DESIGNING A SUSTAINABLE MANAGEMENT SYSTEM FOR STUDENT LABORATORIES

López-Escalante M.C.[1*], López-Ramírez M.R[2], Contreras R.[3], Peinado-Pérez J.J.[4], Cuevas A. L.[d], Romero-Pareja R. [5], Navarrete-Astorga E.[4], Martín F. [1].

[1] Departamento de Ingeniería Química. Unidad de Nanotecnología, Laboratorio de Materiales y Superficies, Facultad de Ciencias. Universidad de Málaga 2907. ESPAÑA
[2] Departamento de Química-Física, Facultad de Ciencias. Universidad de Málaga 2907.
[3] Departamento de Ciencias Químicas en Farmacia, Facultad de Farmacia. Universidad Complutense de Madrid 28040.ESPAÑA
[4] Departamento de Física Aplicada I. Unidad de Nanotecnología, Laboratorio de Materiales y Superficies. Facultad de Ciencias. Universidad de Málaga 29071, ESPAÑA

Abstract

Students from science degrees will develop works with high experimental level. Therefore, it is important for them to acquire a solid training in good laboratory practice, a responsible use of resources and a suitable management of risk at workplace. In this initiative, all these items are considered and taken the form of a sustainable management system which also offer them the opportunity to work with management system commitment with Circular Economy and the Sustainable Development principles. This sustainable management system has been designed and implemented for different laboratory practice courses at Environmental Science Degrees. The presented work has been developed in two levels. The first one is the design a versatile sustainable management system which can be applied to student laboratory practices from a general point of view and at different degrees. This system is a general document which presents the main key performance indicators linked to the different necessary resources, for instance, chemical products, energy, protection devices or waste management. The second one concerns its particular application to the selected courses mainly from Environmental Science Degree and it will be named as "Global Laboratory Management System". In this document each key performance indicator is broken down for each specifical experiment. These two documents will be developed by the teachers and only the second one will be provided to the students. Students will complete the "Global Laboratory Management System" with their own experimental data obtaining key performance indicator. value. Finally, key performance indicator is expressed as economic value which can help to students how to manage the employed resources with the aim to be more sustainable.

Keywords: Innovation, sustainable, management system, resources

1 INTRODUCTION

Nowadays, jobs related with scientific degrees demand a high experimentation level. Due to this, one of the main objectives for the scientific degrees syllabus is to bring students into close contact with laboratory work. This implies a big leap for most students starting their university studies which have to begin by devoting time to perfecting introductory techniques for laboratory work. Therefore, this is the best moment and the best environment to incorporate transversal tools which will help them in the development of their future job as a high commitment to the principles of Circular Economy [1] and the Sustainable Development [2].

Based on the former dissertation, this initiative works on two principal lines: one is the promotion of highly transversal skills and the other is a strong commitment to the environment and safety. Therefore, priority has been given to students enrolled in subjects with a high practical laboratory component in the Environmental Sciences degree.

The way to translate this idea to the student laboratory is by the design of a global laboratory management system also named as sustainable management system. This system is based on a suitable and general key parameter indicator definition (named as KPI). [3], and their incorporation in a specifically spreadsheet for each course. The indicators are defined in five different areas: chemical resources, energetic resources, human resources, prevention of risk at work and waste management.

They will be implemented in a spreadsheet by the involved teachers and results will be reported as economic value. Then, the spreadsheet will be given to the students which will complete by their own experimental data obtaining a final value per each indicator and another global value.

Finally, this system provides an overview of the resources needed to carry out a practice. Moreover, KPIs expression as an economic value will help students to a better comprehension of how to manage resources, how poor resources management leads to a deviation from a common objective, as well as the improving possibilities. Furthermore, with this work system, they are introduced to concepts such as management system, quality and KPIs, which are widely used in today's work environments.

2 METHODOLOGY

The main objective of this work is to define a versatile sustainable management system for laboratory practices. This general document will provide the KPI definition and the sections where they will apply. Then, this general document will be adapted to the selected degrees. All this work will be done by the involved teachers.

The selected degree is Environmental Science and the involved courses are" Fundamental of Environment Engineering" and "Water and Soil Contamination". These two courses have a high laboratory charge.

The adapted global laboratory management system will be provided to the students which will be completed by their own data.

The spreadsheet will report them several values. One per each defined section and another global value. All indicators will be expressed as economic results and their analysis will be carried out by the teachers. Finally, results will be share with students and a discussion session will be opened to analyse and compare the results

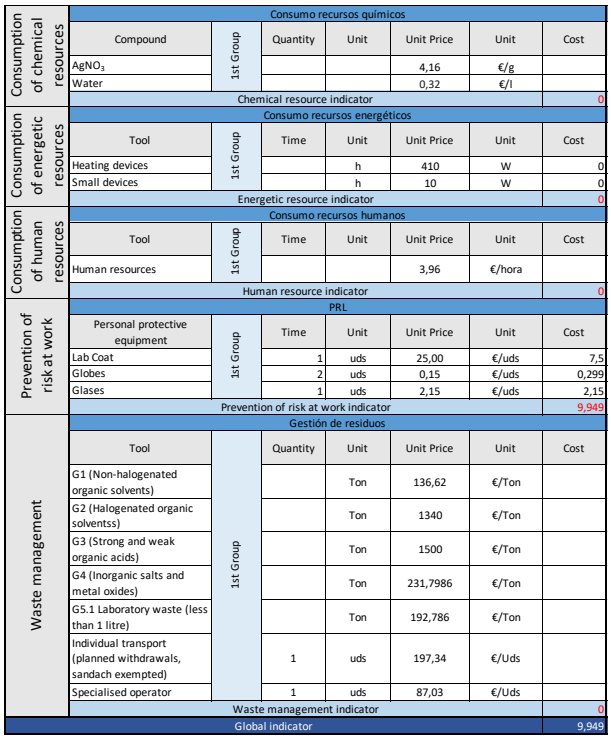
3 RESULTS

This section is devoted to experimental results and it will be separated in two main sections: the first one related with the versatile global laboratory management system and the second one its adaptation to the selected courses.

3.1 Design of the versatile sustainable management system for laboratory practices

The main objective of this general document is to select the suitable KPIs and where they will be applied. The definition of KPIs is not a trivial task because they must be sufficiently general so that translation to other subjects is not a tedious task, and at the same time sufficiently simple so that students can understand them and have a satisfactory first contact with management systems. In addition, it is also crucial to establish the metrics in which the indicators are to be expressed. In particular, the economic expression has been chosen

In this work, five general KPIs have been selected: chemical resources, energetic resources, human resources, prevention of risk at work and waste management. Figure 1 shows the six defined KPI and their incorporation in a spreadsheet. As can be observed the main concept, to be general, has been successfully reached because the unique that has to be modified per course is chemical and energetic resource consumptions.



Consumption of chemical resources	Consumo recursos químicos						
	Compound	1st Group	Quantity	Unit	Unit Price	Unit	Cost
	$AgNO_3$				4,16	€/g	
	Water				0,32	€/l	
	Chemical resource indicator						0
Consumption of energetic resources	Consumo recursos energéticos						
	Tool	1st Group	Time	Unit	Unit Price	Unit	Cost
	Heating devices			h	410	W	0
	Small devices			h	10	W	0
	Energetic resource indicator						0
Consumption of human resources	Consumo recursos humanos						
	Tool	1st Group	Time	Unit	Unit Price	Unit	Cost
	Human resources				3,96	€/hora	
	Human resource indicator						0
Prevention of risk at work	PRL						
	Personal protective equipment	1st Group	Time	Unit	Unit Price	Unit	Cost
	Lab Coat		1	uds	25,00	€/uds	7,5
	Globes		2	uds	0,15	€/uds	0,299
	Glases		1	uds	2,15	€/uds	2,15
	Prevention of risk at work indicator						9,949
Waste management	Gestión de residuos						
	Tool	1st Group	Quantity	Unit	Unit Price	Unit	Cost
	G1 (Non-halogenated organic solvents)			Ton	136,62	€/Ton	
	G2 (Halogenated organic solventss)			Ton	1340	€/Ton	
	G3 (Strong and weak organic acids)			Ton	1500	€/Ton	
	G4 (Inorganic salts and metal oxides)			Ton	231,7986	€/Ton	
	G5.1 Laboratory waste (less than 1 litre)			Ton	192,786	€/Ton	
	Individual transport (planned withdrawals, sandach exempted)		1	uds	197,34	€/Uds	
	Specialised operator		1	uds	87,03	€/Uds	
	Waste management indicator						0
	Global indicator						9,949

Figure 1. versatile global laboratory management system.

3.2 Design of global laboratory management per course

The adaptation of the designed global laboratory management has been done for each involved course. Figure 2a shows the specific spreadsheet for the practice named as “Chemical reaction velocity”. All the resources have been included by the teacher and they have to complete the spreadsheet with their own values. As can be seen economic values have been obtained per each KPI and finally, their summatory provides the global indicator. These results can be grouped in one table and different comparison can be done. For instance, it can be study and make comparisons between groups inside the same course, respect a common target or even perform a monitorization which includes several year. A comparison with a target has been represented in Figure 2b. It is possible to check that most of the student groups have been developed their practices with responsibility because are near the target and just two of them are far from the objective.

Consumption of chemical resource	1st GRUP	Chemical resource indicator					
		Compuesto	Molecular weight	Quantity	Unit	Unit cost	Cost
		KNO_3	101,06	0,08	g	37,30 €	2,98 €
		Water	18	0,016	L	73,30 €	1,17 €
		Chemical resource indicator					4,15 €
Consumption of material resources		Material resource indicator					
		Material resource indicator	Characteristic	Quantity	Unit	Unit cost	Cost
		Beaker	Volumentriz	1	1	14,45 €	14,45 €
		Test tube	Volumentriz	1	1	0,41 €	0,41 €
		Pipefitter	Volumentriz	1	1	38,74 €	38,74 €
		Funne	Volumentriz	1	1	2,13 €	2,13 €
		Mechero bunsen	Hot	1	1	32,19 €	32,19 €
		Tripod with grille	Support	1	1	4,94 €	4,94 €
		Pipette	Volumentriz	1	1	25 €	25,00 €
		Material resource indicator					117,86 €
Consumption of energetic resources		Energetic resource					
		Tool	Time	Consumption (kW)	Invest energy	Unit	Cost
		Balanza analitica	0,05	0,008	0,0004	kW/h	0,0001 €
		Energetic resource indicator					0,00 €
Prevention of risk at work		Prevention of risk at work					
		EPI	Objective		Quantity	Unit price	Cost
		Lab coat	Protection		1	24,93 €	7,48 €
		Glasses	Protection		1	3,56 €	1,07 €
		Globes	Protection		4	0,01 €	0,04 €
		Prevention of risk at work indicator					8,59 €
Waste management		Waste management					
		Group	Waste	Quantity	Unit	Price	Cost
		G4	KNO_3	0,022	g	37,30 €	0,82 €
		Waste management indicator					0,82 €
Global indicator							48,92 €

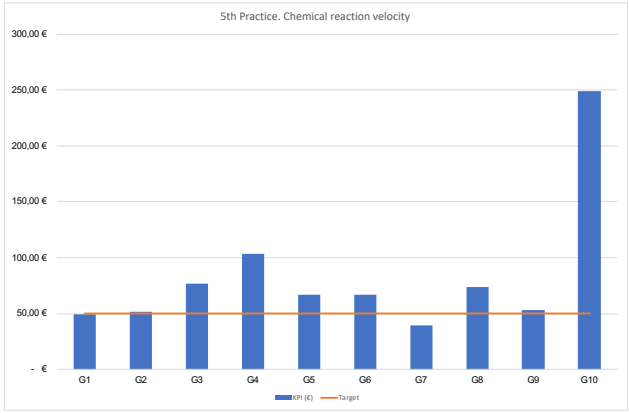


Figure 2. (a) Global laboratory management system for a specific practice and (b) comparison between experimental values and the target.

4 CONCLUSIONS

This work shows a successful case for the design and implantation of a global laboratory management system for experimental courses in science degrees. This management system is based on five different indicators with are expressed as economic value with the aim to facilitate its comprehension by the students. This information it is an opportunity to understand the relevance of responsibility in resource consumption and waste management together with the be close to management systems. The key performance indicator common expression allows their comparison between groups in the same course or even between different academic courses leading to the possibility of its monitor.

ACKNOWLEDGEMENTS

Este proyecto de innovación educativa denominado “Diseño de un protocolo para la gestión sostenible de recursos en laboratorios de alumnos”, está financiado por la Universidad de Málaga a través del PIE19-056.

References [Arial, 10-point, left alignment, upper and lower case] should be cited according to the Bibliography and Citation Style https://iated.org/citation_guide

[1] Circular Economy principles. Available at: https://ec.europa.eu/commission/presscorner/detail/es/ip_20_420

[2] Sustainable Development principles. Available at: https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-approach-sustainable-development_es

[3] D. S.Kourkoumpas, G. Benekos, N.Nikolopoulos, S. Karellas, P.Grammelis, E.Kakaras. A review of key environmental and energy performance indicators for the case of renewable energy systems when integrated with storage solutions. Applied Energy 231 (2018) 380-398