soil layers (TSL), independently of the quantity of CBW used to precipitate the sludge. This is due to the fact that CBW has a small amount of nutrients that can be associated with the enrichment of organic amendment, and its only action is in aggregating particulate material from the sewage, which leads to the formation of sludge. This indicates that the nutrients of the organic amendment came exclusively from the sewage (organic matter that precipitated into sludge). The best condition was the one in which a TSL of 2 cm and 100 mL/L of organic amendment was used, which yielded a gain in soil fertility of 11.11% and minor quantity of organic amendment is used.

Yamanishi et al. (2004) found that mixing humus or manure in soils increases the rate of germination and growth of parts of the

Table 2
Inorganic composition of control soil, CBW and organic amendment.

Analysis	Soil	CBW	Organic amendment
Na (g/kg)	32.0	11.7	20.4
Ca (g/kg)	22.7	55.1	37.7
Fe (g/kg)	63.7	18.5	13.7
K (g/kg)	0.92	2.40	7.49
Pb (ppm)	41.4	89.4	ND[a]

[a] ND = not detected or outside of detection limit.

Table 3
Chemical characteristics of the crude sewage and the Brazilian resolution for water quality (at 20 °C).

Parameter	Crude sewage	Reuse water	CONAMA 357/05
pH	7.08	7.77	6–9
Turbidity (NTU)	139	9.43	40–100
DQO (mg/L)	541	54	90
Total solid (mg/L)	3.5	0.0	1.0
O_2 (mg/L)	5.2	5.9	>5
Bacterial (UFC/mL)	39,700	–	500

Table 4
Comparison between control and reuse water and percents of reduction of quality parameter for reuse water.

Water	Germination (%)	Reusing yield (%)	% change, relative to control water
Control	80.0 ± 2.5	100.0 ± 2.5	25.0
Reuse	85.0 ± 2.5	106.2 ± 2.2	24.7

castor oil plant, *Ricinus communis*, presenting better results than those attained with commercial NPK fertilizers (nitrogen, phosphorus and potassium). Silva et al. (2006) studied the growth and production of radish cultivated on organic amendment from earthworm and bovines excrements. Now, Mazen et al. (2010) have been proved the potential of using sewage sludge in the amendment of desert reclaimed soil on wheat and Jews mallow plants. One of the results obtained in this work, a 100% germination rate was achieved, while the rates attained by the above cited authors did not exceed 80%. It can therefore be stated that the germination rates achieved in this work were higher than those reported (Mazen et al., 2010; Silva et al., 2006; Yamanishi et al., 2004).

Table 2 shows the results for inorganic contents of control soil, CBW and organic amendment, by mass spectrum analysis. It noted an increase in Ca and K contents of organic amendment added from CBW to soil and, a decrease of Fe and Pb, which reduces the soil contamination for these metals. It is provable that Pb concentration has been reduced into CBW by solubilization in liquid phase of crud sewage and into soil by dilution when was added to the sludge decanted from crude sewage.

In Table 3 are showed the chemical characteristics of the crude sewage and reuse water to compare with the Brazilian resolution for river water quality (CONAMA 357/05 Laws). As it noted all parameter of reuse water are within the standards set by Brazilian Laws, as well as an efficiency of 90% removal of COD, 93.3% removal of turbidity and 100% removal of removal of total solid and bacterial contents. However, the crude sewage only the pH and O_2 are within the norms. This demonstrates the efficiency of the treatment process used in this work.

Table 4 shows that 85% of bean seeds have been germinated on soil, when it irrigated these seeds with the reusing water and 80% were germinated when it irrigated with control water. This value is approximately 6% more than amount germinated when irrigated with the control water; what it demonstrates a high yield for reuse water, 106%, proving its viability in the irrigation of seeds. Parameters that lower the water quality were reduced above of 90%, leaving the water inside of Brazilian standards. These results were higher 70% of germination obtained to Sousa et al. (2006) to the chili seed and similar to 80% of germination obtained to Mazen et al. (2010) to the wheat and jews mallow seeds, both works the seeds growing with crud sewage irrigation. For cotton crops, Andrade Filho et al. (2013) have observed that increasing the amount of sewage sludge inserted in the soil fertility by increasing the fertility of achieving commercial fertilizer.

Table 5 shows the accounting of cost of the sewage treatment process of according to propose by this work. In table, it finds the possible flows of inputs and output of money from the company's cash. All methods to calculations and its equations are showed in item 2.2. The organic amendment mass produced was considered as equal to CBW mass. As is perceived, the saving with the sale of the reuse water was about US$ 14.1 million and with the sale of the organic amendment was about US$ 81.7 million. The transport cost of reuse water was US$ 6.6 million which was 47% of reuse water of its profit by selling; however the transport cost of organic amendment was US$ 0.8 million which was 1% of its profit by selling. The CBW cost was 7.3 million and about 9% of profit with the sale of organic amendment and of total profit. However, when it did the sums of profits with the product sale and after subtracted the cost with transport and material acquirement was obtained a profit of US$ 81.1 million for month. It is demonstrated that this technology is ecologically and economically viable.

Table 6 displays a simplified demonstration of the strategy to be adopted for the city of Campinas to attain ecological sustainability in relation to the reutilization of CBW and sewage, on three dimensions: environmental, economical and social. A previous analysis of the city of Campinas with regard to the environmental management of CBW revealed that the civil construction companies are not concerned with this waste, which is basically discarded in soil of the sanitary terrify. This has significant environmental, social and economic impacts and increases the ecological costs of the city. The current situation is considered critical (Burritt and Saka, 2006; Fresner and Engelhardt, 2004; Giraçol et al., 2011; Labodová, 2004).

As a first step for the application of ECA, the local authorities will be shown that it is possible to use these waste products. The

Table 5
Accounting of the production of the organic amendment and reuse water from CBW and organic amendment.

Input				Output			
Item	Amount	Sally price (US$)	Profit (US$)	Item	Amount	Unit price (US$)	Cost (US$)
Reuse water (m^3)	2,001,769	7.06	14,132,491.00	CBW (ton)	498,182.4	14.7	7,323,281.30
OA (ton)	505,213.2	161.76	81,723,287.00	Water transport (for truck)	235,503	28.21	6,643,540.00
				OA transport (for truck)	28,304	28.21	798,455.80
Total			95,855,778.00				14,765,277.00
Total profit							81,090,501.00

OA = organic amendment.

Table 6
Stages of the ecological cost accounting for the reuse of the CBW and sewage.

Fields	Stage 1	Stage 2	Stage 3	Stage 4
	Unsustainable	Sustainable		Full sustainable
Environmental	Disposal of CBW on soil from sanitary terrify	Raise population awareness to store the CBW	Collect and treatment of CBW for a specialist company	Reutilization of CBW in the sewage treatment and to obtain the organic amendment and reuse water
Economical	High cost with sewage treatment and with the purchase of chemicals	Cost with propaganda and lectures	Cost with CBW	Solving between US$ 1193 million/mother
Social	Bad image of city	Motivation of population	Good image of city	Good life quality for the population

intention is to pull the authorities from this current state of inertia and alert them to the effects that the disposal of this waste causes to the environment and society of the city of Campinas, leading them to create an ECA policy for such waste. The Environmental Bureau of City hall should prepare a primer about how people should proceed to store the waste from civil construction and to make the approach of companies that treat these wastes so that they can get their raw material directly from the population and, after treatment sell it to SANASA. With regard to sewage, politicians should visit the communities that have not been met and provide designs for these populations have access to basic sanitation. A equip from City Hall should assess the potential buyers of products (Farms, companies gardening and ornamental products) and to demonstrate its advantages compared to others that are being marketed. At this stage, the ECA policy would be underway and the environmental costs would be coming down (Burritt and Saka, 2006; Fresner and Engelhardt, 2004; Giraçol et al., 2011; Labodová, 2004).

The third stage is expected that all the sewage is being collected and treated by the novel process and that all CBW generated is being collected by the company responsible for processing and used in wastewater treatment and in the production of humus. In this stage, the environmental cost of CBW and sewage disposal would be zero and the city would no longer be polluting by means of these waste products. The fourth stage is the sewage treatment and manufacturing of organic amendment with the CBW, also the obtaining of reuse water and all products are being marketed and generating profit for the company. The results would demonstrate to the Campinas city hall a possible solution to its current ecological debt based on ECA theory (Burritt and Saka, 2006; Fresner and Engelhardt, 2004; Labodová, 2004). Furthermore, the production of the organic amendment and reuse water will improve the city's

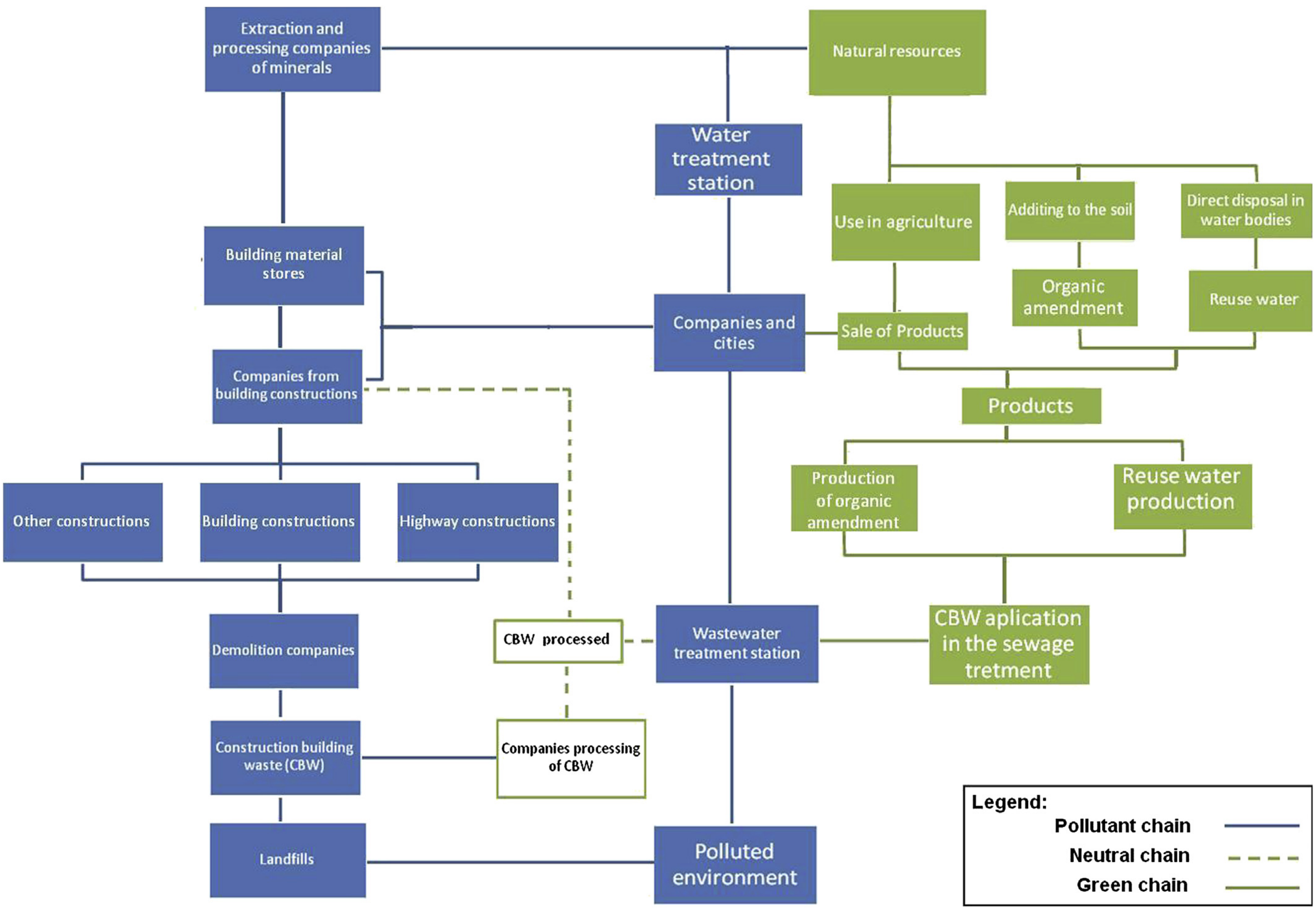

Fig. 2. Flowchart of the material and water since its exit from nature until his return.

image, provide financial returns and good life quality for the population.

Fig. 2 shows production chain of the construction industry (in blue), how the soil and minerals are extracted from nature, processed and used by construction building companies. At the end of the process, can be observed partial reuse of these solid materials, through processing of rubbish to generate the CBW (dotted line). However, most of this residue will end up in sanitary landfills and thus contaminating the soil (Levy, 2007). In this same figure was noted the chain of production of drinking water, from the collection of water in the environment (rivers or lakes), through their treatment at the water treatment plants. After consumption of this water by the population of the cities the sewage is generated, which is treated in wastewater treatment plants and as previously mentioned (Oliveira and Von Sperling, 2005, 2007; Von Sperling and Oliveira, 2009), the effluent quality is poor, which carries out to water contamination of rivers and lakes that receive this disposal. In this figure, in green, stands the environmental friendly chain (green chain) in which he proposes the reuse of CBW with membranes in wastewater treatment. It is shown the possible use of sludge decanted to generate organic amendment and this being using in agriculture or soil remediation. Also shown is the application of reuse water for irrigation in agriculture or its reuse by companies or city interested in purchasing this product. Thus, it is possible to show how you can reuse the CBW and sewage, returning their solid and liquid materials to the environment, making these chains more sustainable.

4. Conclusion

Seed germination in the soils enriched with organic amendment was faster than in pure soil, and the best condition was the one in which a total soil layer of 2 cm and 100 mL/L of CBW were used, which yielded a gain in soil fertility of 11.11% more than control soil and 100% of the seeds germinated.

Reuse water from sewage treated by membrane separation process has a high potential of applying in irrigation, showed results better than control water. Moreover, all the parameters were within the Brazilian standards for water quality.

From the ECA results, a total saving of US$ 81.1 million was found. Moreover, the reutilization of CBW in the sewage treatment and to obtain the organic amendment and reuse water will improve the city's image and good life quality for the population.

The results demonstrate the possibility of reducing environmental impacts caused by the lack of adequate treatment of construction waste and sewage produced in large urban agglomerates and of promoting the necessary conditions for soil recovery through gains in its fertility.

It is demonstrated that this technology is ecologically and economically viable. This work therefore shows that it is possible to reuse construction and demolition waste and domestic sewage, reducing their environmental impacts.

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