Methodological proposal for the assessment of environmental aspects in Higher Education Institutions (HEIs)

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Abstract. This work proposes a methodology specially aimed at Higher Education Institutions (HEIs). The methodology is based on the use of quantitative and qualitative indicators that allow diminishing the assessment's subjectivity and the uncertainty of the results. This proposal was designed within the implementation of Environmental Management Systems (EMS) according to the ISO standard 14.001/2015, so it can be applied by any kind of organization interested in improving its environmental performance by identifying its environmental aspects, as well as assessing and preventing its environmental impacts. The methodological proposal assesses standard criteria like the affected area and the frequency of the activities that generate the environmental aspects. This analysis is complemented by innovative indicators such as the danger of the substances related to the environmental aspect, the time of exposure and the effects on human health. Additionally, some indicators that allow measuring the magnitude of the harm generated by the identified aspects are also included. The proposed approach has two main advantages: first, it allows integrating the environmental analysis with other management systems, such as the Occupational Health and Safety Assessment Series (OHSAS 18001), quality (ISO 9001) and general requirements for the competence of testing and calibration laboratories (ISO 17025), among others; and second, it establishes an indicators system whose frequent assessment allows following up the environmental aspects and evaluate the effectiveness of its management measures. The application of this methodology in the main seat of Universidad Nacional de Colombia revealed that the most significant environmental aspects were: generation of ordinary solid waste, consumption of potable water, consumption of electric power, generation of recyclable solid waste, and wastewater discharge.

1 Introduction

The HEIs work as a system where exchanges of matter, energy and information take place, even though their missional purpose is the training and generation of knowledge, rather than the production of goods and services for the market or the business sector.

In the development of their missional functions, the HEIs generate environmental impacts that affect the university communities (students, teachers and administrative staff) and interfere with the learning and teaching processes, as well as with the human health and the natural resources of the campuses.

As a consequence, a high number of HEIs worldwide have turned to the implementation of EMS from a preventive approach as a strategic measure that integrates the university community in general and constitutes a didactic tool for environmental education.

The main basis of the EMS is the determination of those activities or actions developed by the HEIs that may interact with the environment. They are called Environmental Aspects (EA) and their identification and scope is essential for the subsequent design of action plans. The methodologies for their identification and assessment are mostly qualitative, therefore their associated subjectivity and uncertainty may interfere with the objectives of the EMS.

A methodology for the assessment of the EA has been designed taking into account this necessity. This proposal is based on the analysis of objective indicators that provide more credibility and it is framed in the implementation of EMS according to the ISO standard 14.001/2015, so it can be applied by any kind of organization interested in improving its environmental performance by identifying its environmental aspects, as well as assessing and preventing its environmental impacts. The proposed methodology was tested in Universidad Nacional de Colombia (Bogotá Seat) and it allowed obtaining more objective results and criteria that will contribute to a more effective decision-making process in the short, medium and long term. **Table 1.** Setting Word's margins. Use a two-column format, and set the spacing between the columns at 8 mm. Do not add any page numbers.

2 Conceptual foundations

According to the ISO 14001 standard, an EA is an element of the organization's activities, products or services that may interact with the environment. Carretero (2007) points out that "an EA is something

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generated by an activity [1], product or service that may have incidence on the environment, which is defined as the natural setting that contains those EA as well as other living beings". Two concepts are proposed for the development of this methodology: unit of analysis (UA) and macro unit (MU). The UA refers to a space or a combination of spaces presenting homogeneous physical conditions and where common activities take place, so they have similar EA. Spaces such as warehouses, auditoriums, libraries, cafeterias, sport halls, laboratories, offices, classrooms and green areas can be considered as UA. On the other hand, the MU is the combination of UA that belong to a physical space clearly distinguishable due to its structural elements (e.g., a building). Unlike the UA, several types of activities may take place inside an MU.

3 Methodological proposal

This methodology has two main stages: identification of EA and their assessment. The following are the steps for its application.

3.1 Staff selection and training

Once the processes developed by the institution have been identified, a group of interviewers must be selected and trained. One MU will be assigned to each interviewer, who must identify all the UA and the person in charge in order to schedule an interview. Thus, will be obtained the information required to assess the EA.

3.2 Identification of UA and associated activities

The interviewee must provide all the information related to the activities developed in his/her UA. These activities must be grouped into generic categories, according to their nature. For instance, if the interviewee performs duties such as answering emails and writing documents, these tasks can be grouped into the "office and IT activities".

3.3 Identification of EA

Once the generic activities of each UA are defined, then the EA must be identified. In the case of Universidad Nacional de Colombia (Bogotá Seat), 33 EA were determined (see Table 1).

3.4 Assessment of EA

The assessment of the EA's significance takes into account the attributes of time, severity and magnitude:

Table 1. EA identified at Universidad Nacional de Colombia – Bogotá Seat. Source: based on [1] and [2]

EA			
1	Combustion emissions	19	Generation of fat, oil and grease waste
2	Non-combustion emissions	20	Disposal of tires
3	Noise emissions	21	Disposal of rechargeable batteries
4	Emissions of offensive odors	22	Disposal of alkaline batteries
5	Saturation of visual objects	23	Disposal of light bulbs
6	Discharge of domestic wastewater	24	Disposal of waste of electrical and electronic equipment (WEEE)
7	Discharge of water with environmental effects	25	Disposal of tonners and cartridges
8	Discharge of water with sanitary effects	26	Disposal of expired medications
9	Generation of leachates	27	Disposal of pesticide containers
10	Generation of biodegradable waste	28	Consumption of potable water
11	Generation of ordinary solid waste	29	Consumption of non-potable water
12	Generation of inert waste	30	Consumption of electric power
13	Generation of recyclable solid waste	31	Consumption of fossil fuels
14	Generation of bio-sanitary waste	32	Consumption of paper
15	Generation of sharps waste	33	Consumption of disposable materials
16	Generation of human anatomopathological waste	34	Consumption of fertilizers
17	Generation of animal anatomopathological waste	35	Consumption of pesticides
18	Generation of chemical waste		

- **Time**: it is assessed according to the frequency of the EA and its duration (in hours). The ranks presented in Table 2 must be used in order to assess this attribute. The logarithm base 5 of the total of hours of EA per year (obtained from the multiplication of the frequency and the duration) was calculated to define the values included in Table 2. Values below 1 were approximated to that number, so that the scale could be limited to the rank from 1 to 5, and thus the significance of the EA is not underestimated (those values are identified in Table 2 with an asterisk).
- **Severity:** it is calculated from the interaction between the coverage (range), danger and effects of the EA on human health. Table 3 includes the description of each component of this attribute.
- **Magnitude:** it refers to the quantification of the EA based on quantitative or qualitative indicators. In order to assess this criterion, the results obtained from the indicators must be classified into 5 categories, each one of them with a particular value: "very high" (10), "high" (8), "medium" (6), "low" (4) and "very low" (2). The use of these categories and their associated values allows to standardize the magnitude of the EA, regardless of the units that were employed for their measurement. Some of the proposed indicators for the assessment of the EA in the case of Universidad

Nacional de Colombia (Bogotá Seat) are presented in Table 4. The defined values and ranges for these indicators are included in Table 5.

Table 2. Scale of values for the assessment of the Time attribute (own elaboration).

Frequency		Duration (hours)												
		≤1	2	3	4	5	6	7	8	9	10	11	12	≥13
Daily	240	3.4	3.8	4.1	4.3	4.4	4.5	4.6	4.7	4.7	4.8	4.9	5	5
Weekly	54	2.5	2.9	3.2	3.3	3.5	3.6	3.7	3.8	3.8	3.9	4	4	4.1
Biweekly	27	2.1	2.5	2.7	2.9	3.1	3.2	3.3	3.3	3.4	3.5	3.5	3.6	3.6
Monthly	12	1.5	2	2.2	2.4	2.5	2.7	2.8	2.8	2.9	3	3	3.1	3.1
Quarterly	4	1*	1.3	1.5	1.7	1.9	2	2.1	2.1	2.2	2.3	2.4	2.4	2.5
Biannually	2	1*	1*	1.1	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2	2
Annually	1	1*	1*	1*	1*	1	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.6

Table 3. Values for the assessment of the Severity attribute (own elaboration).

Criterion	Categories	Value
Coverage: area of influence of the EA	**Widespread**: when the effects of the EA go beyond the UA	2
	Local: when the effects of the EA are located inside the UA	1
Danger: inherent qualities of the substance related to the EA	**Dangerous**: corrosive, reactive, explosive, toxic, flammable, infectious or radioactive substance	5
	Not dangerous: a substance that does not present any kind of hazard	3
Effects on human health: level of damage that the EA or its associated substance may cause on human health	**Extreme**: death or disability	5
	Critical: acute or chronic diseases that generate partial or permanent disability	4
	Severe: diseases that cause temporary disability (*e.g.* hearing loss)	3
	Moderate: temporary diseases that cause any kind of malaise (*e.g.* diarrhea)	2
	Minor: does not have any effect on human health or only generates minor discomfort or irritation (*e.g.* headache)	1

3.5 Significance of the EA

After assessing the attributes, the significance of each EA has to be determined by using the following formula:

Significance = Severity + [Time x Magnitude] (1)

Where: Severity = Danger x Effects on human health x Coverage (2)

Time = Frequency x Duration (3)

Depending on the result, the significance can be classified according to the values presented in Table 6.

Table 4. Indicators for the calculation of the magnitude (own elaboration).

EA	Indicator	Formula*
Combustion emissions	Emission of CO_2-eq	$EC = \sum_{\alpha,\beta} CC_\alpha \times FE_\beta \times PCG_\beta$ EC = Emission of CO_2-eq (kg/month) CC = Fuel consumption (TJ/month) FE = Emission factor (kg/TJ) PCG = Global Warming Potential α = type of fuel β = Molecule
Generation of recyclable solid waste	Recyclable solid waste per capita	$RSRpc = \frac{\sum RSR}{N}$ RSRpc = Recyclable solid waste per capita (kg/per-month) RSR = Recyclable solid waste (kg/month) N= Number of individuals per UA
Generation of chemical waste	Solid chemical waste per capita	$RQSpc = \frac{\sum RQS}{N}$ RQSpc = Solid chemical waste per capita (kg/per-month) RQS = Solid chemical waste (kg/month) N= Number of individuals per UA
Consumption of paper	Consumption of paper	$CP = \sum NRM$ * 2.26 CP = Consumption of paper (kg/month) NRM = Number of realms of paper per month

*Note: the abbreviations of the elements integrating the formulae correspond to the initials of the words in Spanish.

Once the significance is obtained, then some measures need to be designed in order to prevent, correct or mitigate the EA. The priority of these measures can be defined according to the category of the EA and the values presented in Table 6.

Table 5. Classification categories of some EA (own elaboration). All Unit are in kg/month.

EA	Indicator	Very low (2)	Low (4)	Medium (6)	High (8)	Very high (10)
Combustion emissions	Emission of CO_2.eq	≤10.21	>10.21 and ≤102.1	>102.1 and ≤510.5	>510.5 and ≤1021	>1021
Generation of recyclable solid waste	Recyclable solid waste per capita	≤0.23	>0.23 and ≤0.26	>0.26 and ≤0.28	>0.28 and ≤0.31	>0.31
Generation of chemical waste	Chemical waste per capita	<0.102	≥0.102 and <0.114	≥0.114 and <0.126	≥0.126 and <0.138	≥0.138
Consumption of paper	Consumption of paper	<2,26	≥2,26 and <4,52	≥4,52 and <9,04	≥9,04 and <18,08	≥18,08

Table 6. Scale of values for the interpretation of the EA's significance (own elaboration).

Category	Values	Significance	Priority for decision-making and actions
Critical	81-100	Yes	Immediate
Severe	61-80	Yes	Short term
Moderate	41-60	Yes	Medium term
Minor	21-40	No	Long term
Irrelevant	<20	No	Does not require any action

3.6. Assessment of the EA in the MU

A set of indicators for the MU is proposed in order to complement the analysis. These indicators can be used to assess the environmental management at a larger scale (campus, other land properties of the HEI, or seat) and they can be formulated in absolute terms (e.g. kg) or in relative terms (e.g. kg/per capita or kg/month). The use of absolute indicators allows analysing the performance of the identified EA in a period of time [3]. On the other hand, the use of relative indicators facilitates the comparison of the EA [4] among buildings, other land properties and seats, which allows assessing plans, programs and actions related to the environmental management of the institution. Table 7 presents some of the indicators proposed for the MU of Universidad Nacional de Colombia (Bogotá Seat).

Table 7. Indicators for the UM (own elaboration).

Category	EA	Absolute indicator	Relative indicator
Atmospheric emissions	Atmospheric emissions	Global emission of CO_2-eq	Emission of CO_2-eq per capita
Waste	Generation of non-hazardous waste	Non-hazardous waste generated	Non-hazardous waste generated per capita
	Generation of hazardous waste	Hazardous waste generated	Hazardous waste generated per capita
Consumption of resources	Consumption of water	Consumption of potable water	Consumption of potable water per capita
	Consumption of electric power	Consumption of electric power	Consumption of electric power per capita
	Consumption of paper	Consumption of paper	Consumption of paper per capita

The proposed methodology has two main advantages: first, it allows integrating the environmental analysis with other management systems, such as OHSAS 18001, ISO 900 and ISO 17025, among others; and second, it establishes an indicators system whose frequent assessment allows following up the environmental aspects and evaluate the effectiveness of its management measures. For a detailed description of the methodology please refer to Martínez Bernal et al. (2018) [5] or the working document published in the web page of the Environmental Management Office of Universidad Nacional de Colombia (Bogotá Seat).

4 Application of the methodology

Table 8 presents the most important results of the application of the proposed methodology in Universidad Nacional de Colombia (Bogotá Seat). This means, table 8 presents the higher values of EA.

Table 8. Results.

EA	% of UA where the EA was significant
Generation of ordinary solid waste	34,5%
Consumption of potable water	28,7%
Consumption of electric power	19,5%
Generation of recyclable solid waste	13,8%
Discharge of domestic	10,0%

EA	% of UA where the EA was significant
wastewater	

Source: own elaboration based on the information provided by the Environmental Management Office of Universidad Nacional de Colombia.

5 Conclusions

The application of this methodology in the main seat of Universidad Nacional de Colombia determined that the most significant environmental aspects were: generation of ordinary solid waste, consumption of potable water, consumption of electric power, generation of recyclable solid waste, and wastewater discharge. This information led to the formulation of programs aimed at the prevention, mitigation and correction of those aspects and their related environmental impacts.

The methodology proved to be easy to apply and effective for the identification of the main environmental aspects and impacts. It can be used by any other kind of institutions (not only HEIs), because it integrates the community in general and constitutes a didactic tool for environmental education.

References

1. A. Carretero Peña. Aspectos ambientales: Identificación y Evaluación. AENOR. Madrid. Spain (2007)
2. L. W. Canter. Manual de evaluación de impacto ambiental. Mc Graw Hill (1998)
3. S. Cecchini. Indicadores sociales en América Latina y el Caribe. CEPAL (2005)
4. D.C. Suárez. Conceptos y formulación de indicadores. Programa de información e indicadores de gestión de riesgos de desastres naturales. BID – Universidad Nacional de Colombia Sede Manizales. (2003)
5. L. F. Martinez Bernal, A. L. Caro, J. C. Duran Dueñas, N. del P. Pacheco and J. J. Toro. Propuesta metodológica para la identificación y evaluación de aspectos ambientales en instituciones de educación superior. Gestion y Ambiente I. (2018).