SOLID WASTE MANAGEMENT IN A COLOMBIAN UNIVERSITY

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Abstract
Higher education institutions (HEI) play a unique role and responsibility in promoting an environmentally sustainable society. Between the greatest challenges they have to achieve a high environmental performance is to implement comprehensive solid waste management programs. In this research work, the characterization and the trend of solid waste generated in a Colombian University, Universidad Nacional de Colombia Palmira campus (UNALP), was carried out before and after 8 years of the implementations of a Comprehensive Solid Waste Management Program (CSWMP). This paper analyses the changes in time and the impact of strategies for waste minimization and recycling, in addition describes some of the barriers and challenges that has to face a University in a developing country, in this regard. Between 2008-2016, there was an increase of 33% in solid waste generation per capita, with a current value of 79.62 g/day/person and changes in consuming habits caused a reduction of 11.8% in bulk density. As a result of the strategy developed at the UNALP, from 2008 to 2016 a saving of €11k in waste disposal cost and a recycling rate of 30% were achieved. However, there are some internal and external barriers that the institution still has to face to improve its environmental performance. It was discussed that being a public university in a developing country poses additional difficulties but nevertheless UNALP has proved its environmental responsibility through strong leadership, administrative will and proper planning.

Keywords: Solid waste management, Waste characterization, Higher Education, Developing country, Recycling.

1. Introduction

Currently, universities can be regarded as small towns given their large size, growing university population and the complexity of activities that are taken place on campuses [1]. As a consequence, they cause direct and indirect impacts on the environment that must be addressed by the universities. The impacts must be controlled and minimised by applying the technical and organisational capacity of the institutions with the aim of becoming sustainable universities that can be models for modern society. The role of higher education in sustainability was emphasised in United Nations Conference on Sustainable Development (UNCSD) 2012 [2]. Besides, in this conference it was stated the need for research on sustainable development issues and supporting sustainability efforts within universities. UNESCO [3] also showed the crucial need to integrate the principles, values, and practices that make up sustainable development into all aspects of education and learning by declaring 2005-2014 as de decade of Education for sustainable Development.

A comprehensive solid waste management system is one of the main challenges to achieving institutional sustainability [4]. Such system should consider waste minimization, reuse, recycling and managing of waste in a way that causes no damage to the human health and to the environment [5]. In order to ensure a successful waste management system, one of the first stages that has been identified is to carry out waste characterization studies [6]. In that sense, several HEI have conducted this type of research as reported in the literature [4, 6, 7, 8, 10]

Many of these studies were carried out in Universities of developed countries where the state of the art of the solid waste management of those HEI was described [4, 7-8]. It is evident the great progress they have achieved not only at the university but also at the community level. Key factors to highlight are: clear legislation with targets well defined, modern and adequate infrastructure and, public financial support in addition to internal funding. In contrast, studies related to the management of solid waste in HEI of developing countries and particularly of Latin American Universities (with the exception of Mexico) are scarce, possibly due to the lack of progress in these initiatives or the difficult access to reliable sources of information. Additionally, as has been recognised in the literature, campus recycling activities/programmes began around 20 years ago in developed countries [8] and only few years ago in campuses of developing countries; therefore, their achieved results are lesser [9].

It becomes clear that the implementation of an integrated waste management system in Universities of developing countries is a great challenge [10], such is the Colombian case. In Colombia only 17% of solid waste are recycled,

reused or transformed to resource recovery [11], this is in part because there are no economic and regulatory incentives to minimize the generation of solid waste and increase the levels of reuse and recycling. Education on source separation, recycling and reuse has been precarious and has been limited to the location of mostly green, blue and grey bins, in schools, offices, medical centres, parks, among others. Recent studies showed that only 44% of Colombian households classify waste and that 7 out of 10 people do not know how to make an adequate separation [12], which causes waste of different types (plastics, organic waste, paper, among others) to be erroneously disposed, contaminated and cannot be used as they should be. This means that the potentially usable material is more expensive to reuse or recycling, or in the end, that it must be landfill disposed, even when its raw material is at an optimum level of reuse or resource recovery. Only in 2016, with the entry into force of Decree 596, the operational framework for recycling, reuse and resource recovery from waste was established.

In this paper the evolution of the solid waste generation, changes in the composition, as well as the impact of the implementation of a Comprehensive Solid Waste Management Program (CSWMP) in a Colombian University are described. In addition, some of the barriers and challenges that has to face a University in a developing country are discussed.

2. Materials and methods

The research was carried out at the UNALP, located in the south of Colombia in a tropical region (Fig 1), the annual environmental conditions of humidity and temperature correspond to 60% and 25 °C respectively and the area of the campus is 13.9 hectares of which 67.2 % corresponds to green areas.

The campus is the place of confluence of students, teachers, staff and visitors, with a population of approximately 3756 persons, for the year 2016. The University is open all year, from Monday to Saturday and between 6:00 AM and 7:00 PM. There are three academic periods during the year, the first one from February to June, the second one from June to July and the third one from August to December. In addition, there are research and consulting projects being developed uninterrupted throughout all year long.

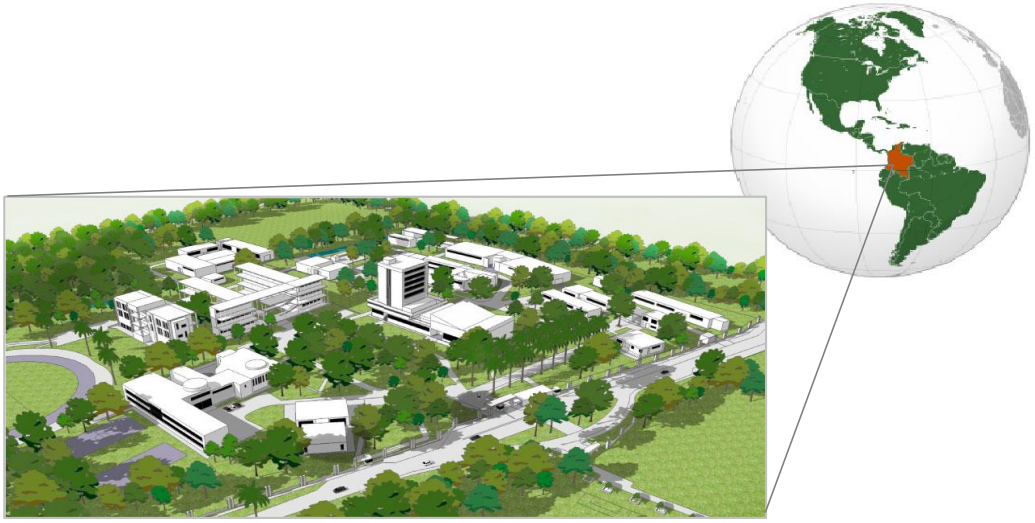

Fig. 1. UNALP location in Colombia.

2.1. *Estimation of waste generation*

Recyclable materials are internally collected and segregated at the UNALP Recycling Centre. As part of the CSWMP a registration of the type and amount of recycled material is carried out by the Environmental Management Office staff. Therefore, the registers from 2008-2016 were used to determine the annual recyclable material production.

Non-recyclable materials are sent to landfill through the external operator, Proactiva-Valle del Cauca, of group *Veolia Environnement* from France. The operator collects three times a week the non-recyclable materials and deliver a weekly report of the total volume collected. Then by using the mentioned reports, between 2008 and 2016, was possible to estimate the annual amount of solid waste sent to landfill.

2.2. *Waste characterization*

Two waste audits or characterizations were carried out. The first one in 2007, before implementing a CSWMP, which started in 2008, and the second one in 2016.

Waste characterization categories were adapted from various waste characterization methodologies, reported in: Technical Regulation of the Potable Water and Basic Sanitation Sector (RAS by its initials in Spanish, Colombian government directive) [13]; Guidelines for source separation [14] and Integrated Solid Waste Management: Engineering Principles and Management Issues [15]. After a critical literature review, 9 primary categories were defined, which comprise different materials described in Table 1.

In both waste audits the same methodology was used. **S**ampling was carried out during 6 days from Monday to Saturday. The waste was quantified in the different points of generation of the campus and taken out of the bins in bags labelled with the purpose of eliminating duplicity and errors in measurement. After this, each type of material was separated in accordance with the 9 main categories established. Then, weights and volumes of the materials were estimated using scales and volumetric containers. Finally, the information was organized, digitized and the corresponding statistical analyses were performed.

Table 1. Waste component categories and description

Category	Description
Paper	Sheets, notebooks, newspapers, invoices strip, magazines, books.
Cardboard	Plain cardboards, corrugated cardboard, paperboard.
Plastics	Plastic beverage containers, plastics bags, packaging, soda bottle caps.
Polystyrene	Polystyrene food packaging, Expand polystyrene packaging.
Food waste	Fruits, vegetable, coffee grounds, tea bags, leftovers of prepared food, frying oil.
Garden waste	Grass waste, leaf litter.
Glass	Bottle glass, plain glass and other glasses.
Metal	Empty cans, ferrous metals and non-ferrous metals.
Others	Non-recyclable (clean or dirty napkins, waxed cardboard boxes for food packaging, paper bags for the packaging of bakery products, paper towels for bathrooms, packaging of dairy products such as milk, cheese and yogurt, street waste, dust, cigarette butts).

3. Results and discussion

3.1. *Waste generation*

Between 2008 and 2016, solid waste generation presented periods of increase and reduction with a slight tendency to increase (Fig. 2). For the first year of study, 2008, it was found a waste generation rate of 59435 kg/year and, with a university population of 2727, it translates in a per capita production of 59.71 g/day/person. In 2016, the waste generation rate raised to 109156 kg/year and university population reached 3756, which means a per capita production of 79.62 g/day/person. The increase of 33% in per capita solid waste generation can be explained in part for the steady increase in the number of students, reaching 38% during that period of time, mainly in postgraduate programs which implies more research projects. Another cause can be the improvement of economic income for the Colombian people during 2008-2016, the economy of the nation grew at an average rate of 3.7% [16], which caused increase in the consumption and therefore generation of more waste material. This is evident with the 57% increase in the per capita solid waste generation in Colombia, which went from 700 g/day/person in 2008 to 1100 g/day/person in 2016 [16].

In spite of the increased observed, the UNALP waste generation is well below to 110 g/day/person, that was the data observed for the UNAM University in México [9], and also for the one found in University of Southampton, with 197 g/day/person [7]. However, our data is higher compared to the one reported by University of Northern British Columbia, with 59.20 g/day/person [4], and by Universidad Autónoma de Baja California, with 45.60 g/day/person [6].

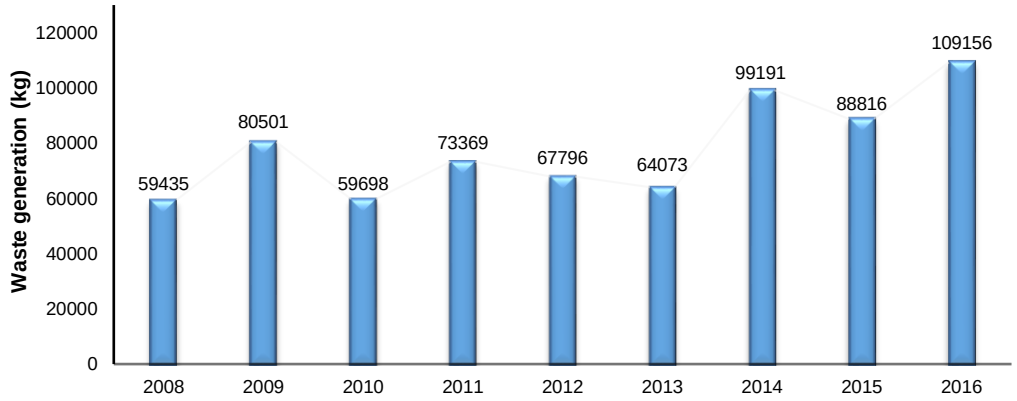

Fig. 2. Solid waste generated at UNALP

3.2. *Recycling level*

To the extent that the total solid waste generated has raised in time, the recyclable material has accordingly also increased (Fig. 3). Nevertheless, the amount of recyclable material from the total waste has remained invariable, around 70%. This finding is similar to the data reported by University of Lagos Ankoka campus [5], by University of Northern British Columbia [4] and Universiti Teknologi Malaysia [17], with 75%, 71% and 86.6%, respectively. Therefore, it can be said that between 70% to 87% of the total solid waste generated in HEI is recyclable.

It is worth noting that the quantities of material effectively recycled have remarkably increased from one year to the next, from 5.7% in 2008 to 30% in 2016 (Fig. 3). This makes evident the positive impact of the CSWMP implemented. The increase in recycling at UNALP between 2008 and 2016, in addition to avoiding the disposal of 73.6 tons of waste in landfill, has represented a saving of €11,111 EUR (~$13,100) for the institution, due to the payment that was avoided by the final landfill disposal of this waste, without mention the additional economic benefit that has been achieved by the sale of recycled material.

However, contamination by non-recyclable materials is still regularly found in recycling bin, which reduces the amount of material to be recycled. Therefore, one of the challenges of UNALP is improve source segregation and recycling, in order to recycle 40% of the material which, even though being recyclable is being sending to landfill.

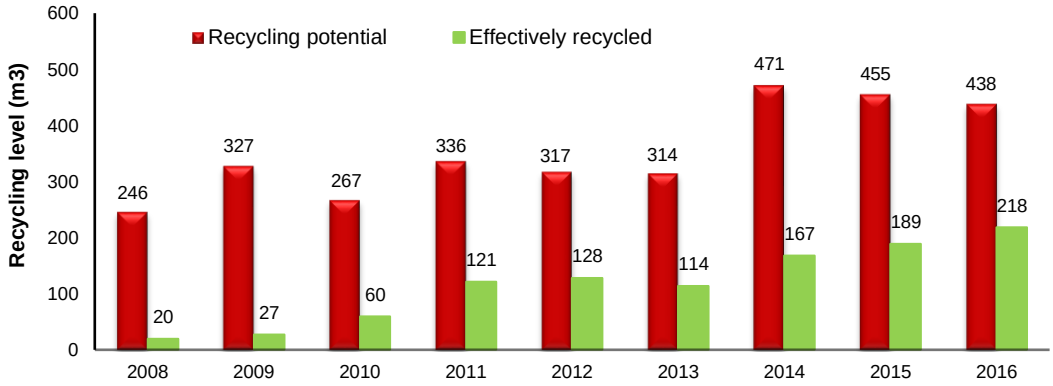

Fig. 3. Recycling level at UNALP

3.3. *Waste composition*

One of the properties that notably changed in the UNALP solid waste was bulk density. This parameter decreased 11.8% during the period analysed, going from 170 kg/m^3 in 2008 to 149 kg/m^3 in 2016 (Fig. 4).

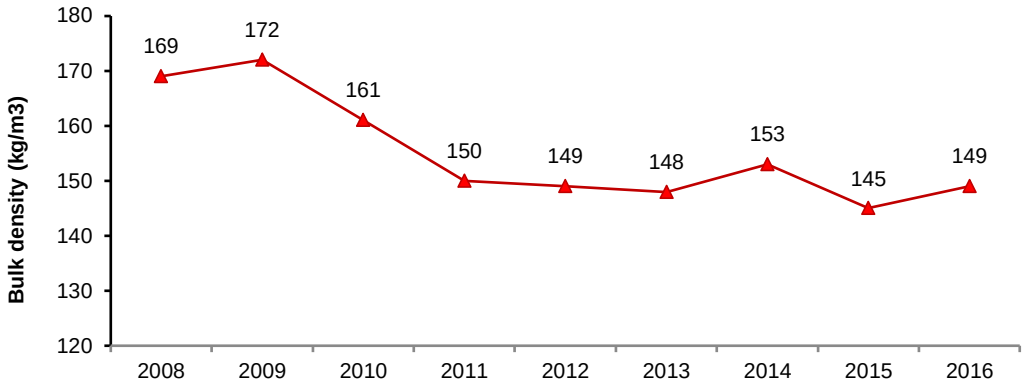

Fig. 4. Historical bulk density of the solid waste generated at UNALP

The reduction in the bulk density is related to changes in the solid waste composition, specifically with the reduction in heavier materials and/or the increase in the lighter ones. Indeed, it can be seen in the UNALP waste characterization (Fig. 5) that heavier materials, such as food waste, garden waste, glass and metal, were greatly reduced from 2007 to 2016. On the other hand, lighter materials, such as plastics, cardboard, polystyrene and others increased in time. These changes in solid waste composition is a consequence of changes in consuming habits of staff and students and, in general, in the Colombian society in recent years. Modern life implies that people have less time to cook at home or produce items for themselves, in that way "ready-to-eat" or "ready-to-use" products are preferable nowadays.

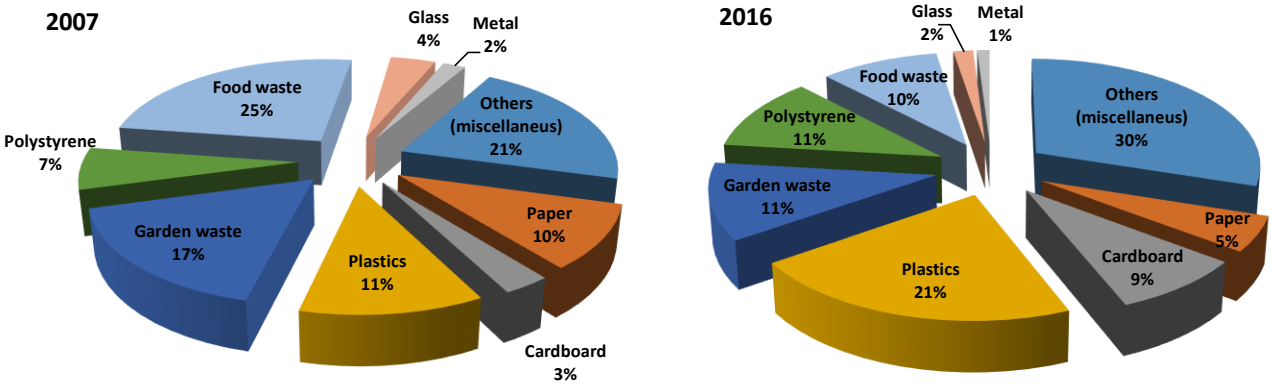

Fig. 5. Solid waste characterization 2007-2016

3.3.1. *Paper waste and cardboard*

It is noteworthy the 50% reduction in paper generation (Fig 5) from 10% (2007) to 5% (2016), mainly due to the policy of "use email instead of paper" and of "do not print if not necessary". In addition, paper recycling containers were provided in each office and administrative area on campus. They are emptied regularly by the University's cleaning staff and the material is recycled properly. These actions are part of the "zero paper" policy that is being implemented in the institution during the last 5 years, and are part, in time, of the national directive: Administrative efficiency and zero paper policy in the public administration, promoted by the national government, since 2012 [18].

Currently, UNALP paper generation is similar to the one reported by Islamic University of Indonesia with 5.71% [19] and is lower than the one reported by University of Lagos Ankoka campus [5] and by Universiti Teknologi Malaysia [17], with 15% and 16.1%, respectively.

3.3.2. *Plastics and polystyrene*

The plastic waste generation has increased from 2007 to 2016, rising from 11% to 21%, which can be explained for the increase in the use of plastic bags, the demand of bottle water and commodities with excess of packaging.

In the same period, expanded polystyrene has increased from 7% to 11%, this is due to the increased in disposable polystyrene food packaging caused by the raising in “ready-to-eat” products, as mentioned before.

Plastics generation of others HEI are as follows: 4.8% for the University of Baja California [6], 8.1% for University of Northern British Columbia [4], 19.9% for the Universiti Teknologi Malaysia [17] and 33% for the University of Lagos Ankoka campus [5]. It can be stated that UNALP plastics rate generation is in the range of others HEI.

3.3.3. *Organic waste*
Food waste generation decreased from 25% to 10% and garden waste decreased from 17% to 11%. Organic waste generation for UNALP has been ranging from 42% to 21%, which means that this is an important waste with potential to be recycled. Therefore, it is strongly recommended that the institution implements environmentally safe disposal and resource recovery technologies for organics waste. Such technologies can be composting and anaerobic digestion given that the tropical conditions are very convenient for biological processes.

3.3.4. *Glass and metal*
There was a reduction in glass generation from 4% to 2%, mainly due to the changes in the bottle containers materials which went from glass to plastics materials or tetrapack. This UNALP glass rate generation is similar to the ones reported by University of Lagos Ankoka campus [5] with 2%, and by University of Baja California [6] with 2.6%. Metal waste production was ranging between 2% to 1%, which means that this type of material is one of the minor waste.

3.3.5 *Others (micellaneus)*
Others materials (non-recyclable) generation rate increased from 21% to 30%, which is a reflection of changes in the community consuming habits as expressed before in section 3.3. It is important to notice that activities such as packaging of food in the daily basis and the increase in the number of events held on campus, have raised the use of disposable materials without possibilities of reuse or recycling.

3.4 *Solid waste management at the UNALP*

3.4.1. *Initial state and actions taken*
Before 2008, inadequate handling of solid waste at the UNALP prevented the reuse or recycling of materials. There was a bad distribution and use of bins, solid waste containers and bins were not protected from the weather, and there was no collection with plastic bags (Fig. 6a.). The lack of environmental practices and inadequate infrastructure did not allow an efficient source separation. It was clear that, at that moment, the sustainability was not important for the UNALP administration.

a. 2007 b. 2016

Fig. 6. Collection site of solid waste, in 2007 and 2016

In 2007 the institution made the decision of "putting its own home in order" to reach coherence with its mission as well as providing real-life examples of the application of the Environmental Engineering, one of its academic programs. There were two important initial milestones, the first one was the development of a CSWMP in 2007, which lead to the second one, the formulation and implementation of an Environmental Management System (EMS) for the UNALP in 2008.

Under the frame of the EMS and the CSWMP, the main actions implemented from 2008 to 2016, were:
- Creation of the UNALP Environmental Policy (2008).
- Construction and starting up of an internal Recycling Centre (Fig. 6b. up) (2009-2010).
- Design of an environmental educational program that included awareness activities regarding reduce, reuse and recycling solid waste (2007 with improvements in the following years). Small talks in the classes, teaching students on how to segregate solid waste adequately. Support from Environmental Management practicing technicians, in the waste segregation process and in the infrastructure of recycling.
- Student initiatives such as *the material bank*, were Industrial Design students can find solid material used for their courses projects and also deposit their remaining materials for others to use (2012).
- Teaching and training to the cleaning staff in segregation, reuse and recycling of solid waste (from 2008 on a regular basis).
- Designed a solid waste collection route within the University to make more effective the collection and recycling of waste materials (2008).
- Installation of a network of selective bins, inside and outside the buildings (2010-2011). In that way, the non-hazardous waste is separated into three fractions: paper and cardboard (grey bin), clean plastics (blue bin) and mixed waste (green bin) (Fig. 6b. down).
- Initiatives from different departments staff in reuse and recycling of material that they use on the daily basis.
- Paper cups instead of expanded polystyrene in the cafeteria and canteens (2015).

3.4.2. *Barriers and challenges*

Despite of the great efforts made by UNALP to improve its solid waste management, still has to deal with some barriers, such as:
- Lack of real commitment and demonstrated support for environmental actions. Even though, throughout the implementation of the CSWMP and the EMS, many people have joined and supported the process, there are still some professors, administrators and students who show no interest not commitment, or simply they think that it is not important.
- Lack of sufficient money for projects. UNALP is a public University, whose financing is subject to the investment in education made by the Colombian government and, unfortunately, Colombia invests $3,245 a year per student, the lowest figure in all of Latin America, while on average the countries that are part of the Organisation for Economic Co-operation and Development (OECD) invest $10,182 [20]. Therefore, UNALP should prioritise its expenses and sometimes sustainability is not a first priority. Despite the future and long-term benefits, a lack of funding remains a major concern for all involved in sustainability initiatives [8].
- Lack of time. Most of the people in charge of environmental tasks and sustainability projects have other primary responsibilities in the University. Professors, as well as others university members are busy people who devote part of their time to promote sustainability [21].
- There is not local/regional recycling infrastructure and expertise in order to recycling new materials. Currently, in the municipality of Palmira there are small associative companies dedicated to recycling, the material they collect to recycling is basically paper, cardboard, clean plastic, white glass, aluminium cans and metals. Therefore, materials such as polystyrene, coloured glass and packaging cannot be recycled in the region.
- Lack of clear national policy in recycling. Colombian regulations still favour the disposal of solid waste in landfills instead of motivating reuse and recycling.

The main challenges for the progress of the CSWMP in UNALP are:
- Obtain internal and external financing to carry out projects already proposed and future initiatives.
- Involved researchers and professors in present and future projects.
- Increased of level of recycling.
- Arise awareness in consumption habits in the academic community.

From the above, it is evident that becoming a sustainable university in a developing country is not an easy task. Some of the few authors that addressed the topic, recognize that the rapid economic development and population growth, inadequate infrastructure and expertise, have contributed to the problem of solid waste management in most developing nations [10].

However, with the leadership of a small team, the support of the administration of the University, the knowledge and proper planning, it has been possible to improve the environmental performance at UNALP and to become the second most sustainable university in Latin America [22]. Being a public university in a developing country is not an excuse for not fulfilling the moral and ethical duty to act responsibly with the environment. Inasmuch as, the University as an educational institution of future generations, many of which will be at the forefront of research and development of the industry, should be aware that it influences its students through curriculum, teaching and research, but also through the environment that it provides, the very experience of the campus and through the leadership of the University [23].

4. Conclusions

The effectiveness of a CSWMP and the EMS implemented at the Universidad Nacional de Colombia Campus Palmira, since 2008, have been proved because: the rate of waste generation has remained low despite the increase in the number of students and the economic grow of the nation, the level of recycling significantly increased to 30% and paper generation declined importantly.

Changes in the consuming habits of staff and students has an important impact in the type of waste generated and its availability of recycling, this should be taken into account to design strategies to reduce waste at the source and good solid waste management practices. Additionally, it was evidenced that the inability to recycle new materials reflects the lack of infrastructure and expertise of the local/regional industry.

As public University in a developing country, the main barriers that the institution has to face are: lack of commitment by student and staff, insufficient funding, lack of recycling infrastructure and expertise at local/regional level, and delays in the national regulatory framework. Nevertheless, strong leadership, the support of the administration of the University and the knowledge and proper planning are proven to be key factor to improve environmental performance at UNALP, since being a public university in a developing country should not be an excuse for not acting responsibly with the environment.

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