Developing a methodology for the comprehensive management of hazardous chemical residue in higher education institutions[1]

Formulación de una propuesta metodológica para la gestión integral de residuos químicos peligrosos en instituciones de educación superior[1]

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Abstract

In chemical analysis laboratories a great amount of products are handled and many different operations are carried out, either for educational processes or research purposes which lead to the generation of hazardous waste. These are varied and highly complex because of the complex matrix they are part of. Therefore they present a bigger challenge when dealing with them. The objective of this investigation was to formulate a methodological proposal for the management of hazardous chemical waste based on the University's Waste Management Plan. In order to assess the methodology's proper development, the work was done together with the general chemistry laboratories, by doing a preliminary diagnosis and quantifying the total amount of waste generated. Then we characterize it since this stage of the methodology is crucial for the management and identification of the waste for further treatment. Once the first stages of the methodology were through, we went ahead and applied the treatments which lowered the temporary storage of chemical waste, by eliminating it by evaporation, encapsulation and bioremediation by 35% of the total waste generated in 2010. We were also able to properly apply the established methodology, obtaining results in the improvement of the waste segregation and characterization, helping lower the uncontrolled storage that it was in the temporary storage room, which did not have any kind of treatment or control. This situation presented a high risk of environmental impact for the institution in the long term.

Keywords: Waste; segregation; generation; management; disposal; record; posting.

Introduction

The Environmental Protection Agency-*EPA* from the USA define the hazardous residues as the residues or combination of them that present a determined risk, whether it's current or potential, for the human health or other living organisms, due to the cause of the next generic reasons:

• No-degradation and persistence in the dumping place

• Possibility of noxious effects due to accumulative effects.

• Possibility to suffer biological transformations with aggravation of their effects.

• High content of lethal compounds.
(Environmental Protection Agency, 2014).

The Irish Protection Agency in their national plan of hazardous residues management, between the years 2014 and 2020, was focused in four objectives for the right management of the residues:

• Preventing and reducing the generation of said.

• Maximize the residue collection with the goal to decrease the impacts.

• To fight with a self-sufficiency in the residues management.

• Reducing to the minimum the impacts that these residues generate. (Environmental Protection Agency, 2014).

In Colombian legislation a residue or hazardous residue is considered as the one that, for its corrosive, reactive, explosive, toxic, flammable, infectious or radioactive characteristics, can cause risk for the human health or the environment. Likewise, it is considered residues or hazardous residues the, containers and packages that have been in contact with them (Decree 4741/2005). At the same time the legislation defines the term generator, that is natural or legal person that produces hospital or similar residues in the development of health care activities, included the actions of: health promotion, disease prevention, diagnose, treatment and rehabilitation; the teaching and research with living and dead organisms; the vivaria and biotechnology labs; the cemeteries, morgues, funeral home and crematorium ovens , clinics, medical practices, pharmacies, pigmentation centers and/or tattoos, veterinary labs, zoonosis centers and zoological gardens. (Decree 2676/2006).

From there to the superior education institutions are generator establishments of hazardous residues that have become in one of the main problems for the universities that haven implemented a residue management system, because every operation done with hazardous residues from its generation to its final dispose generator of negative environmental impacts (Benítez, 2005). All of them are characterized in general by their variety, very heterogeneous compositions and because it is used to be produced in very low and variable quantities through time. Besides, in most of the cases these residues tend to present a toxicity and/or high risk, which difficult its management (Peñalver, 2000).

In the University of Maryland in the USA, like in other superior level institutions there are labs that generate hazardous residues; for the management of the aforementioned the University designed a manual that focused in six aspects:

Residue identification.

Tagging and marking.

Accumulation and storing.

Control documents and registers.

Transportation and disposal

Emergency preparation

Residue minimization

Recycling. (University of Maryland, 2004)

The researchers Mecklem R and Neumann performed a research for the management of hazardous wastes in the universities of the US finding an advanced diagnose with the health and occupational safety offices. 122 institutions were surveyed, finding that the 84% of the institutions treat the non-infectious cell cultivation residues as hazardous residues, likewise the 90% of the institutions uses sterilization in autoclave as a treatment system for the biological residues treatment, but only the 52% verify its efficiency through biological indicators. The incineration *In Situ* is used by the 42% of the universities (Mecklen and Neumann, 2003).

In the Universidad de Concepción a project was presented about university hazardous substances and residues management, it was implemented under a residue management ruling for all the faculties of the education center, it was identified that each one of the generator units, guaranteed the personal, environmental and infrastructure health.(Universidad de Concepcion, 2005).

The universities in Colombia have solved the segregation and treatment of solid residues problematic with the formulation of integral management plans and are example of it, the Corporación Universitaria Lasallista that got to save $18´114.772 pesos in the cleaning index, when decreasing the volume of residues for their final dispose, producing organic compost and selling recyclable material (Castrillon and Puerta (2012); in the Fundación Universitaria María Cano a diagnose was elaborated and a diagnosed was formulated with an integral residue management (Silva, 2010).

In the Universidad del Cauca a research was made about the segregation of chemical residues alternatives in the environmental and sanitary engineering of the institution (Mera, 2007), like a hospital residue management plan in the Health Unity from the same institution, with the support from the Research Funds of the University (*FINU-UFPS*). Through the *GIBA* (2008-2009) group a project was made: "Execution of the first stage of the liquid and solid hazardous and non-hazardous residues management generated in the offices of the Universidad Francisco de Paula Santander, in the Champs Elysées the city of Los Patios Norte de Santander, and in the Universidad de Pamplona the "*Plan de Manejo de Residuos Peligrosos del Campus Universitario* (Hazardous Residues from the University Campus Management Plan" was implemented and functioning since 2008.

Due to the previous reasons it is necessary to formulate a methodology that takes the necessary elements for the elaboration of a management plan in the superior education institutions tending to the treatment and diminution or mitigation costs reductions of the environmental impacts done by them.

The methodology that was proposed counted with a series of stages that took in account the ruling standards for Colombia and the international standards tending to the adequate management of hazardous residues. The main objectives that were looked for were:

Reducing the health risk, impeding that the infectious or special wastes, that are generally in small fractions, pollute the other wastes generated in the institution.

Reducing the costs, as it will only give a special treatment to a fraction and not all the generated wastes.

Recycling directly some wastes that don't require treatment nor previous conditioning. (Junco, 2000).

Materials and methods

For the application of the methodology 7 stages were established, in each of them different integral management activities for the chemical residues. In the Figure 1 is presented the used methodology for the integral management of the hazardous wastes; in its characterization amber colored 2.5 liters bottles were used, which were marked according to the specified lines, in the Figure 2. The shelf used for the segregation of chemical residues is presented.

The first stage started with diagnosing the generator establishment, to identify the aspects did not present conformity with the environmental and current sanitary normativity and this way establish the adjustments and pertinent corrective measures. (*Ministerio de salud-Health Departamentent and Ministerio del medio ambiente-Environmental Departament*,2002).

In the implementation of the methodology for the integral management of hazardous residues it was taken in account relevant aspects such as:

- Normativity and legislation.
- Implementation and control proper control procedures (biosecurity standards).
- Adopt adequate services for the recycling, treatment and disposal of hazardous residues (temporary residue storage sheds, containers, evacuation routes).
- Application of an adequate personal and operators capacitation directly implied in the problem.
- Risk conditions.
- Residue quantification update by the generator units.

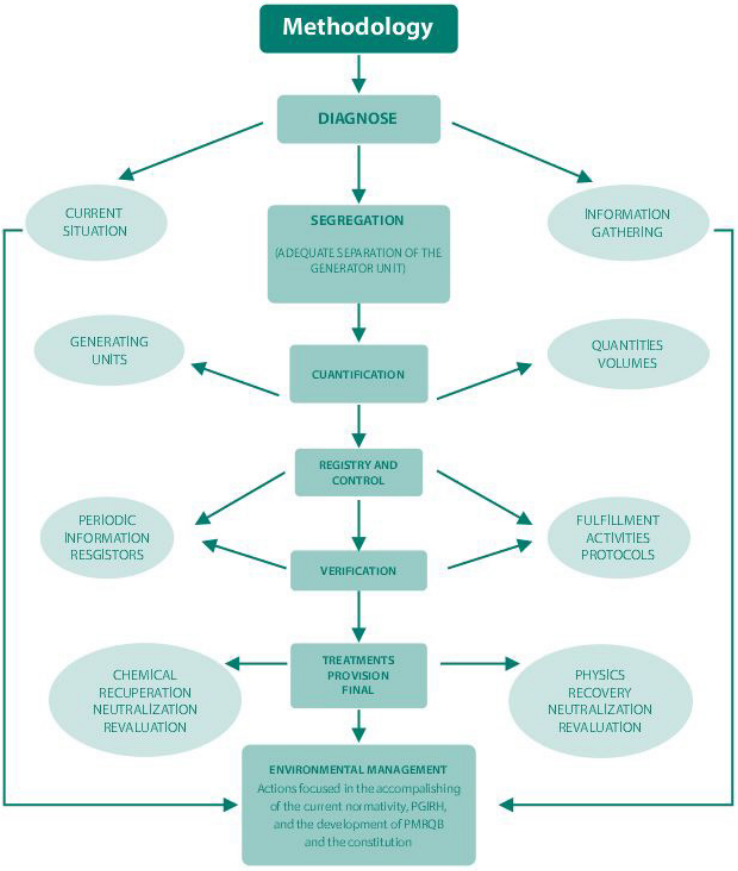


Figure 1. Methodology for the integral management of the hazardous residues.
Source: The authors

Figure 2. Shelf for the chemical residues segregation.
Source: The authors

Diagnostic

In this stage, it was described, without evaluating the current situation of the institution regarding the hazardous residues management and it was established a method to detect problems, needs and interests in a real context. In it, it was observed if a residue management plan was implemented, if there was a residue quantification and if there were registers.

Segregation or classification

The residues segregation was made according with the residue type where they belong according to their characteristics.

The infectious biological residues were classified according to the current standard for Colombia according to the *Ministerio de salud* (Health Ministry), *Protección Social* (Social Protection) and *Ministerio de Ambiente y Desarrollo Sostenible* (Environment and Sustainable Development Ministry) (Figure 3).

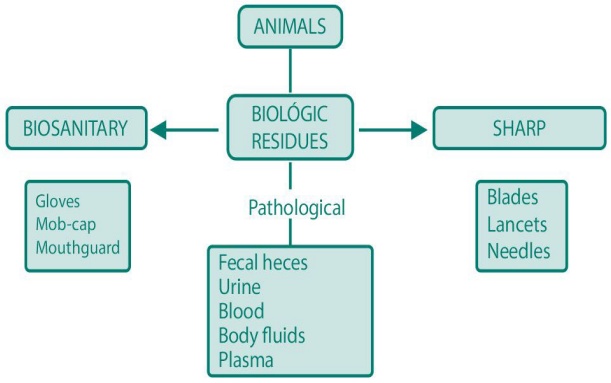


Figure 3. Classification of the infectious biological residues
Source: The authors

The chemical wastes can be classified according the most adequate diagnose done in the institution taking in account the:

- Volume
- Generation periodicity
- Compatibility
- Physical-Chemical characteristics.

In the figure 4 is presented une of the most used classifications.

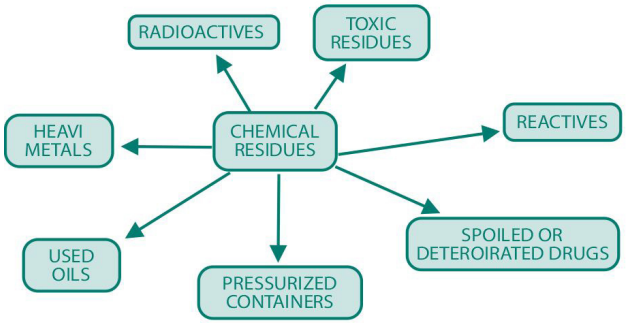


Figure 4. General classifications of the chemical residues
Source: The authors.

Residue quantification

Once that the generator presented and identified the residues as hazardous residues generated in the installation, it was recommended to present the generated quantities of each one of them. Thus, it was recommended that the generator will quantify the residues and will take the information registers to forwardly evaluate the management advances, principally regarding the minimization of its generation.

In the information it was reported, that the generated residues in a continuous or sporadic form amounts were included. In an updated way, the amounts of the stored hazardous residues were reported in stand-by to be managed. (MPGIR).

According to this quantification the institution could classify as big, medium or small generator. (Resolución 1362/ 2007), in order for the reports to be presented in an environmental entity.

Register and Management

The register and management plans were done through formats where the periodic information of the residue volume generation, its characteristics, entry and exit dates, the work unity who threw it, the kind of residue, the person who delivered it and the person who received it were.

The registers were clearly diligence with true and specific data, a strict control and tracking of the pathological, biosanitary, animal and chemical residues was done.

Verification and Accomplishment

The verification and accomplishment were done when the quantification, register and control stage matched with the exit of the wastes; to its treatment or last place in disposal. That is to say, if certain weight and volume was quantified; it must have matched with the registers and hence with the total residues to treat or delete. The verification was done with the periodic inspection of the generator units; it was determined that the residues were classified, storage, tagged and delivered in the agreed schedules and dates with the supervision of a person or professional in charge with the management plan.

Treatment: Recuperation, Deactivation, Elimination

The treatment depended in the residues' characteristics. An efficient residue management plan must maintain a lot of clarity in the waste classification, taking in account the: physical-chemical characteristics, dangerousness, pathogenicity, manipulation, recollection and storage.

There are various treatments (physical, chemical, and biological) for the hazardous residues, among them we can mention: incineration, oxidation, heavy metals precipitation, chemical reduction, neutralization, pyrolysis, evaporation and gasification among many others.

In Colombia most of the institutions leave the treatment or final disposal in hand of specialized companies in the branch, which take care of the periodic recollection and its transportation to its final neutralization or elimination residue destination, most of them use the incineration treatment for the residues' leftovers.

Environmental Management

The management concept references to the action and effect of managing and handling; managing is to diligence conducives to an objective's goal, to concrete a project organizing it, arranging it and sorting it.

The residue management, was set to look the elements that allow any university institution to implement a project with the objective to maintain applied a methodology for: recollection, transportation, processing, treatment, recycling or waste disposal material.

The management must be continuous; not only to implement the project, but to keep throughout time. From the management depends the optimal performance of a residue management plan, its efficient internal and external functioning, the acceptance and perception level that could have the project.

From a bad management comes out the inefficiency of a work methodology; the goals are not met; in the case of the residue management plans, the worsening of the stages: from the segregation in the origin source, recollection, register and control, verification and accomplishment, and the most important, the final disposal treatment.

Results

The specified methodology was implemented in a practical way in the general chemistry laboratories of the Universidad de Pamplona, where results that allow to optimize the *Plan de Manejo de Residuos Químicos* (Management Plan of Chemical Residues) in this institution were obtained.

Each one of the seven steps were executed in a systematic way and were presented with the next results.

Diagnose stage

The research methodology in the general chemistry labs (L-203, L-204, L-205) was implemented in the Universidad de Pamplona, City of Pamplona, Department of Norte de Santander, Colombia.

In the diagnose it was observed that there was still a management for chemical and biological residues implemented in the first period of 2008 it had a finished process in which it will quantify in a clear and accurate way the chemical residues of these laboratories whereby the data was not to trust, in the Chart 1 is presented a residue volume for the years 2008 and 2009.

Chart 1. Residues volume for the years 2008 and 2009.

LABORATORIES	MILILITERS QUANTITY (mL)		
	Year2009	First period of 2008	Second Period of 2008
Chemistry laboratory (L-205)	2319	2515	3143
Chemistry laboratory (L-204)	14721	14034.05	11626
Chemistry laboratory (L-203)	6892	8387	12876
Total	23932 mL	24936.05	27645.05
	23.932 liters	**24.936 liters**	**27.645 liters**

Source: The authors

Segregation stage

In this stage a new chemical residue characterization with the objective to make a more exact volume residue quantification that were generated during a period. Before starting, there were fourteen residue lines, in which a mix of components were presented in a clear way, to apply them a treatment.

Quantification stage

Once done the new characterization of the chemical residues, according to its physical-chemical characteristics and compatibilities, it was proceeded to quantify them during the first two semesters of the year 2010, which gave as a result the data presented in the Chart 2.

Register and control

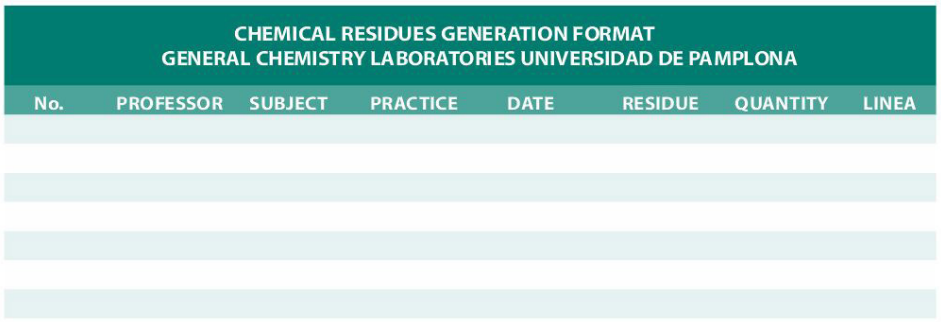
The format made for each one of the laboratory practices, registered the daily volume that was generated in each practice held at the laboratories L-203, L-204, L-205. Each time the format was filled, it was proceeded to change it for a new one and each month a total tabulation of the generated residues in that period.

In the Figure 5 a residue recollection format for the practices is presented.

Chart 2. Residue classification and quantification in 2010.

Line	COMPONENTS	VOLUME (mL)
Line 1	Sulfuric acid residues	161
Line 2	Hydrochloric acid residues	2605
Line 3	Nitric acid residues	670
Line 4	Boric and phosphoric acid residues	
Line 5	Inorganic acid residues	74
Line 6	Sodium hydroxide residues	1785
Line 7	Other hydroxides or inorganic bases residues	765
Line 8	Inorganic salts residues (fertilizers)	3167
Line 9	Other inorganic salts residues	2350
Line 10	Silver nitrate residues	155
Line 11	Organic salts, organic acids and organic peroxides residues	948
Line 12	Phenol residues from phenolic compounds	116
Line 13	Potassium dichromate residue	290
Line 14	Lead chlorides residues	10
Line 15	Cyanide substances results	195
Line 16	Ethidium bromide residues	
Line 17	DQO determination residues	
Line 18	Salts and Cr (VI), Ca, As, Hg compounds residues.	70
Line 19	Non-halogenated organic residues	2512
Line 20	Halogenated solvents	245
TOTAL		**16308**

Source: The authors


CHEMICAL RESIDUES GENERATION FORMAT
GENERAL CHEMISTRY LABORATORIES UNIVERSIDAD DE PAMPLONA

No.	PROFESSOR	SUBJECT	PRACTICE	DATE	RESIDUE	QUANTITY	LINEA

Figure 5. Residue recollection per practice format
Source. The authors

Verification and accomplishment

The verification is the result of comparing the disposed residues volumes generated with the registers of disposed residues in each line. At the same time the treated or eliminated chemical wastes was checked, to know the total that could be storage and feasibly reused.

Treatment: Recuperation, Deactivation, Elimination.

The applying treatment determination was done based in the chemical characteristics of the residues, the compatibility of the compound, toxicity, eco-toxicity, dangerousness, generation volume, degradation level and the contamination level that can produce. Besides that it was taken in account the elimination and neutralization alternatives of the residues are neatly favorable to the environment, without the use of more reactive, and the energy waste as is presented in Chart 3.

Environmental Management

In the look for elements and resources for the implementation of the methodology, a new place was managed for the chemical residues container storage, because there was no place for such.

Likewise shelves were design that allowed the location of residues according the new classification of twenty segregation lines, for its easy handling, and recognition by the students, teachers and laboratory auxiliary, equally it was proceeded to the normalization of the standards and formats by the institution's management system, for the residue management.

Chart 3. Residue recollection per practice format

Line	Evaporation	Phytoremediacion	Fixation or solidification	Bioremediation	Refused
1	X				X
2	X				X
3	X				
4	X				
5	X			X	
6	X				
7		X	X		
8		X		X	
9		X	X		

Source: The authors

Discussion

The characterization and classification of chemical residues in twenty lines, according to Chart 1, allowed that the segregation of these were more adjusted with the purpose to identify possible treatments that would apply to each kind of residue. It is identified that the inorganic salts (2350 mL) like sodium chlorides and potassium, are the ones that present the most volume along with the Hydrochloride acid residues (2605 mL) and other inorganic salts.

The Ethidium bromide residues and DQO determination are not quantified in the Chart 1 because they not only are generated in the biology laboratories and water quality controls which are not included in this chart.

For the year 2010 there were no boric acid or phosphoric acid residues, due to that none of these laboratory practices were held during this period, requirements were done for these chemical reactive.

According to the Chart 1 the residues volume that generated in average per year (2008) was of 26 liters in average but was a completely accurate volume because residue segregation and its characterization properly done. For the year 2009 thare was only information where the volume was of 23 liters.

When applying the methodology it was determined that the exact volume of generated residues in the first two semesters of the year 2012 was an approx. average of 16.38 liters, because a verifiably register of the results is carried.

For the different residue treatments analytic proofs and atomics absorption were done, to verify the content and compounds of the lines with the purpose to detect that there aren't compounds or traces highly polluting

With the evaporation treatment during the year 2010 a total of 17329 mL was deleted what equals to 17.32 liters of chemical residues such as inorganic salts, residues from other inorganic salts, silver nitrate residues, other hydroxide residues or inorganic bases, nitric acid residues and sodium hydroxide residues

The environmental management in the residue handling without caring about its origin, is essential, because from it comes the execution of any other methodology for this research. This stage was done with the help of

the laboratories of the Universidad de Pamplona coordination, and like that everything was managed with the residues analysis, the allocation for the storage, the segregation laboratories, the elimination implements and in general everything related with the integral handling of the chemical residues.

Conclusions

- It's essential to highlight that the initial diagnose of the residues, branches the rest of the methodology, which is designed taking in account the current normativity and other methodologies.

- The segregation and characterization stage is determining for the actions of volume diminution, in the laboratories since the accurate application of it, depends highly in the good functioning of the methodology.

- Once applied the treatment stage it was established that the inorganic salts that were generated in the laboratories, thought the adequate analysis can be eliminated through phytoremediation and evaporation treatments. The sulfuric and hydrochloric acids can be reused; the other hydroxide residues, and other inorganic salts are used to be treated by encapsulation or fixation in solid matrix, demonstrating that these treatments are favorable with the environment, reducing the use of more reactive, dumping in drainages and increasing the storage quantity.

- The increase in the production of chemical residues in general supposes a problem for its management, this aggravates due to the little participation of the teachers, students and auxiliary in the adequate segregation of these.

- There are numerous methodologies that inform about the integral management of the chemical residues, but few demonstrate that work with results and this research contributes in this field.

- The practical application of the methodology is permissible to apply due to its simplicity, and its contribution to decrease the generation of chemical residues and the appearing of environmental impacts and health risks.

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