Gravimetric Analysis as an Environmental Education Tool at the Polytechnic School of the University of Pernambuco

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ABSTRACT: The aim of this study was to map, quantify, and characterize the solid waste generated by the Polytechnic School of the University of Pernambuco (POLI/UPE), and use the data to raise the academic community's awareness as to its social and environmental role. Initially, the school infrastructure for waste collection was mapped and two gravimetric analysis tests were conducted in order to identify and quantify the waste components generated by POLI students, faculty, and staff. To assess the level of environmental awareness in the POLI community and survey the degree of adherence to selective disposal, a 2016 project carried out at the institution on the importance of environmental education, environmentally sound practices, and how well students assimilated the ideas of sustainable actions in engineering design. From the gravimetric analysis, it was found that 73% of the waste could be recycled, a higher percentage than that of recyclable materials produced nationally. It was also noticed that non-recyclable waste consists of organic matter and toxic contaminants. After analyzing the results, it is clear that developing an environmental management system, with support from the institution's administrative offices, could be a potential strategy to raise awareness within the POLI community regarding the correct disposal of waste, as well as the proper destination of such material. This study prompted the creation of several initiatives led by research and extension projects, which were the starting point for evaluating and implementing those initiatives at the studied institution.

Keywords *Environmental education, higher education institution, solid waste, gravimetric analysis.*

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1. INTRODUCTION

The techniques and production methods used in the construction industry have been modernized over time to take into account scientific advances and increased competitiveness. With these advances, man has had to increasingly coexist with environmental waste, augmenting the need to prepare professionals to consider the environmental, social and economic impacts of sustainability on their decisions and projects (Kohlman Rabbani et al. 2013).

In this context, the Higher Education Institutions (HEIs) play an important role, being responsible both for the advancement of scientific knowledge and the development of new technologies, as well as the training of future professionals. Solid waste management plans at these institutions, therefore, can be seen as a new phase of academic management work. This includes actions such as decision-making, policies, and strategies associated with institutional, operational, financial, social, educational, and environmental factors beginning with waste generation until the final disposal of waste generated by academic activities (Conto, 2010).

The identification of the various constituents of solid waste generated by a community, as well as an analysis of them as a percentage of volume and weight, emerges as an educational tool for schools and universities, since those institutions can consume large amounts of resources and produce considerable quantities of waste.

The complexity of waste management at the Polytechnic School of Pernambuco (POLI/UPE), located in the city of Recife, can be explained by the wide variety of environments, including but not limited to classrooms, meeting rooms, laboratories, a canteen, and administrative offices. The institution graduates about 211 students annually in several areas of knowledge: construction, computing, electronics, electrical engineering, telecommunications, mechanical engineering, and automation and control (Escola Politécnica De Pernambuco, 2012).

According to Risso (1993), the characterization of waste allows for the identification of its constituents and it also can assist in proposing environmental education programs, which can lead to green initiatives and community actions. In order to evaluate the perception of future engineers and sensitize the academic community to the possible environmental and social problems caused by their activities, it is necessary to assess the academic community's adhesion to selective collection, waste donation campaigns, and the degree of environmental awareness and eco-friendly consumption.

With this in mind, a couple of questions should be asked: what is the profile of the graduate student, compared to the societal expectation of being able to deal rationally and sustainably with environmental issues? How do academic classes contribute to new professionals forming a distinct approach to designing their projects, contracts, inspections, maintenance and the disposal of waste generated in their work areas?

The purpose of this article is to show the academic community the characterization and mapping of solid waste produced at POLI/UPE, analyzing the flow of such waste through the phases of generation, storage, collection, and finally disposal. Through gravimetric composition testing, the various constituents of the waste will be indentified and

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quantified as a percentage of weight, and data will be provided to establish guidelines for the implementation of an effective selective collection process at the institution.

2. LITERATURE REVIEW: GRAVIMETRIC ANALYSIS AS AN EDUCATIONAL TOOL IN ENGINEERING

According to Polito (2004), engineering is the art of applying scientific knowledge to invention, improvement or use of industrial technique in all its determinations. However, the benefits generated for society, such as improved health, longevity, comfort, and alimentation brought, in return, rampant population growth, overconsumption, and negative impacts such as environmental degradation and pollution which now plague the urban-industrial society (Braga, 2007).

In this scenario, environmental education is presented as a basic instrument for the conscious use of natural resources. In Environmental Education (EE), there is a widespread policy with respect to solid waste that focuses on the three R's: reduce, reuse, and recycle. As Bonelli (2015) stated, the first "R" implies reducing the consumption of everything that is not really necessary. The second "R" means the reuse of products in other ways, and the last "R" is recycle: the process of producing new things from others already used. The latter term can also be defined as the action or recycling process that converts solid waste by changing its physical, physical-chemical or biological properties, resulting in new raw material (Brasil, 2010).

According to Santos and Sato (2001), several conferences have been held to discuss the role of the university, seeking alternatives that would boost the inclusion of environmental education in higher education. Because issues such as practical aspects, as well as managerial, administrative, social, and environmental expertise are poorly explored in the classroom, as Danna (1996) pointed out, the characterization of solid waste can be seen as an environmental education tool at the educational institution. This characterization procedure examines the relationship between the weight of each component present in the sample and the total weight of the sample.

For Boscov (2006), the gravimetric composition assay is one of the characteristics that most influences the geo-mechanical properties of waste, since once the profile of the mass has been determined, one can evaluate the possibility of using both the recyclable fractions and the organic matter to produce organic compound, both of which can be used for marketing.

The waste characterization process is not standardized in Brazil, and because of its heterogeneity, it is not considered a simple procedure. To perform the characterization process, it is necessary to sample the waste, a procedure that is standardized in Brazil by ABNT NBR 10.007/2004. According to Loureiro (2005), gravimetric analysis may be described in the following steps:

- Select samples of loose waste from different areas of collection, to find results that are as representative as possible;
- Mix samples with the help of shovels and hoes in the same "lot", ripping up plastic bags, cardboard boxes, cases, etc.;

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- Divid the mass of waste into four parts. One of the resulting quarters is chosen for a new four-piece division, and so forth, a procedure called quartering. The quartering must cease when the volume of each of the parts is approximately $1m^3$. One of the four parts of the material must then be separated for analysis;
- Choose five containers of known weights (200-liter drums, used to store oil, are ideal);
- Fill the containers to the brim with garbage from the selected "quarter";
- Choose two trash barrels and separate the components manually: paper and cardboard; plastic; wood; leather and rubber; cloth and burlap; leaf, bush and antlered; organic matter (food waste); ferrous metal; non-ferrous metal (aluminum, copper, etc.); glass; crockery, ceramic and stone; and fine aggregate, i.e. all material that passes through a one-inch mesh sieve, consisting of dust, dirt, grains of rice, etc.; and
- Determine the weight of each of the separate materials. Finally, through simple mathematics, the percentage by weight of each component is obtained. This is called the gravimetric composition of the waste.

3. METHODOLOGY

In order to identify problems in disposal, storage, and collection of waste, a literature review was conducted prior to the mapping of the main sectors of POLI/UPE. An infrastructure survey was carried out, quantifying the buildings in the institution, and verifying how trash bins are positioned around the school.

To quantify each component of the waste, gravimetric composition tests were performed in July and December of 2015. Prior to the tests, meetings and training with the cleaning staff were held, in order to instruct the person responsible for cleaning to collect all waste produced at the institution during a 24-hour period.

In order to sample material for the gravimetric composition tests, the quartering method established by NBR 10.007/2004 was followed, with adaptations. The first test was carried out with waste from the previous day’s collection, with the help of POLI's cleaning staff. A 600 g drum and a 122 g bucket were chosen as containers. They were filled to the brim with residue from the "quarter" and then the weight of the mass of waste from each sampled block was determined with the aid of the following scales: SCA-301, SCA-pocket and an electronic scale. For the second test, only the 600 g barrel was used as a container along with a digital luggage scale.

The gravimetric composition tests were performed in a standardized manner and followed the methodology used by Loureiro (2005), already mentioned in this paper. Finally, using the mathematical rule of three, the percentage by weight of each component was obtained, i.e. the gravimetric composition of the residue. This information was compiled based on the buildings and material types. Graphs were generated from this data and statistical tools were applied to identify the parameters interesting to the study.

In order to assess the degree of environmental awareness of POLI's undergraduate and graduate students, a questionnaire was developed and applied from September to October 2015, containing 20 questions on the importance of environmental education, environmentally sound practices, and the students' assimilation of knowledge regarding sustainable practices in engineering. A total of 360 students were interviewed, and data was compiled using the Google Forms tool. A thorough analysis of students' perceptions can be found in Kohlman Rabbani et al. (2016, in press), where the authors discuss the students' profile, their behavior with regard to waste disposal, their perception of environmental content covered in the engineering classes, their interest in participating in the selective collection and campaigns for waste donation, and their degree of understanding about the elements of sustainability in engineering projects.

4. INFRASTRUCTURE AND WASTE CHARACTERIZATION AT THE POLYTECHNIC SCHOOL OF PERNAMBUCO

In northeastern Brazil, Pernambuco stands out for its potential in various productive and technological areas in addition to its large research and educational institutions, such as the University of Pernambuco (UPE), one of the state's most important higher education institutions. UPE currently consists of 13 colleges, distributed across various regions of the state. One of them is the Polytechnic School of Pernambuco (POLI), recently named the 16th best engineering college in northeastern Brazil, according to Folha de São Paulo (2015).

Throughout the engineering programs, which are five years long, POLI offers a set courses composed of a basic cycle plus specific courses that contribute to professional education, addressing directly or indirectly the engineer's responsibility in a society that increasingly requires sustainable development. The school is composed of 10 buildings lettered from A to G, in which are distributed administrative offices, departments for extension activities, scientific research areas, graduate programs, meeting rooms, lecture halls, study areas, laboratories, an auditorium, a library, a student union, parking spaces, and a small area equipped with benches and tables where students can get together to talk, study, play, and eat quick meals in intervals between classes. Currently, POLI contains approximately 4000 people, comprising students (3600 from undergraduate and graduate programs), teachers (147), and employees (43) (Escola Politécnica de Pernambuco, 2012). For a clearer understanding of the infrastructure mapping, a blueprint of POLI is shown in Figure 1.

Figure 1. Blueprint of POLI.

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According to data obtained through the infrastructure survey, 204 trash bins were counted, distributed among all buildings. It is noteworthy that each building has many different rooms and specific areas, and therefore the results shown below are directly connected with how trash bins are set at each point within the buildings. Graphically, Figure 2 shows the quantity of bins per building. It was also noted that most of the buildings have some sort of recyclable material bins such as those for paper, metal, and plastic. Bins for recyclable glass were not found in any of the visited buildings.

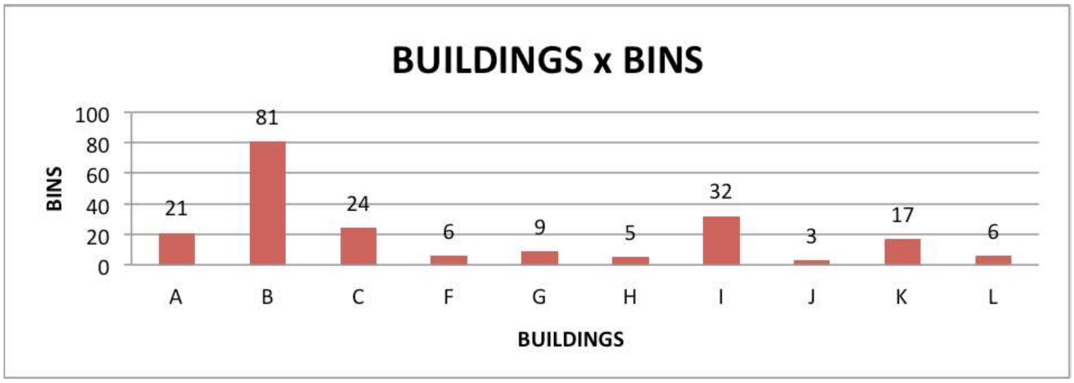

Figure 2. Trash bins per building.

In the first gravimetric composition assay performed at POLI, during school holidays, 12.75 kilograms of waste were collected. This waste consisted of 9.31 kg of recyclable materials (4.72 kg paper, 2.93 kg laminated packaging, 0.89 kg plastic, 0.77 kg metal) and 3.44 kg of waste. It is important to point out that the waste collected was only about 80% of the total actually produced by the institution, given that some sectors have individualized collection services (e.g. graduate program offices).

From graphical analysis of gravimetric composition, shown in Figure 3, it was observed that 73% of the residual mass is recyclable. This percentage may highlight the amount of laminated packaging residue found, which, although classified as recyclable, have a very high cost of integration back into the productive chain. This material is often considered as waste due to the lack of machines with the technology to separate the types of materials that make up its various layers. Because there are no qualified companies in Pernambuco, this kind of waste is destined to end up in landfills.

Also shown in the chart, about 27% of all waste was found to be potentially recyclable. The presence of such waste complicates and increases the cost of the sorting process, because once mixed with recyclable materials, they will be sent to landfills. This will end up harming the entire process, because only a portion of the materials can be sent to the cooperative collectors and to recycling. The collection and sorting process would be more profitable if the academic community were aware of its role in the proper management of waste, and took responsibility for its proper segregation and disposal.

In the second gravimetric composition assay, 46.35 kg of residue were collected, from which 17.92 kg were recyclable materials (11.16 kg plastic, 6.64 kg paper, 0.10 kg metal, 0.020 kg laminated packaging), 11.76 kg were organic waste, and 16.68 kg were waste

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with no recycling potential. It is worth mentioning that, as in the first assay, the data collected was considered to be approximately 80% of the total actually produced by POLI.

According to the graph shown in Figure 4, approximately 26% of the mass of residue consists of organic waste, due to the opening of a new cafeteria at the institution. This new reality brings another challenge to the academic community regarding organic waste disposal, that is, rather than discard it along with non-recyclable waste, it can be used in the composting process.

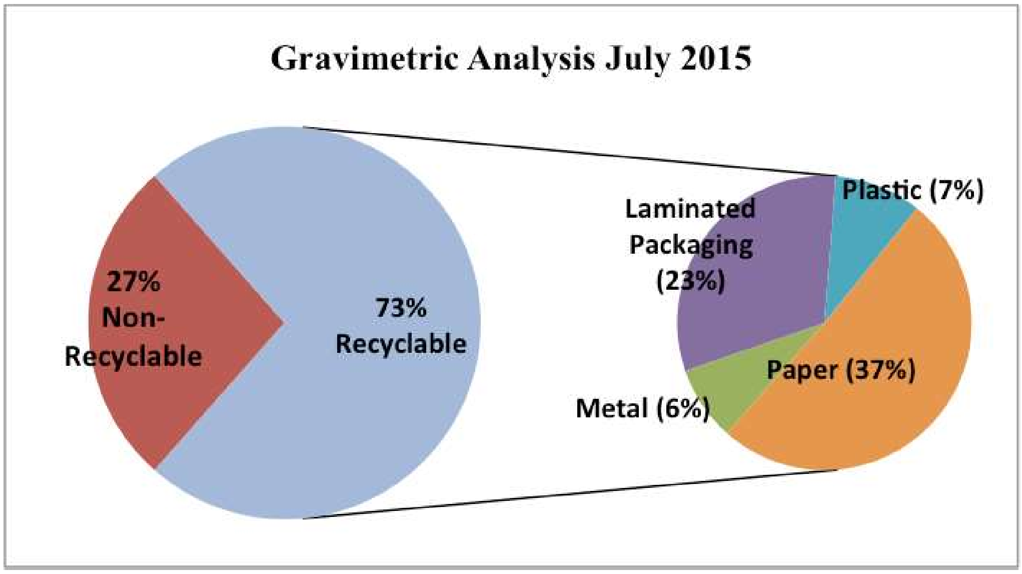

Figure 3. First gravimetricanalysis assay.

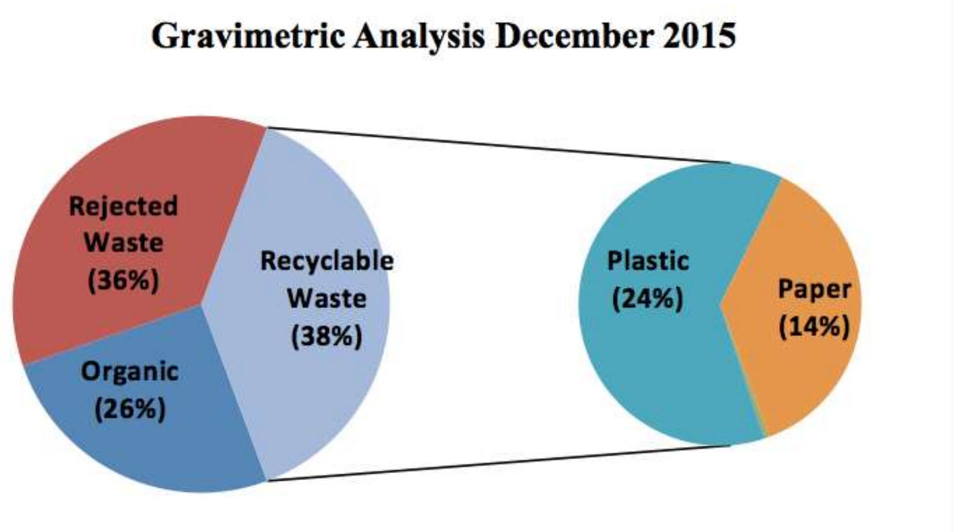

Figure 4. Second gravimetric analysis assay.

The strategy of using questionnaires to understand the target research audience was based on Fantinatti et al. (2015). According to the authors, the analysis of the questionnaires will improve the understanding of the academic community, and the

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development of tools and strategic methodologies will allow a better comprehension, not only of the environmental aspects, but also the social, cultural, and scientific aspects at POLI .

From the questionnaire, some questions are noteworthy because they reflect the lack of students' knowledge on the material that is disposed at the institution and could be reinserted into the productive chain, reducing the amount deposited in landfills as well as the amount of new raw materials extracted. According to Figure 5, from a total of 365 students who answered the survey, only 30.7% have a real sense of the quantity of waste generated at POLI that could be recycled (between 50% and 80%). It was also observed that for over 30% of the students, the amount of potentially recyclable waste is only between 0 and 20%.

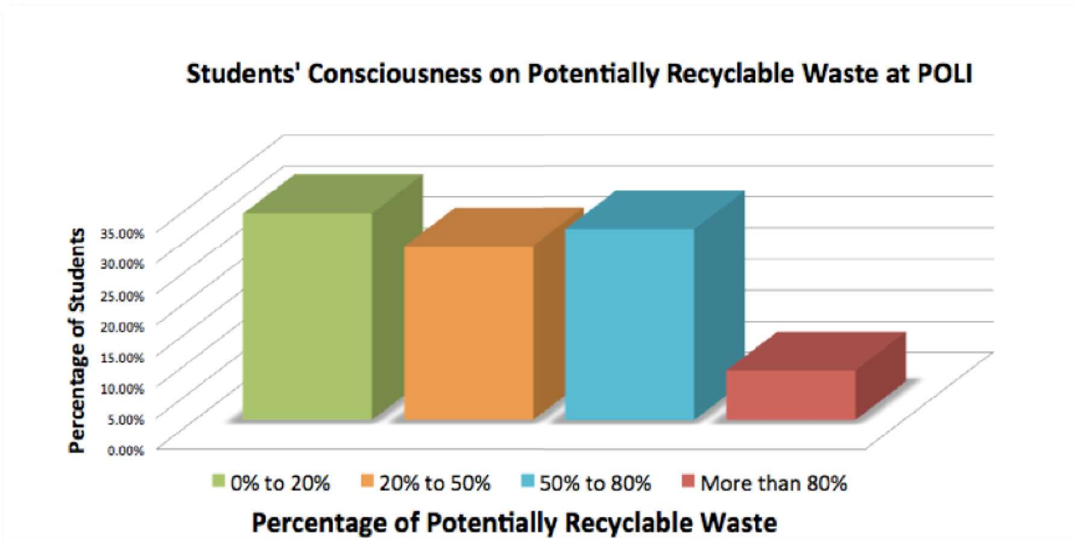

Figure 5. Students' knowledge about recyclable waste at POLI. Source: Kohlman Rabbani et al. (2016, in press).

5. RESULTS AND ANALYSIS

The data presented made it possible to verify a wide variety of materials that compose the common waste at POLI. According to the data obtained in the study, the institution currently has an average potential of 64.0% of recyclable material during the time when school is in session, representing an average of 46.35 kg of waste per day and 9270 kg per year. However, this residue has been entirely destined to landfills and is not being reused as raw materials in other production cycles.

During the characterization process, it was perceived that perhaps a lack of signposting for trash bins, infrastructure for proper disposal in classrooms and laboratories, and information about what to do with waste may be causing people to improperly dispose of it.

Therefore, the characterization method was an important tool to better understand the origin, composition, and disposal of common solid waste generated at the Polytechnic School of the University of Pernambuco. However, it is important for this process to be

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repeated periodically, considering factors that influence the generation of waste, such as seasonality, occupancy rate of dependencies, separation at source, academic community habits, sectorization by academic center, and the holding of academic events.

In order to know the professors' opinion toward sustainable practices in terms of engineering design, an interview was conducted in which it was noticeable an emphasis on suggestions such as selective waste collection, savings in paper consumption, reducing energy and water consumption, campaigns for proper disposal of produced waste, and proper disposal of waste requiring special treatment, such as batteries, oils, etc. Most of the professors claim that these sustainable actions should be practiced in schools and civil engineering companies.

Through a survey applied with students of the HEI, it was found that most of them considered as sustainable practices and supported the following actions: a selective collection system deployment (support of 98% of students) and the installation of electronic and cooking oil collection points (support of 83%of students).

6. CONCLUSIONS

In light of the data obtained, it is suggested that the first measure to be taken should be the identification of bins and collectors to separate two types of waste, recyclable and organic, as well as the placing of illustrative posters above each collector with images indicative of each type of waste. It is believed that this action will help the students to properly identify bins and assist in the disposal of waste.

The organizing of educational campaigns is also suggested, utilizing the media, websites, e-mails, posters, brochures, lectures, and other means to disseminate the results found in this study, and advice regarding the best way to dispose of waste. For the waste produced in the laboratories, new studies to identify the best allocation should be conducted, and the existence of the Reverse Logistics application during tyhe purchasing process.

Clarification of environmental issues is a right of society, and this theme is found in the National Environmental Education Policy, Law No. 9795 of 27 April 1999. The selective collection issues and proper disposal of waste are in line with the principles of sustainable development, and thus environmental education is an important tool in the ecological awareness of society. It is hoped that the actions suggested and implemented at POLI, such as the mapping of the potential of discarded waste, guidance on waste disposal, and awareness campaigns assist in the construction of social values and behavioral changes regarding environmental preservation. It is also hoped that these practices experienced at POLI may be later applied in the working environments of future engineers.

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