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CONTAMINATED SITES, WASTE MANAGEMENT AND GREEN CHEMISTRY: NEW CHALLENGES FROM MONITORING TO REMEDIATION

Environmental assessment in health care organizations

Isabel Romero[1] · María Carmen Carnero[1]

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Abstract
The aim of this research is to design a multi-criteria model for environmental assessment of health care organizations. This is a model which guarantees the objectivity of the results obtained, is easy to apply, and incorporates a series of criteria, and their corresponding descriptors, relevant to the internal environmental auditing processes of the hospital. Furthermore, judgments were given by three experts from the areas of health, the environment, and multi-criteria decision techniques. From the values assigned, geometric means were calculated, giving weightings for the criteria of the model. This innovative model is intended for application within a continuous improvement process. A practical case from a Spanish hospital is included at the end. Information contained in the sustainability report provided the data needed to apply the model. The example contains all the criteria previously defined in the model. The results obtained show that the best-satisfied criteria are those related to energy consumption, generation of hazardous waste, legal matters, environmental sensitivity of staff, patients and others, and the environmental management of suppliers. On the other hand, those areas returning poor results are control of atmospheric emissions, increase in consumption of renewable energies, and the logistics of waste produced. It is recommended that steps be taken to correct these deficiencies, thus leading to an acceptable increase in the sustainability of the hospital.

Keywords Health care organization · Environment · Sustainability · Environmental management system · Environmental assessment · Analytical hierarchy process · Multi-criteria decision making

Introduction

Concern about the environment is currently of great importance to European, national, and regional authorities, companies and organizations in general, and also with public opinion. Given the significance of the subject, it is useful for organizations to develop and introduce an environmental management system to assess the risks and environmental impact they have, and so control, reduce, or improve outcomes. This reality is reflected in the strategies used by governments when designing policies and systems intended to build a society committed to sustainable development, eliminating or alleviating negative effects on the environment (Lee et al. 2017).

There are in existence environmental audits as management tools for performing assessments of the behavior of organizations, of the management system, and actions taken to protect the environment. The literature includes many contributions showing the importance of evaluating environmental activity, for example, with regard to sintering in the steel industry (Geldermann et al. 2000), in farming systems (Halberg et al. 2005; Pishgar-Komleh et al. 2017), in buildings (Ding 2008), with assessment of risk to human health (Linkow et al. 2009), on agricultural land (Carballo et al. 2016), in local government action plans (Herraz-Pascual et al. 2013), environmental risk assessment in deposits of red sludge (Wen et al. 2016), in capture and usage processes for CO_2 by carbonation cycles (Pan et al. 2016), in urban heating networks fed by large-scale cogeneration plants (Ravina et al. 2017), etc. This is, however, not true in health care organizations, even though they are the only type of organization that produces all categories of waste (Carnero 2015). Hospitals are composed

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✉ Isabel Romero
Isabel.Romero3@alu.uclm.es

[1] Business Administration, Technical School of Industrial Engineering, University of Castilla-La Mancha, Avda. Camilo José Cela, s/n, 13071 Ciudad Real, Spain

of several departments with contrasting purposes. They are complex systems due the appropriate use and operation of the buildings is a critical responsibility. Zimmer and McKinley (2008) list, for example, hospital rooms with needs similar to residential buildings, laboratories preparing chemistries, and operating or surgery rooms that need absolute cleaning needs. In this type of organization, the literature on environmental assessment systems built on mathematical models, and so objective and able to be judged openly, is almost non-existent, but worthy of note is Carnero (2015), which develops an environmental sustainability assessment system via a fuzzy analytical hierarchy process using the annual number of treatments undertaken to make objective comparisons between different organizations. Carnero (2018) constructs a model in the fuzzy environment of the Technique for Order Preference by Similarity to Ideal Situation (TOPSIS), to assess the environmental responsibility of a health care organization. Nevertheless, these studies do not perform an environmental audit in the field of health care, as they do not include economic or legal criteria, which are included in the present research.

Life cycle assessment (LCA) and life cycle cost assessment (LCCA) are methodologies widely used in environmental management. In Geldermann et al. (1999), the environmental impact of kerosene burning during the flight of an aircraft is examined with an LCA. The ecological evaluation shows the substances which contribute to the potential environmental impacts caused by the kerosene burning. Brentrup et al. (2004) describe an LCA method to evaluate the environmental effects which are relevant to crop production. The study summarizes the environmental impacts into the following two indicators: human health and resource depletion and impacts on ecosystems. Song et al. (2013) evaluate the environmental impacts of municipal solid waste management using LCA method to know the relation between recycling rate and total environmental impact. Unger and Landis (2016) use LCA and LCCA to evaluate the environmental and economic impacts of medical device supply chains when varying levels of devices are used in a hospital. In this context, Unger et al. (2016) suggest a sustainable health care checklist in order to evaluate the sustainability of medical devices and services using an environmental and economic LCA.

There are also several methods in literature that are focused on the assessment of healthcare buildings. For instance, Wood et al. (2016) determine the most important aspects that could be affected during a hospital design process through the House of Quality tool for green design. Energy efficiency, indoor environmental quality, sustainability site planning and management, materials and resources, water efficiency, and innovation are issues that are taken into consideration. Castro et al. (2017) propose a methodology based on a list of sustainability indicators which are considered in health care buildings. This study classifies the criteria in five categories: environmental, sociocultural and functional, economic, technical, and site. Németh et al. (2017) developed a quantitative aquatic environmental assessment method for the qualitative evaluation of surface and ground water bodies to provide an importance weighting among the environmental parameters evaluated.

Some researchers are considered around specific environmental issues. The study of concentrations of antibiotics in hospital wastewater is researched in Hamjinda et al. (2015) The aim is to know the effectiveness of hospital wastewater treatment processes that are treated. Xin (2015) only focuses on gathering information about hazardous and non-hazardous medical waste generated by hospitals to develop a way for medical waste assessment in future researches. Data are classified according to their characteristics. Successful medical waste management is beneficial for risk reduction of hazardous waste (Noman et al. 2016). Other authors (see Kern et al. 2013 and Zotesso et al. 2017) study different chemical processes for the treatment of hospital laundry wastewater to determine if the techniques are environmental friendly with a view to minimize the negative effects on the environment. In Ryan-Fogarty et al. (2016), a case study about energy and waste management in a health care organization is shown. The aim is to create a relation between both regulatory requirement and voluntary initiatives to get an environmental impact mitigation though an environmental education program. Pinzone et al. (2016) study the improvement of sustainability in health care organizations that happens after the enhancement of human resources attitudes and behaviors toward the environment by means of green practices. In Blass et al. (2017), a system to measure environmental performance in health care organizations is proposed. Lack of strategic focus of performance indicators as well as difficulties for the improvement of environmental performance in hospitals is shown.

Other techniques are applied to overall new constructions, existing buildings, or overhauls and conversion of buildings with the common objective to control the use of their resources. Apart from this general objective, the aim of this article is to ensure that health care organizations obtain a certification in accordance with standard ISO 14001 or Regulation EMAS to get successful results in environmental audits, all of this being framed within a continuous improvement process.

Regulation (EC) 1221/2009 defines an environmental audit as a management tool comprising a systematic, documented, periodic, and objective assessment of the behavior of an organization, the management system, and the procedures designed to protect the environment with the aim of facilitating operational control of the practices that can impact the environment, and assessing compliance with the environmental policy of the organization, and particularly of its environmental objectives and goals.

There exists a variety of environmental audits, depending on the objective sought, the staff who will carry it out, and the environmental areas assessed (Ximénez and Zulueta 2001).

The first classification reflects the body that commissions the audit:

- Internal audit: commissioned by the organization itself and the auditing staff may or may not belong to the company audited.
- External audit: commissioned by another organization (for example a certifying body) and always carried out by an independent company.

The second classification depends on the stage of the Environmental Management System (EMS) audited:

- Initial review audit: carried out at the initial stage of EMS introduction so as to know the state of the organization before the system is activated, paying special attention to applicable environmental standards.
- Review audit: commissioned when the EMS is up and running, to check the continuous improvement process and assess the degree of compliance with the objectives and goals set out.

The third classification depends on some specific environmental aspect to be addressed in order to establish new objectives and foals in the organization.

Environmental audits in health care organizations are within the third classification. For this kind, standard ISO 14001 does not specify any particular question, but it does consider it a highly useful support tool for an organization that wishes to introduce an EMS.

The EMS of a health center has the global objective of assessing the management with regard to protection of the environment and the handling of natural resources. On the other hand, there are other objectives such as assessment of treatment and disposal of waste produced by the hospital in carrying out its activities (Orozco 2009). This system may be introduced in accordance with standard ISO 14001 or regulation (EC) 1221/2009 on the voluntary participation of organizations in the EC environmental management and auditing systems (EMAS). The EMAS regulation is more demanding than the standard ISO 14001, and those organizations that comply with it have an excellent environmental image (Bracke et al. 2008).

To introduce an EMS, it is necessary to define a series of environmental indicators which will serve to quantify the development over time of the environmental protection of an organization (IHOBE 2000). In recent years, environmental indicators have become an essential part of environmental impact assessments. For this reason, it has an influence on environmental management and the development of policy at all levels of decision making (Niemejier and de Groot 2008). These indicators are also useful for converting the data analyzed by the decision group into valuable information when developing management policy (Peterson and Granados 2002). The purpose of these indicators is to control the environmental response of an organization and the human activities which affect the efficiency of current policies. An indicator should also reflect changes over time, and should be reliable and reproducible (Hammond et al. 1995).

The intention of this paper is to present an innovative and objective system able to provide an environmental assessment of a health care organization. As the current trend is to obtain environmental and energy management system certificates in all kinds of companies (Mas-Alique et al. 2014), using this system would help any medical center when requesting recognition in accordance with standard ISO 14001 or the regulation EMAS. To this end, a set of hierarchically organized environmental indicators is defined, with the aim of applying the multi-criteria decision technique, analytic hierarchy process (AHP). Criteria used are characterized by the descriptors, and it is not as subjective a model as if a traditional AHP were applied. The analysis carried out in (Herva and Roca 2013) shows that multi-criteria decision methods are useful when many criteria are considered. Finally, the results obtained from applying the model in a Spanish public hospital are set out to check the validity of the system.

The paper is organized as follows. The following section describes the foundation of the methodology used and the environmental indicators used in the assessment. Then, the results are shown. Later, the conclusions are given. Last section the acknowledgements and Section 6 the bibliography.

Materials and methods

Analytic hierarchy process

AHP is a technique which allows complex multi-criteria decisions to be analyzed and organized. According to Saaty (Saaty 1980), AHP consists of dividing a problem and then joining the solutions to the sub-problems into a conclusion.

The application of AHP starts with the design of the decision structure hierarchy (Eskandari et al. 2016), produced by a decision maker or a decision group. This hierarchy comprises the objective of the problem to be analyzed, the criteria and sub-criteria to be taken into account, and the alternatives considered in the decision. Then, an evaluation of the elements is performed, by pairwise comparisons of the criteria and sub-criteria, which may be qualitative or quantitative. To do this, it is necessary to make a value scale indicating how many times more relevant one element is than another with respect to a

Table 1 Fundamental scale of Saaty

Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Compromise values between those above
Reciprocal	If activity *i* has one of the numbers assigned above zero in comparison with activity *j*, then *j* has the inverse value in comparison to *i*
Rational	Ratios derived from the scale

criterion or a property in which they are compared (Saaty 2008). The scale used, established by Saaty (Triantaphyllou and Mann 1995) is shown in Table 1 These pairwise comparisons make up, together, a pairwise comparison matrix.

In general, the pairwise comparison matrices are like that shown in Eq. (1)

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

Matrix A has the following characteristics:

- It is a square matrix, size $n \times n$, where n is the number of elements compared.
- Matrix A is reciprocal and positive.
- a_{ij} is the preference of the alternative in row i when compared with the alternative in column j.
- When $i = j$, the value of a_{ij} will be equal to 1, as the alternative is compared with itself.
- It can be verified that $a_{ij} \times a_{ji} = 1$.

Once the pairwise comparison matrix is obtained, the priority of each element must be calculated. This establishes a ranking of alternatives, and the alternative with the highest value is chosen as the most satisfactory (Chowdhury & Roy, 2016).

AHP allows the level of consistency of the judgments given to be assessed, to guarantee the quality of the final decision (Buiza-Camacho et al. 2016). To calculate the consistency of the judgments given by the decision maker, Saaty proposes the Consistency Index (CI), defined as in Eq. (2):

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

where λ_{max} is the main value or maximum autovalue of matrix A and n is its order, such that $\lambda_{max} \geq n$. The CI depends on the order of the matrix, and so Saaty defines the Consistency Ratio (CR) as:

$$CR = \frac{CI}{RCI} \quad (3)$$

where RCI is the mean random consistency index obtained by randomly simulating the judgments for reciprocal matrices of order n. The values of the RCI (Aguarón and Moreno-Jiménez, 2003) are calculated as shown in Table 2.

Consistency is considered acceptable when RC is less than 10%.

This technique is very widely applied due to its ease of use and its simplicity, and thus, AHP is better accepted by decision makers and used extensively in the literature. Among the most important applications are (Bhushan and Rai 2004):

- Choice: selection of an alternative from a group of alternatives.
- Prioritization: determining the advantages of a set of alternatives.
- Resource assignment: searching for the best combination of alternatives subject to a series of restrictions.
- Market comparison: comparing processes or systems with other markets, with prior knowledge of the processes or systems.
- Quality control: guaranteeing consistent application.

Environmental indicators

In recent years, environmental indicators have become an essential part of environmental impact assessment (Luna-González and Rodríguez-Hurtado 2012). For this reason, its influence on environmental management and the creation of policies at all levels of decision making has increased (Niemejier and de Groot 2008). They have an important role in defining environmental policies, as they allow the evolution of the state of the environment, human influence, and the effectiveness of the measures taken to protect the environment, to be measured (van der Voet et al. 1999).

The Public Society for Environmental Management defines environmental indicators as an instrument that quantifies evolution over time of environmental protection in an organization, identifying trends and allowing immediate correction if necessary (IHOBE 2000). Among the features that environmental indicators should have are the following (Royuela 2001):

- Relevance: at national level, although they may be used at regional or local levels.
- Pertinence: with respect to the goals of sustainable development and others.

Table 2 Random Consistency Indices (RCI)

n	3	4	5	6	7	8	9	10	11	12	13
RCI	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484	1.513	1.535	1.555

- Clarity: comprehensible, simple, and unambiguous.
- Viability: within the limits of the national statistical system and available at the lowest possible cost.
- Limitation: in number, but covered by an enrichment criterion.
- Representativeness: chosen by consent.

Among the objectives of these environmental indicators is control of the environmental response of an organization and the human actions that affect the efficiency of current policy. Furthermore, an indicator should reflect changes in a time period after being introduced, and should be reliable and reproducible (Hammond et al. 1995).

Environmental criteria in health centers

Following the recommendations of the Commission of the European Communities for applying regulation (EC) no. 761/2001 (European Union, 2009), the criteria used in this paper are classified into three main groups: Criteria for environmental behavior, Criteria for environmental management, and Criteria for environmental condition. Each criterion includes a set of first level sub-criteria, which, in turn, contain second level sub-criteria. A series of indicators have been defined for the latter, with associated scale levels. For reasons of space, they are not all defined in this article, but they may be seen in full in the supporting file (Online Resource 1).

The criteria for environmental behavior allow assessment and follow-up of the environmental impact of an organization. They focus on the planning of processes and the material means available, and on controlling their use. This group includes the following sub-criteria: Atmospheric emissions, Water, Energy consumption, Consumption of materials, and Waste.

As an example, we now give the definition of the sub-criterion Waste and one of its associated indicators. For the other criteria, sub-criteria, and indicators used in the model, the same methodology and format has been used to describe them.

Waste: the quantity of waste generated is a big environmental problem for health care organizations. Thorough control of waste is necessary in order to manage it effectively. According to Law 83/1999, of the 3rd of June, which regulates activities related to the production and management of bio-sanitary and cytotoxic waste in the Comunidad de Madrid (Comunidad de Madrid 1999), waste generated by health centers is classified as follows:

Class I: General waste.
Class II: Bio-sanitary waste treatable as urban waste.
Class III: Special bio-sanitary waste.
Class IV: Bodies and human remains.
Class V: Chemical waste.
Class VI: Cytotoxic waste.
Class VII: Radioactive waste.

Once the types of waste that can appear in a Health Care Organization are known, a choice is made of those that may cause most problems if not adequately controlled, and indicators are defined for them. Here is an example of an indicator:

Ratio of potentially infectious waste per patient: This indicator assesses the quantity of potentially infectious waste collected and eliminated in accordance with statute. The lower the value of this criterion, the better the sustainability of the center. If disposed of directly, like waste treatable as urban

Table 3 Scale levels for the indicator Ratio of potentially infectious waste per patient

Levels	Definition
L1 (highest level)	A value of 0 kg/patient of potentially infectious waste is obtained and is disposed of according to by-law
L2	A value from (0, 0.45] kg/patient of potentially infectious waste is obtained and is disposed of according to by-law
L3	A value from (0.45, 0.90] kg/patient of potentially infectious waste is obtained and is disposed of according to by-law
L4	A value > 0.90 kg/patient of potentially infectious waste is obtained and is not disposed of according to by-law
L5 (lowest level)	Does not know/does not answer

Table 4 Scale levels for the indicator Environmental management of suppliers

Levels	Definition
L1 (best level)	The health care organization has a system of green purchasing whereby the suppliers are responsible for removing, transporting, and disposing of or recycling the clinical waste produced, in accordance with the environmental management of the center
L2	The health center does not have a system of green purchasing
L3 (worst level)	Does not know/does not answer

Table 5 Hierarchy structure

Objective	Criteria	First-level sub-criteria	Second-level sub-criteria	Indicator
Environmental assessment system	Environmental performance	Atmospheric emissions	Sulfur dioxide (SO_2)	
			Nitrogen oxide (NO_x)	
			Non-methane volatile organic compounds (NMVOCs)	
			Ammonia (NH_3)	
			Suspended particles ($SP_{2.5}$)	
			Methane (CH_4)	
			Carbon footprint	
		Water	Total water consumption	
			Waste water discharges	
			Recycling and reuse	
		Energy consumption	Gas oil consumption	
			Electricity consumption	
			Diesel/natural gas consumption	
			Renewable sources consumption	
		Materials consumption	Office supplier	
			Paper consumption	
			Chemical materials	
			Ink/batteries/toner consumption	
			Fluorescent tubes consumption	
			Radiographs	
		Waste	Ratio of potentially infectious waste per patient	
			Ratio of cytotoxic waste per treatment	
			Ratio of chemical products with hazardous substances	
			Water waste with hazardous substances	
	Environmental management	Legal aspects	ISO 14001	
			EMAS	
		Staff/patients/environment sensitivity	Environmental training plan	
			Awareness campaigns	
			Meeting with professionals from management and improvement area	
			Information of environmental progress	
			Environmental costs	
			Fulfillment environmental objectives	
			Complains and suggestions	
		Green purchasing	Environmental management of suppliers	
		Waste management	Identification	
			Proper identification of waste	
			Segregation	
			Proper segregation of waste	
			Packaging	
			Type of packaging	
			Colors	
			Reuse	
			Waste collection	
			Waste collection	
			Medicines collection	
			Transport	
			Internal transport of waste	
			Disposal	
			Protection and risk prevention policies of staff	
			Responsibilities	
	Environmental situation	Biodiversity	Take care of species included in the IUCN Red List	
		Acoustic pollution	Noise inside the health center	
			Noise outside the health center	
		Emergency situations	Environmental accidents	

waste, there is a risk to the staff of the clinic, to the wider community, and to the environment. In the case of health centers, the maximum quantity of waste whose collection and disposal is subject to local laws to prevent infections is 0.90 kg/patient (Carnero 2014). The scale levels for this indicator are shown in Table 3.

On the other hand, the criteria for environmental management are related to the need to control and assess the management of the processes and efficiency in achievement of a company or organization (Atehortúa 2005). This group comprises the following sub-criteria: Legal matters, Staff/patient/environment sensitivity, Green purchasing, and Waste management.

Table 6 Pairwise comparison matrix for the sub-criterion Waste

Index		A51	A52	A53	A54
Ratio of potentially infectious waste per patient	A51	1	0.320	4.000	5.000
Ratio of cytotoxic waste per treatment	A52	3.125	1	6.950	5.940
Ratio of chemical products containing hazardous substances	A53	0.250	0.144	1	0.320
Water-based waste containing hazardous substances	A54	0.200	0.168	3.125	1
	Local weighting	0.278	0.565	0.056	0.089
	Global weighting	0.024	0.056	0.006	0.010
				CR=	0.099

In this case, the example shows the definition of the sub-criterion Green purchasing and one of its associated indicators.

Green purchasing: health care organizations purchase many products every year. Among these purchases are computer equipment, cleaning products, furniture, electrical apparatus, paper, clinical materials, etc. All these things have an impact on the environment during sourcing, production, use, and disposal; this may include emission of greenhouse gases, exhausting of natural resources, and loss of biodiversity.

Green purchasing is a tool that centers may use voluntarily to contribute to the reduction in damaging effects on the environment. It consists of, when buying or contracting products and services, taking into account not only economic or technical aspects but also their environmental impact over their life cycle, that is, considering the environmental behavior of the supplier. This system offers benefits to the health care organization, such as improving its image and leading to environmental progress. The indicator associated with this sub-criterion is defined here:

Environmental management of suppliers: This indicator is defined as, when contracting suppliers, demanding a series of special conditions so that the contract respects the environment as much as possible. The conditions are that the suppliers should remove, transport, and dispose of or recycle the waste produced in accordance with the environmental management of the health center. The health care center informs the suppliers of its environmental policies and responsibilities. Suppliers should accept this commitment and keep to it. The levels defined for this indicator are shown in Table 4.

Finally, the criteria for environmental condition give information about the environmental situation in the area where the organization or company is located. They are made up of the following sub-criteria: Biodiversity, Noise pollution, and Emergency situations.

Results and discussion

Hierarchy model

Table 5 shows the elements that make up the hierarchy model used in the environmental assessment model described. The model obtained is complete and non-redundant, and the criteria and sub-criteria are mutually independent. Also, the number of elements involved in the comparisons is no greater than nine, and so the Miller index is satisfied. The hierarchy consists of an objective, 3 criteria, 12 first-level sub-criteria, 8 second-level sub-criteria, 46 indicators, and 5 alternatives. These last correspond to the levels of excellence of the environmental assessment system, and are

- Alternative 1 (A1): EXCELLENT: All levels required are always satisfied, and so there is an optimal and correct environmental assessment system.
- Alternative 2 (A2): VERY GOOD: All levels required are nearly always satisfied, that is, most of the indicators reach optimal levels. The system is highly acceptable although the indicators with poorer outcomes should be improved.
- Alternative 3 (A3): GOOD: The level required are satisfied sporadically. The indicators achieve medium or low levels. The EAS is acceptable although there should be work done to improve it.
- Alternative 4 (A4): DEFICIENT: The levels required are not satisfied. The indicators achieve low or undesired levels. The EAS should be grossly changed.
- Alternative 5 (A5): VERY DEFICIENT: Reaches the worst levels present in the assessment system. Corrective management action should be carried out to improve it.

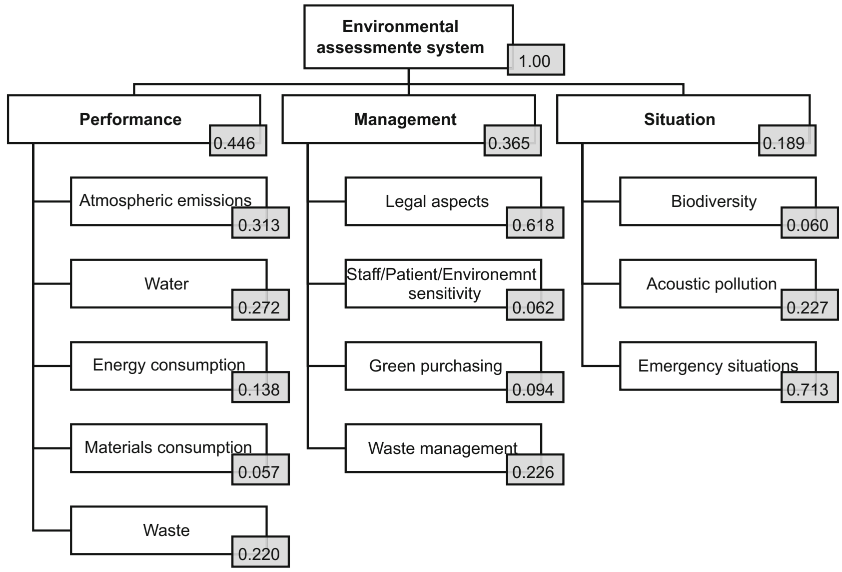
Two additional alternatives are also defined:

- MAXIMUM (M): This level is reached when expectations are more than met, and the level of the indicator is above the alternative Excellent.

Table 7 Pairwise comparison matrix for the indicator Environmental management of suppliers

Scale levels	L1	L2	L3
L1	1	3	5
L2	1/3	1	3
L3	1/5	1/3	1
		CR=	0.04

Fig. 1 Weightings obtained



– MINIMUM (m): This level is obtained when expectations are not reached and the level of the indicator is below the alternative Very Deficient.

Pairwise comparison matrices

To perform the environmental assessment according to the hierarchy model set out above, the pairwise comparison matrices are divided into two groups: the first corresponds to the pairwise comparison matrices between the criteria and sub-criteria; and the second, between the scale levels of the indicators. Seventeen matrices of the first type, and 46 of the second, were assessed. In both cases, assigning judgments is done by three decision centers made up of a health professional, an expert in environmental matters, and a specialist in multi-criteria decision techniques. From these three judgments, a geometric mean was taken to calculate the resulting aggregate judgment for each matrix.

Table 6 shows an example of the pairwise comparison matrix for the sub-criterion Waste. This matrix includes the local and global weighting, as well as the CR, indicating inconsistency present in the judgments of the experts. Next, Table 7 shows the pairwise comparison matrix for the indicator Environmental management of suppliers.

It can be seen that the matrices are consistent as they do not exceed the index established by Saaty. As with the definition of criteria, not all the matrices are included, for reasons of space.

Priority and synthesis

Having obtained the pairwise comparison matrices, the local and global priorities must be obtained for each of the matrices calculated at the previous stage. A ranking of alternatives is then established to determine which of them is best for solving the problem in question (Boj et al. 2009). Figure 1 shows the weightings obtained.

It can be seen that the criterion with the greatest weighting, that is, the criterion of greatest importance, is Environmental behavior. In second place is the criterion Environmental manftagement, and in last place is Environmental condition. The result is considered solid because the sub-criteria covered by Environmental behavior are very important in contributing to improving the environment.

On the other hand, one of the sub-criteria with the lowest values is Biodiversity. This result is reasonable because the intention of this sub-criterion is to conserve endangered species included in the International Union for Conservation of Nature (IUCN) in areas belonging to the health center being assessed. As these centers are usually in urban areas, it is not common to find these species, and so the consequences are minimal.

Practical case: Assessment of a Spanish public hospital

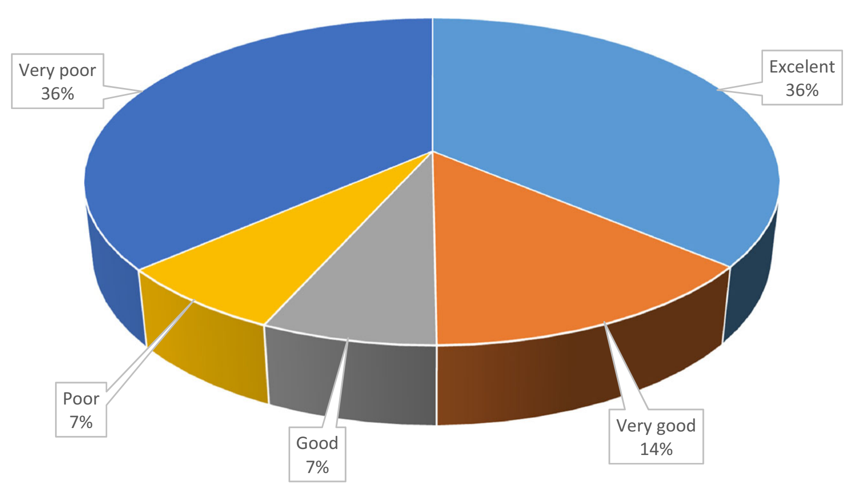
A Spanish public hospital was assessed, to verify its environmental state, and so check that the system described here can be applied to any health center. The health center is located in the Autonomous Community of Andalucía and has nearly 1000 beds. For reasons of confidentiality, no more information about the hospital is given.

The only requirement for using the method is to have the necessary data; in this case, the data can be found in the Sustainability Records for 2011. The questionnaire contains 46 questions. Each has a set of answers corresponding to the scale levels previously defined for each indicator. Depending

Table 8 Section of questionnaire

	Indicators	Scale levels	Alternatives				
			A1	A2	A3	A4	A5
Waste	Ratio of potentially infectious waste per patient	A value equal to 0 kg/patient of potentially infectious waste is obtained					
		A value between (0, 0.45] kg/patient of potentially infectious waste is obtained and it is removed complying with regulations		X			
		A value between (0.45, 0.90] kg/patient of potentially infectious waste is obtained and it is not removed complying with regulations					
		A value higher than 0.90 kg/patient of potentially infectious waste is obtained and it is not removed complying with regulations					
		Does not know/does not answer					
	Ratio of cytotoxic waste per treatment	An equal value to 0 kg/treatment of cytotoxic waste is obtained					
		A value between (0, 0.35] kg/treatment of cytotoxic waste is obtained		X			
		A value between (0.35, 0.70] kg/treatment of cytotoxic waste is obtained					
		A value higher than 0.70 kg/treatment of cytotoxic waste is obtained					
		Does not know/does not answer					
	Ratio of chemical products with hazardous substances	An equal value to 0 kg/analysis of chemical products is obtained					
		A value between (0, 0.05] kg/analysis of chemical products is obtained					
		A value between (0.05, 0.1] kg/analysis of chemical products is obtained			X		
		A value higher than 0.1 kg/analysis of chemical products is obtained					
		Does not know/does not answer					
	Water waste with hazardous substances	An equal value to 0 kg/analysis of water waste with hazardous substances is obtained					
		A value between (0, 0.075] kg/analysis of water waste with hazardous substances is obtained					
		A value between (0.075, 0.15] kg/analysis of water waste with hazardous substances is obtained					
		A value higher than 0.15 kg/analysis of water waste with hazardous substances is obtained					
		Does not know/does not answer					X

Fig. 2 Results of the sustainability assessment in a Spanish hospital



on the answer chosen, the appropriate alternative is selected. Table 8 shows a section of the questionnaire. The complete questionnaire that was filled out in shown in Annex A.

Results

Figure 2 shows the results of the questionnaire summarized as a pie chart. Thirty-six percent of the questions, that is, of the indicators calculated, gave a value of EXCELLENT, 14% VERY GOOD, 7% GOOD, 7% DEFICIENT, and 36% VERY DEFICIENT. This final result appears striking, but it is because the center assessed did not have or did not know the information requested and was penalized for it.

The alternatives MAXIMUM and MINIMUM are included in the alternatives EXCELLENT and VERY DEFICIENT, respectively, since they have the same values. They are, therefore, not shown.

It can be said, then, that the health center assessed obtains, in general, very good results in the environmental criteria that it manages. These criteria are related to energy consumption, the production of hazardous waste, legal matters, environmental sensitivity of staff, patients, and others, and the environmental management of suppliers. On the other hand, issues to be borne in mind to continue contributing to the environment are, for example, the control of atmospheric emissions, the increase in consumption of renewable energy, and the logistics of the waste produced.

In the final assessment, a score of 0.6286 out of 1 was obtained. Therefore, the center assessed is well on the way to improving its overall environmental management. As a suggestion, it is proposed that they focus on those criteria with the weakest scores in order to assess them and take action to improve the results. Once these actions have been taken, there should be an improvement in the sustainability assessment of the hospital when applying our methodology again.

Conclusions

This paper describes a method for carrying out environmental assessments in health care organizations. With the support of this tool, any hospital that wishes to introduce an EMS according to standard ISO 14001, or to join the EMAS, can check the environmental state it is in and which areas should be improved to obtain certification without difficulty.

Furthermore, the model is a novel means of contributing to improvements in sustainability in health centers. Unlike traditional audits, the use of multi-criteria decision techniques, including a hierarchy structure for the problem, helps the decision makers to organize the problem easily and define the desired objective explicitly. The method as a whole is able to measure criteria both qualitatively and quantitatively through a common scale. Finally, it is shown that the model can be used to assess different hospitals; the only requirement is to have access to the information in their sustainability reports.

As future work, the intention is to assess other hospitals to compare the results obtained and thus establish an improved hierarchy, eliminating the criteria that it is not in fact necessary to assess, if there were any, and redefining those that need it, adding new criteria as appropriate. Also, the model could be validated by means of other multi-criteria techniques, such as MACBETH or TOPSIS.

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