Views on Life, the Universe, and Everything

Sustainable Processing in Brazilian Industrial Infrastructures: An Utopia or Feasible Challenge?

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Received 14.03.2016, accepted 25.04.2016, published 26.07.2016

The continuous growth in human population implicates an increasing need for water. This demand encloses especially industrial structures. The federal state Pernambuco is one of the leading textile producers in Brazil. Although, the dry sub-humid state represents less than 5% of its national population, it covers approximately 20% of nationally manufactured jeans. Its high water consumption exacerbates the environmental situation during the actual strong drought which continues to impact the entire northern part of the South American continent. One main factor is the emission of chemically contaminated effluents from industrial laundries to Ipojuca river, being the third most contaminated river in Brazil. In this study, we analyse impact factors contributing to anthropogenic environmental damage in one of Pernambuco's main jeans producing region, Caruaru, and provide a sustainable solution towards waste water treatment. The methodology encloses a comparison of the exemplary sewage water management in the city Hof, Germany. Our results enclose parameters responsible for the damage to the fragile environment in Pernambuco and the Ipojuca River as well as a model for a sustainable infrastructure of the intended expansion of the industrial park in Caruaru.

1 Environmental Situation in Caruaru

The city of Caruaru is located in the state of Pernambuco, approximately 130 km from Recife (capital of Pernambuco). It is part of the semi-arid region, a transition area between the area of the Atlantic jungle and the arid region, approximately $540\,\mathrm{m}$ in altitude and divided by the river Ipojuca. The city expanded mainly due to factories producing textiles. The condition of the river Ipojuca as shown in Fig. 1 is considered to be critical since it is the third most polluted river of Brazil. Ipojuca river is contaminated by color pigments due to chemicals used to color denim. The rich wildlife is replaced by a small number of species like turtles that feed on waste water. The basin of the Ipojuca river is located between latitudes 8º09' and 8º40' south and longitudes 34º58' and 37º03' west of Greenwich, constituting the UP3 water planning unit, the State Water Resources Plan of Pernambuco - PERH/PE. Confined to the north by the river basin of the river Capibaribe, to the south, by the river basins of the rivers Una and Sirinhaém; east, by the second and third groups of basins of small coastal rivers and the Atlantic Ocean and to the west by the river basin Ipanema and the state of Paraiba. Thus, in general, the industrial laundries in Caruaru are responsible for the environmental degradation of the Ipojuca river, which bisects the city and receives chemical waste from jeans beneficiation processes. Studies of the State Agency for the Environment and Water Resources (CPRH) in 2005 show that in the Textile Local Productive Arrangement (APL), about 70% of industrial and sanitary waste generated by laundries are discarded without any treatment in the rainwater drainage system; 85% of them have no smog control system.[1] It was also observed that 40% of laundries discard their industrial effluents into the public sewage and 38% into canals.

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The percentage of sewage spilled into the river Ipojuca is 18%. In 2014, the Pernambuco Sanitation Company (COMPESA) which acts as the local water supplier had been ordered by the Federal Court to restore 37 sewage treatment plants in the state. Although domestic sewage contains approximately 99.9% water, it is due to the fraction of the remaining 0.1% high power contaminant, which required a treatment system.[2]

Figure 1: Contamination of the river Ipojuca with industrial sewage in 2015 in Caruaru, Pernambuco, Brazil.

Figure 2: Solid waste after sewage treatment of the water used throughout the processes (2014).

After the treatment of effluents, there usually remains solid waste (sludge) from drying, which is packed in bags for disposal by contractors in controlled landfill sites in the city of Recife (Fig. 2). The processing of jeans is one of the main economic pillars in the region. According to the Association of Textile Industries Brazilian (ABIT), in 2011, the Textile Local Productive Arrangement of Pernambuco (APLCAPE) accounted for 15% of jeans production in Brazil and for 3% of Pernambuco state GDP. Water is the main natural resource used throughout the process.

1.1 Water Usage in the Process of Jeans Manufacturing

During the laundry process, water is used for steam generation, boiler gas washing, cleaning of different instruments and in jeans beneficiation operations. The water used in various processing processes is stored in the primary water tank. To supply the primary tank, laundries in Caruaru use as the main water resource local water reservoirs like river water (Fig. 3). The water originates from ponds and pits in the area (up to 25 km away). This water is transported to the laundries by tanker trucks (owned or chartered). Most reservoirs are fueled solely by these sources, but some laundries use different sources of water, such as the local utility and water from artesian wells. In the research conducted by Silva in 2013 with the cooperation of local laundries in city of Caruaru, 105 laundries were addressed of which 62 completed the provided questionnaire.[10] It could be obtained that about 3% use solely water suppliers like COMPESA, and 97% utilize regional water of rivers and reservoirs. The water is transported by tanker trucks. Effluents can be directed to Effluent Treatment Plants (ETE) or discarded (some laundries do not use the ETE permanently due to higher process costs) in the rainwater drainage system.

2 Sewage Treatment in Caruaru and Hof

Nowadays, the pollution of natural water is one of the major problems in our contemporary society.

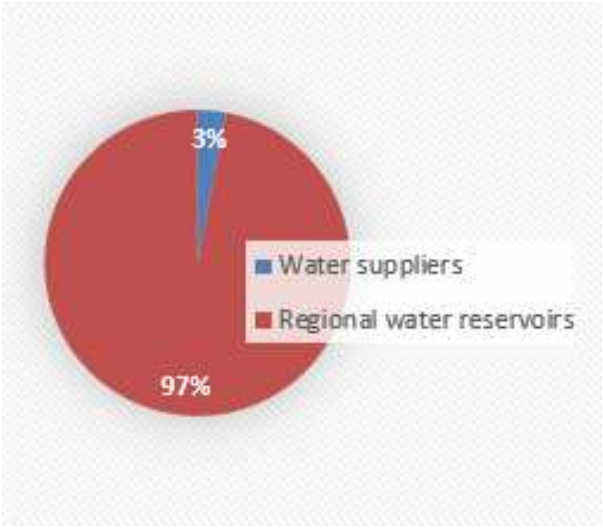

Figure 3: Water resources for jeans manufacturing in Caruaru (2014).

In 2010, through Resolution 64/292, the United Nations General Assembly recognized the human right to clean drinking water.[3] Recent studies address the issue of industrial jeans laundries' waste water disposal into rivers. Vieira *et al.* used a smectite clay to eliminate contaminants.[4] Santos *et al.* demonstrated that the use of solar Fenton process is an efficient alternative towards treating laundry

effluents.[5] Tutillo analyzes sustainability indicators of the 'Global Reporting Initiative' for companies of the jeans laundry industry. Results of this study show that some practices related to sustainable development have been adopted by various organizations. These practices are (1) the control of materials used in the production process of atmospheric emissions produced by operations and (2) water disposal control of laundry and dry cleaning processes, besides (3) control of expenditures and investments for environmental protection.[6] The work of Silva *et al.*[7] concludes that more attention is required in the waste water treatment with regard to parameters such as Biochemical Oxygen Demand (BOD), color and turbidity. Lima *et al.* made a mapping of the textile laundries of the Pernambuco clothing industry in relation to environmental aspects and the operational management of these laundries.[8] In their results, a major part indicated to have all environmental regulatory documentation, also claimed to have knowledge about environmental laws and never had to pay fines related to environmental damage. It was also noted that most of the respective laundries emit residues. Nascimento's work showed that industrial effluents can be made innocuous by advanced oxidation process with TiO_2 / H_2, O_2 and sunlight.[9] The minority of laundries use physicochemical treatment systems, where the effluent is subjected to solids separation processes (fluff and stones) as the first phase. In the second phase of the process, effluents are segregated in the equalization tank, which receives all waste water operations. The effluent is pumped to a physicochemical treatment tank, the treatment can be on batches or continuous, without addition of aluminum sulfate solution ($Al_2(SO_4)_3$) and calcium hydroxide ($Ca(OH)_2$) through metering pumps. After the addition of chemicals, the effluent flows into the coagulation / flocculation tank where there are two outlets for treated effluent and sludge discharge. The entire process as described can be compared to the treatment processes as applied in Hof. Caruaru has only one ETE located in the neighborhood of Rendeiras, but there is the possibility of building a second one, which is practically negligible in perception of the magnitude of population and quantitative population size. The textile industries are the main villains for the city of Caruaru, because there is no effective environmental enforcement to combat these irregularities. Currently COMPESA does not have a treatment plant incorporating the entire city. A way out of this problem is the waste disposal from the laundries and residences in channels which will pollute the river Ipojuca without any treatment, affecting water resources and their partly unique flora and fauna that make up this complex river. With its well in the Serra do Pau d'Arco, in the city of Arco Verde, it has a distance of 323.9 km and supplies several municipalities, among them Sanharó, Belo Jardim, Tacaimbó, São Caetano, Caruaru, Bezerros, Gravatá, Primavera, Escada and Ipojuca. In addition to direct pollution by waste disposal in the water, the site still receives all the city sewage.[10] The streams of Salgado, Mocó and Santa Rosa are channels that receive sewage *in natura*, released into the river without any treatment. There are two interconnected visions: the environmental one, in its preservation, and the other one in public health. This second vision does not efficiently exist in Caruaru and therefore causes the proliferation of rats and cockroaches, spread of diseases, verminosis, hepatitis, cholera and leptospirosis among others. That being said, it is of extreme importance to take care of this good outlook which is essential to life cycle. There was an impasse in 2011 with the First Civil Court of Caruaru suspending the sewage tax charges by COMPESA. This case received wide scale repercussion and was handled by Justice Court of Pernambuco (TJPE), which recommended to restart charging taxes as it could worsen the treatment situation in the city. Nowadays, the industrial residues are dumped in canals which consequently get access to the river that bisects the city. Its solid waste, in general, is collected and deposited on a landfill which is partner of Caruaru City Council. In the city of Hof, the sewage treatment system follows three stages consisting of mechanical, biological and chemical processes. The flow from ETE passes through large and fine grids. The system of large grid retains substances such as textiles or paper. The filtered materials are pressed in residue elimination facilities. In sand and grease tanks, air flows to waste water streams. Diverse greasy substances lift up to the surface. Sand is deposited on the bottom of the tank. These parts are finally stored in appropriate landfills. In primary sedimentation, gravity separates other salable materials, since they do not float on liquid surfaces. The final form of the material for the floating sludge is called primary mud and is removed from primary clarifiers.[11] Seven hundred kilometers of sewage channels are annually disposed in Hof and 60 other cities around its district. Services include the inventory collection and representation on a digital county mapping, axis measurement, gullies and boundaries, water valves, fire hydrants and street illumination. It is observed that both cities use similar processes for sewage treatment. That being said, the deficiency in the river in Caruaru has other factors which are elaborated as follows.

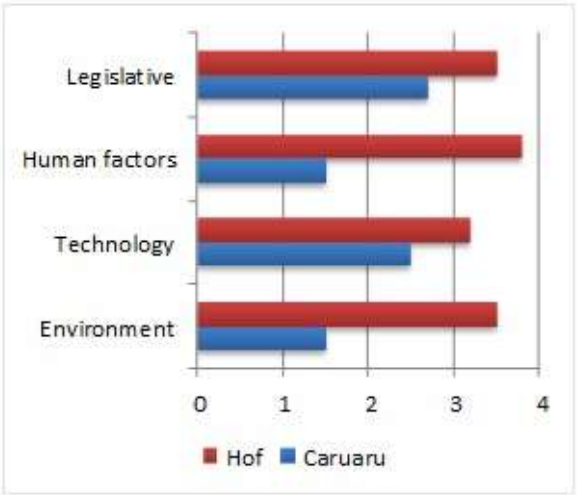

Figure 4: Distribution of potential impacts in the environmental variables in Caruaru and Hof.

3 Environmental Factor Analysis in the Cities of Caruaru and Hof

In order to measure and characterize the pollutant potential of an industrial effluent, the Chemical Oxygen Demand (COD) is utilized.

Table 1: Environmental factors in 2014.

No	ENVIRONMENTAL FACTORS IN BOTH CITIES		
	Factor	***Caruaru***	***Hof***
	Population	289.086	44,522
	Rainfall average in mm/month	45.91	61.8
1	Management plan	x	x
2	Environmental education plan	x	x
3	Selective waste collection	x	x
4	Recycling plant	x	x
5	Composting	-	x
6	Incineration	x	x
7	Effluent treatment	x	x
7.1	Treatment system	four stages	five stages
7.2	Support units	four lakes	four sources
7.3	Installed capacity	$180\,\mathrm{m}^3$ /day	$12\,000\,\mathrm{m}^3$ /day
7.4	Efficiency in organic load remotion	> 90%	> 90%
7.5	Finaltreated effluent destination	Aspersion on ground	Aspersion on river Saale
8	**Quality parameters of urban rivers**		
8.1	pH [6 to 9]	8.1	6.8
8.2	DO (mg/l) [$\geq$ 5]	2.7	6.1
8.3	BOD (5 days in 20 °C) [$\leq$ 5]	5.1	2.7
8.4	Ammonia (mg/l) [$\leq$ 1.0 - to 8.0 $\leq$ pH $\leq$ 8.5; $\leq$ 3.7 - to pH $\leq$ 7.5]	1.4	1.9
8.5	Phosphorous [$\leq$ 0.05]	1.155	0.023
8.6	Fecal coliforms [1000]	35.616	512
9	**City council professional qualification (%)**		
9.1	Primary school	79.6	18.7
9.2	Secondary school	19.4	59.2
9.3	Tertiary school	0.90	22.1

It is responsible to measure the quantity of required oxygen for organic matter oxidation of samples through the usage of chemical agents such as potassium dichromate, for example.[12] Beyond COD, the BOD is stated as the quantity of necessary oxygen for biochemical oxidation of organic matter, through aerobic bacteria, under specific conditions. According to CPRH N 2.001 Standard, the higher the relation COD / BOD is, the more biodegradable will be the effluent. According to CONAMA 357/2005 resolution, the river Ipojuca is classified as Class 2.[13] Generated effluent must be treated before it is released into rivers. The exigencies for pollutant sources with loads equal or superior to 100 kg/day must remove at least 90% of the BOD. Textile industries should establish a reduction of at least 80% in the values of COD, according to their types. According to Santos (2006), effluents from semi-arid textile regions present an average value of 1.135 mgO_2 / L.[14] After surveying both counties based on samples, the acts and industrial processes of waste management activities as well as effluent treatment have been analyzed. Based on samples and technical visits performed in the cities of Caruaru and Hof, acts and industrial processes of waste management and effluent treatment have been observed, analyzed and compared. Data in Table I has been analysed using Eq. 1.

$$\sum_{s=0}^{n+1} F_s = D_x \tag{1}$$

with F_S = +1 or F_S = -1

where F_s represents the specific group factor and D_x represents the distribution value. Thus, each positive factor received a positive score and each negative value, a negative score. Results of this evaluation can be observed in Fig. 4.

3.1 Environmental Laws

The first national law protecting the environment was issued in 1981 (n 6.938/81) and it is the milestone in terms of environmental protection standards. It is the most important environmental law and resolves the polluting group who are obliged to give restitution against environmental damages. Ministry of Public Affairs might propose civil responsibility for damages caused to environments. Imposing on the polluting group, there is obligation of recovering and / or the act to give restitution for caused damages. This Act created the necessity of studies and respective Environmental Impact Reports (EIA-RIMA).

4 Results

From Fig. 5, it can be observed that Caruaru has a strong political factor in terms of protective laws and sufficient technology to observe the sustainable environmental protection patterns.[15] However, human factors considering the profession and maintenance, as well as measurement of parameters in both rivers demonstrate the opposite. Water

quality parameters measured in river Ipojuca are 83.3% below the requirements of an intact river. Based on our interviews and technical visits, it can be said that although there exists the perception of the actual environmental issues a simultaneous paralysis in solving the problem with proposed methods is dominating. This result is alarming and requires immediate attention. In order to provide a solution to that, we propose a model encompassing quantity (horizontal axes) and quality in vertical extensions. From Fig. 5, it can be seen that public policies (first point from left) in diverse approaches for the sustainable waste water demand less horizontal than vertical approaches (x = 0.7; y = 2.7). Human factors (second point from left) represent another parameter, which requires improvement. Vertical development is needed to execute the laws and regulations including technology (third point from left) in order to guarantee the quality in the process (x = 1.8; y = 3.2).

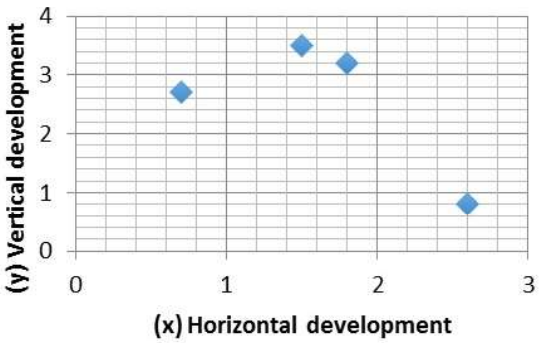

Figure 5: Vertical and horizontal development suggested from the factors in order to perform a sustainable sewage treatment facility.

Technically, the technology is sufficient to guarantee a process of requirements in standards of waste water treatment. However, the facilities need to be improved in order to realize this approach. Therefore, it is suggested in the model to focus in the horizontal instead of vertical (x = 2.6; y = 0.8). When it comes to the environment (fourth point from left), it is important to know that there are educational approaches installed. Education is not sufficient though, strict regulations must be applied so as to guarantee information and awareness. Therefore, both directions must be taken into consideration, vertical and horizontal (x = 1.5; y = 3.5). From the analysis of the results, a model was created that proposes the directions of a sustainable solution towards river depollution. In this model, an industrial waste water plant is considered, which is linked to the river Ipojuca, 12% of green area within an ecological park and sufficient area covering the needs for the industrial textile fabrication. Our model is based on the regulations given by the Economic Development Secretary of Caruaru (SDE). The basic principles were in conformation to municipal and state laws and recommendations for sustainable, efficient industrial facilities. In public areas, this model has (1) preservation areas of the river Ipojuca (30 m lateral), (2) forest park next to BR-232, (3) green belt around the entire textile district, (4) Technical School of Environmental Practice, (5) usage of high pressure sodium light bulbs (HPS). In industries, this model considers (1) reservoirs of rainfall water collection system, (2) turbid tiles usage for natural illumination, (3) garden irrigation with treated effluent, (4) green belt in 70% of the industry perimeter, (5) green area between front wall and industry sidewalk, (6) preview of water heating with solar energy, (7) preview of natural gas usage in energy matrix, (8) atmospheric emissions control system, (9) wastewater management system, (10) effluent treatment and reuse of 70% of water and (11) sanitary effluent treatment.

5 Conclusion

In this study, it was possible to show important factors that require consideration in order to perform consequently a sustainable sewage treatment. These factors include public policies, human factors, technology and environment. However, a main issue for the current situation is the lack of profit for governmental and industrial organs. It requires financial incentives in order to achieve consequent and sustainable sewage treatment. Rudimentary process quality control will then self-regulate itself. In contrast to other research articles, which do not investigate the origin of the problem, this article provides a state of the art solution.

Acknowledgment

Authors thank Federal Ministry for Cooperation and Economical Development (BMZ) for the financial support through the ASA program. Moreover, we would like to express our gratitude to Sanitation Company of the State of Pernambuco (COMPESA), State Agency for Environment and Water Resources (CPHR), Economic Development Secretary of Caruaru (SDE), Water Resources Secretary of Pernambuco (SRH) and Regulatory Agency of Pernambuco (ARPE) for the further information. Moreover gratitude goes to the Abfall Zweck Verband (AZV) Hof for the provision of access to several industrial process plants.

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