`APPLICATION OF THE SOFT SYSTEMS METHODOLOGY (SSM) FOR MANAGEMENT OF LABORATORY HAZARDOUS WASTES

Giuliana Baccarin, Luciana Oranges Cezarino, Lara Bartocci Liboni, Adriana Cristina Ferreira Caldana, Dante Pinheiro Martinelli

ABSTRACT

Higher education institutions generate a significant amount of wastes in their laboratories. Toxic reagents can react to other chemicals and form unknown products which are dangerous to both human and environment. Despite the severity of the situation, these wastes are not always discarded properly due to either lack of awareness by students and employees or lack of follow-up inspection. As education institutions, the universities should be the best example of how to manage their wastes and therefore show concern about the environment. This work is aimed at applying the Soft Systems Methodology (SSM) for management of hazardous wastes in a laboratory at the Federal University of Uberlândia, including their storage and disposal, in order to improve the awareness by those involved in scientific laboratory research about this issue.

Keywords: Reagents, hazardous wastes, SSM, laboratories.

1. INTRODUCTION

The Industrial Revolution brought with it an increase in urban population and many cities were not capable to keep up with such a large settlement of people. Therefore, the cities had to adjust to shelter and support people accordingly, which increased the demands for goods and services and in turn resulted in increased generation of wastes in the world.

The planet's environmental situation is in alarm as wastes have been incorrectly discarded over the decades, thus endangering the population's health as well as soil, water and air. In the past one hundred years the planet's temperature has increased, and there is a scientific consensus that this increase in temperature can lead to serious impacts, such as thawing of the ice caps, which can affect directly the coastal zones and increase both rain rate in some regions of the planet and drought in others (FURRIELA, 2001).

In Brazil, it was not until the 1950's that there was an effective preoccupation with environment despite the increasing industrialisation and consequent increase in pollution in the three environmental components. This environmental preoccupation was with basic sanitation, conservation of the natural patrimony and search for solutions for problems of flooding and drought (IBAMA, 2014).

Only in 1981, with the first law aimed at preserving the nature (by-law number 6938/81) through the creation of the National Environment Police Department (*PNMA*), the Brazilians became more aware of the care they should take regarding the environment. Among the principles established by the *PNMA*, the "environmental education at all levels of school education" (2nd clause of by-law number 6938/81) (MINISTRY OF ENVIRONMENT, 2014) should cause an impact on the entire educational spectrum, from educators to learners, regarding the preoccupation with reducing effectively the practices which affect the nature.

Brazil participates in international forums on chemical safety and has a great amount of laws and decrees, including resolutions and norms, which demonstrate the country's preoccupation with the situation of chemical substances and hazardous wastes (FIGUERÊDO, 2006).

Much has been discussed about the accountability of those who generate wastes in the environment. One focus of analysis is the potential human health risk posed by these wastes, including intoxication by ingestion, allergies and infections, which are outcomes of the inadequate waste disposal by economic agents. Industries are the major generators of hazardous wastes, thus they are expected to be inspected and accounted for by the society (MINISTÉRIO DO MEIO AMBIENTE, 2014).

Although the majority of the companies contract outsourced services for waste disposal believing that they make their part, most of them are not aware of the financial importance of taking advantage of some residues by re-using or even recycling them (BUTTER, 2003).

Differently from the industry, the education institutions generate a significant amount of low-volume wastes, but which are great in diversity (GERBASE et. al, 2005) as they can be biologically, organically and chemically hazardous in terms of inflammability, corrosiveness, reactivity and toxicity. The majority of these institutions do not have an adequate system for waste management as the disposal of residues is often neglected by the laboratory staff or even due to lack of follow-up inspection (JARDIM, 1997).

Figuerêdo (2006) emphasises that one of the difficulties found in the waste management systems of university laboratories is the lack of laws to be directly applied to the institution, since the activities performed by them are not considered to cause environmental impact.

Many liquid wastes from laboratories are directly disposed into the sink, thus going to the city's sewage treatment plants, which often become overwhelmed. As a result, these wastes cannot be efficiently processed and then they are disposed into the river, being major potential pollutants not because of their volume, but because of the by-products generated.

Figuerêdo (2006) believes that these liquid wastes disposed into the sewerage system should meet parameters and legal restrictions in order to prevent damage to both system and treatment.

Another example of inadequate disposal of laboratory wastes has to do with nutrients rich in bacteria which are also disposed into the sink, since they can cause major damages to other living beings when in contact with the nature.

According to Jardim (1997), due to the important role played by the universities within the society, these institutions should be the first ones to be concerned with waste disposal rather than simply maintaining a coherent stance. The inadequate disposal of these wastes can pose a risky situation at medium and long-term, mainly by accidents involving corrosive and toxic solutions as they can irreversibly affect human population, patrimony and environment (FIGUERÊDO, 2006).

In view of this problem, this work sought to describe and identify the wastes generated in the Microbiology Laboratory of the Federal University of Uberlandia, with emphasis on hazardous residues and their storage, re-use, and disposal. The importance of this research is that the literature on waste management is still obscure in terms of how people deal with the problem, including their perceptions and feelings. As there are a few studies on adequate disposal of hazard wastes generated in educational institutions, it is necessary to propose a methodology in order to improve the behaviour of the laboratory staff by making them aware of the importance of disposing hazardous wastes properly.

2. THEORETICAL REFERENCES

The Soft Systems Management (SSM) is a systemic technique capable of providing factual solutions for ambiguous problems which usually involves physical infra-structure, but which is also impaired by people's behaviour (CEZARINO, 2013).

According to Checkland (1981), who was cited by Freitas et al. (2008), the idea of "system" emerged as a conceptual structure to understand and solve real situations and problems between the parts involved and the product from the interaction between emergency, hierarchy, communication, and control (LEGACY, 2008).

Therefore, the SSM is used not only for solving a problem, but also for contributing to the knowledge of a constantly-changing world (LONGARAY, 2004). In this sense, this work is aimed at applying the SSM to hazardous wastes present in a laboratory at the Federal University of Uberlândia regarding their storage and disposal, thus improving the management of these residues as well as the awareness by those involved in scientific laboratory research about this issue.

Thus, it is necessary to understand some terminologies related to the type of laboratory waste being disposed. Box 1 lists the main concepts used for the development of analysis tool.

Box 1 – Concepts related to laboratory waste disposed.

CONCEPT	DEFINITION
Residual material	Any residue or reject produced by a generating source.
Residue	Residual material remaining from some activity, adaptation or process which can still be used for generator or not, with or without treatment.
Reject	Any material used, but which cannot be reused adequately.
Environmental asset	It is the residual material being generated in current activities.
Environmental liability	It is the residual material generated, accumulated and stored over time which had not been treated or disposed properly. It consists of all unidentified residues stored.
Classification of the residual material	According to the ABNT 10.004, residues can be classified as: hazardous (there is risk to public health or environment due to their inflammability, corrosiveness, reactivity, toxicity or pathogenicity); non-hazardous (there is no risk to public health or environment); non-inert (there is no hazard, but they can be combustible, biodegradable and water soluble); or inert (no components solubilised at concentrations higher than the water potability standards according to the NBR 10.006 solubilisation test).
Inflammability	Liquid reagents with flash point lower than 60ºC, except aqueous solutions with less than 24-percent alcohol by

	volume. Non-liquid reagents capable of producing fire by attrition or chemical changes at conditions of pressure and temperature of 1 atm and 25ºC, respectively, in the presence of atmospheric gases or humidity absorption. This material can also release oxygen, thus stimulating powerful combustion, and become a flammable compressed gas.
Corrosiveness	Reagents presenting either very low or very high pH when mixed with water at a 1:1 ratio. Also, they are extremely basic or acidic at pH lower than or equal to 2, or higher than or equal to 12.5. They are characterised by their corrosiveness, and when mixed at equivalent weight of water, are capable of corroding steel at a rate of 6.35 mm/year at a temperature of 55ºC.
Reactivity	Reactive residues are characteristically unstable and react strongly and immediately, but without detonation. In contact with water, they react strongly or form potentially explosive mixtures. Also, they generate gases, vapours and toxic smokes which can damage the environment. These residues can produce explosions as well as explosive or detonating reactions under the action of stimulants, catalysts or temperature in closed settings. They are also capable of producing detonation/explosive reaction or decomposition at room temperature and atmospheric pressure of 1 atm.
Toxicity	For a residue to be considered toxic, it is necessary that after lixiviation one or more contaminants can be found at high concentrations than the standard ones. There are also other factors which should be analysed to determine whether a residue is toxic: nature of toxicity, concentration of the toxic compound, persistence of the toxic compound or any other toxic by-product after degradation, and capacity of the toxic compound to migrate from the residue to the environment. Additionally, it is necessary to analyse the effect of bio-accumulation of the residue on ecosystems and to assess the harmful potential of teratogenic, mutagenic, carcinogenic or ecotoxic agents. Toxicity is also determined by the concentrations of substances which are lethal to humans or experimental rats, according to standards for this type of study.
Chemical Safety Sheet (CSS)	The chemical safety sheet (CSS) should be used as stated by the International Labour Organization (ILO) Convention 170, 8th clause, and by the ABNT NBR 14725:2001. This sheet should be obligatorily made available by the suppliers. Additionally, CSS is also made available by international public and private institutions as

	well as by CETESB in Brazil. Its obligatory use is expected in all places containing chemical products, usually in entities subject to inspection and lawsuit by the Ministry of Labour and Employment. CSS is standardised based on the American National Standards Institute – ANSI and contains the following information: 1) Identification of substance and company; 2) Chemical composition and information on compounds; 3) identification of the hazards; 4) First-aid measures; 5) Fire-fighting measures; 6) Leak-control measures; 7) Handling and storage; 8) Exposure control plan and individual protection; 9) Physical and chemical properties; 10) Stability and reactivity; 11) Toxicological information; 12) Ecological information; 13) Considerations on treatment and disposition; 14) Information on transport; 15) Norms.

Source: Jardim (1997)

3. METHODOLOGY

This is an investigative study aimed at seeking answers to questions raised by the society by means of scientific procedures (RAUPP; BEUREN, 2014). In addition to the qualitative study, a descriptive study was performed to observe, record, analyse, rate and interpret the facts without researcher's interference. Standardised techniques were also used for data collection (RODRIGUES, 2007).

Data collection was performed between September 2013 and September 2014 in order to contribute to make an inventory of all reagents available in five laboratories of the Institute of Agro-Sciences of the Federal University of Uberlândia, thus helping the local committee for hazardous waste management. As many reagents were available in each laboratory, we used only data from the microbiology laboratory, which is mainly used by the environmental engineering staff.

Each flask of reagent available in the laboratory was individually analysed in terms of amount/volume, manufacture date, and expiration date before inclusion in the inventory.

A total of 111 types of reagents were classified as either hazardous or non-hazardous as proposed by this study, which resulted in 15 hazardous liquid reagents and 16 hazardous solid ones. This finding shows that it is necessary to verify the generation of hazardous wastes and their disposal.

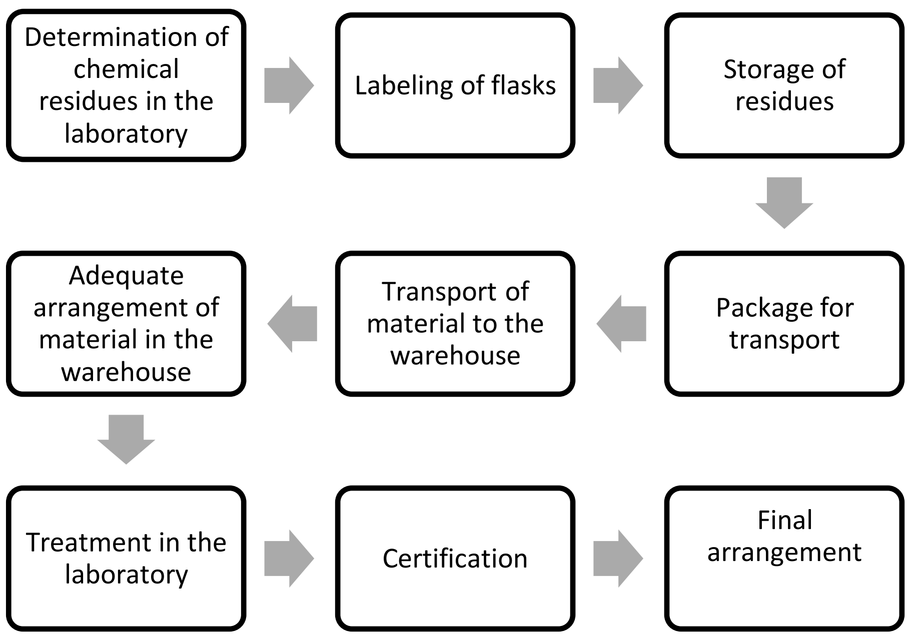
To classify and characterise the hazardous wastes as well as all types of residues present in the laboratory, the methodology proposed by Jardim (1997) was used according to the following phases: labelling of all reagents available, storage of the material for further tests determining their dangerousness, characterisation of non-identified chemical residues, identification of properties/characteristics of material harmful to humans and environment, and destination of the material analysed.

Therefore, according to Jardim (1997), any residual material characterised and classified as hazardous should be handled, stored, segregated, labeled and treated on a judicious basis so that the non-hazardous materials, defined as residues presenting no risk to both public health and environment, can be more easily handled and stored for correct destination. Figure 1 shows the steps followed.

Figure 1. Diagram for residue classification.
Labeling; Identification of properties; Classification
Hazardous; Non-hazardous
Handling; Storage; Segregation; Labeling; Judicious treatment
Less complex handling
Source: Adapted from Jardim, 1997.

In addition, the methodology for disposal of reagents and residues was based on that followed by professors of the Institute of Chemistry at the São Carlos School of Engineering, University of São Paulo, as shown in Figure 5 below.

Figure 2. Flowchart of adequate disposal of hazardous residues.



Source: Adapted from Alberguini et al. 2003.

The application of SSM provides methodological support to develop a model to better equip the research laboratory on a sustainable basis, where reagents and residues are used economically and mindfully so that wastage can be avoided and proper destination achieved without causing harm to the environment.

According to Checkland (1981), cited by Cezarino (2013), the SSM is a good technique to treat poorly-defined and behavioural issues. In this study, the behavioural issue is very important as solutions for problems begin to appear from the reflection by the people directly involved in research laboratory by simply changing their minds and consequently their way of addressing the problem.

In his thesis, Cezarino (2013) highlights that:

The SSM abandons the idea of a problem and instead seeks a solution by addressing situations in which players with problematic conflicts, for several reasons, are involved. Hypothetical models, free of the limitations of actual situations, are built. The systemic world is free of restrictions.

The SSM consists of a systemic technique which can generate factual solutions to problems involving physical infra-structure, but which is compromised by the behaviour of the people involved. This methodology proposes seven steps to be used for description of the problem and the ways to solve it (CEZARINO, 2013).

Box 2 – SSM steps.

1. Assessment of the problem situation by observing the poorly-defined problem in order to gather maximum information on it;
2. Definition and structuralisation of the problem situation regarding facilities and process by identifying the preoccupation of the people, the roles played by them, power hierarchy, the largest number of relationships available, and so on, in order to capture the existing essence;
3. Formulation of essential definitions existing in the system in order to better understand it and to reveal its main elements, namely: objects, relationships, attributes, environment and its constraints, transformation, and worldview. Checkland (1990 after Cezarino et al. 2013) proposed the use of the mnemonic CATWOE as a checklist;
4. Elaboration of conceptual models, that is, ideal situations which should be created so that each previously established definition achieve the expected objectives; 150 | L. B. LIBONI & L. O. CEZARINO
5. Comparison between step 2 and step 4 so that the "systemic world" (ideal situations) is abandoned and the real world is resumed, with problematic issues being raised for discussion as well as solutions and changes being suggested based on the differences found;
6. Selection of changes to be implemented following discussion and assessment whether they are desirable and factual, which can be structural, procedural or attitudinal, according to Checkland (1990);
7. Proposition of actions to solve the problem and of how they will be implemented.

Source: Liboni & Cezarino, 2012

4. RESULTS & DISCUSSION

4.1. Data Gathering from the Inventory of Reagents

Data gathering from the inventory of reagents was performed over several days according to a specific order of cupboards as there is a copybook in the laboratory listing the reagents available in each cupboard.

All nutrients as well as liquid and solid reagents used in research and laboratory activities were recorded, as shown in Tables 1 and 2, respectively.

Table 1 – Inventory of liquid reagents.

Flask	Liquid reagent	Quantity [L]	Flask	Liquid reagent	Quantity (L)
1	TOLUENE (TOLEROL) P.A. - ACS	7	16	ISO-AMYLIC ALCOHOL P.A. (93-METHYL 1-BUTANOL)	1
2	GLACIAL ACETIC ACID P.A -ACS	15	17	ISO-PROPYLIC ALCOHOL	10
3	HYDROCHLORIDRIC ACID P.A.	4	18	METHYL ALCOHOL P.A. (METHANOL)	12
4	HYDROFLUORIC ACID 48% P.A. HF	2	19	CYCLOHEXANE P.A.	8
4ª	HYDROFLUORIC ACID 40% P.A .HF	1	20	CHLOROFORM - ACS	1
5	PHOSPHORIC ACID P.A. (ORTHO)	1	21	ETHYL ALCOHOL	8
6	PHOSPHORIC ACID 85% PURE (H3PO4)	1	22	PETROL ETHER	8
6ª	LACTIC ACID	1	23	FORMALDEHYDE P.A. - ACS	7
7	NITRIC ACID 65% P.A>	5	24	FORMALDEHYDE P.A.	1
8	SULPHURIC ACID P.A.	4	25	BI-DISTILLED GLYCERIN/GLYCEROL	2
9	ACETONE ALCOHOL GRAM-1	1	26	AMMONIUM HYDROXY P.A.	2
10	ISO-AMYLIC ALCOHOL P.A.	3	27	SODIUM HYPOCHLORITE 5-6% P.A.	4
11	NORMAL BUTYL ALCOHOL P.A. - ACS (1-BUTANOL)	1	29	MINERAL OIL (LIQUID VASELINE)	1
12	95% ETHYL ALCOHOL	16	30		7

				HYDROGEN PEROXYDE P.A.	
13	ETHYL ALCOHOL P.A. PM=74.12	2	31	TOLUENE (TOLEROL) P.A. - ACS	9
14	ETHYL ALCOHOL P.A. PM=46.07	2	32	IMMERSION OIL	2
15	HYDRATED ALCOHOL 63.3% (70% ALCOHOL)	8			

Source: Elaborated from data collected.

Table 2 – Inventory of solid reagents.

Flask	Solid reagent	Quantity (L)	Flask	Solid reagent	Quantity (L)
1	POTASSIUM ACETATE P.A. CH3COOK	2	42	POTASSIUM PHOSPHATE DIBASIC ANHYDROUS, P.A. K2HPO4	2
2	CRYSTAL SODIUM ACETATE P.A.- ACS CH3COO Na.3H20	3	44	POTASSIUM PHOSPHATE MONOBASIC ANHYDROUS NaH2PO4	5
3	BORIC ACID P.A. H3BO3	15	45	SODIUM PHOSPHATE DIBASIC HEPTAHYDRATE P.A Na2HPO4.7H2O	1
4	FUMARIC ACID C4H4O4	1	46	MONOBASIC SODIUM PHOSPHATE P.A. C20H10Na2O5	5
5	OXALIC ACID (COOH)2. 2H2O	1	46.1		3

				SODIUM FLUORESCEIN P.A. C20H10 Na2O5	
6	SALICYLIC ACID C7H603	1	47	D+ GLUCOSE ANHYDROUS P.A. C6H12Na2O5	3
7	AGAR AGAR IN POWDER	3	48	GRACILARIA POWDER	1
8	PURE BACTERIOLICAL POWDER	3	49	CALCIUM HYDROXIDE Ca(OH)2	2
8.5	AGAR CASOY	1	50	SODIUM HYDROXIDE MICROPEARLS P.A. NaOH	8
9	TEAGUE’S EOSIN METHYLENE BLUE LACTOSE AGAR	4	51	POTASSIUM IODATE P.A. -ACS KlO3	2
10	SOLUBLE AMIDE P.A	2	51ª	IODATE P.A. I2	1
10ª	AMMONIUM PERSULFATE FOR ELECTROPHORESIS	1	52	L-TRYPTOPHAN C11H12N2O2	1
11	ANILINE BLUE	1	53	GLASS WOVEN	1
11ª	BROMOPHENOL BLUE C19H10Br4O5S	1	54	AMMONIUM MOLYBDATE P.A. (NH4)6Mo7O24. 4H20	1
12	BROMOTHYMOL BLUE C27H28Br2O5S	3	54ª	SODIUM METABISULPHITE P.A. Na2S2O5	1
13	METHYLENE BLUE	1	55	SODIUM MOLYBDATE 2H20 P.A. Na2MoO4. 2H2O	1
14	SODIUM BICARBONATE TECHNICAL GRADE NaHCO3	2	56	SILVER NITRATE P.A. AgNO3	1
15	SODIUM BISULPHITE NaHSO3	1	56ª	AMMONIUM OXALATE MONOHYDRATE P.A	

				(NH4)2CRO4. H2O	
16	SODIUM BORATE P.A. (Borax tetraborate) - CRYSTALLISED Na2B4O7. 10H2O	1	57	SODIUM OXALATE P.A. C2Na2O4	3
17	POTASSIUM BROMATE KBr	1	58	POTASSIUM PERMANGANATE KMnO4	1
18	LACTOSE BROTH	2	59	BROMOCRESOL PURPLE C21H18Br2O8S	1
19	LAURYL TRYPTOSE BROTH	2	60	SAFRANIN	5
20	CALCIUM CARBONATE PA CaCO3	4	61	SILIC GEL BLUE 4-8 mm P.A.	3
21	SODIUM CARBONATE ANHYDROUS PA Na2CO3	2	62	PURE CALCIUM SILICATE	1
22	CARBOXYMETHYL CELLULOSE	2	63	AMMONIUM IRON (III) SULPHATE DODECAHYDRATE P.A. NH4Fe(SO4)2 . 12H2O	2
24	PURIFIED ACTIVATED CHARCOAL IN POWDER, P.A.	2	64	COPPER (II) SULPHATE (ICO) P.A. CuSO4	3
25	PURE FERRIC AMMONIUM CITRATE (GREEN) C6H11FeNO7	1	65	COPPER SULPHATE P.A. CuSO4	2
26	AMMONIUM CHLORIDE NH4CL	1	66	IRON (II) SULPHATE (OSO) (7H2O) PA.A FeSO4. 7H2O	4
27	BARIUM CHLORIDE DI-HYDRATE P.A. BaCl2 . 2H2O	15	66[a]	AMMONIUM IRON (III) SULPHATE HEXAHYDRATE P.A. Fe(NH4)2(SO4)2. 6H	1
28	CALCIUM CHLORIDE DI-	2	66B		1

	HYDRATE CaCL2 . 2 H2O			FERROUS AMMONIUM SULPHATE P.A. MgSO4.H20	
29	PURE CALCIUM CHLORIDE ANHYDROUS	2	66C	FERROUS SULPHATE P.A. FeSO4. 7H2O	1
30	IRON (III) CHLORIDE (ICO)(6 H2O) P.A. FeCl3 . 6H2O	1	67	MAGNESIUM SULPHATE (7 H2O)	1
31	DAMAGED MAGNESIUM CHLORIDE MgCl2 . 6H2O	2	68	MANGANESE (II) SULPHATE (OSO) P.A. MgSO4. H20	2
32	POTASSIUM CHLORIDE P.A. KCl	13	69	MANGANESE (II) SULPHATE (OSO) P.A. MgSO4. H20	3
33	SODIUM CHLORIDE P.A. - ACS NaCl	2	70	POTASSIUM SULPHATE K2SO4	4
34	SODIUM CHLORIDE CRYSTALS P.A. NaCl	1	71	SODIUM SULPHATE ANHYDROUS P.A. Na2SO4	1
35	POTASSIUM CHROMATE K2CrO4	1	72	TRI-HYDROXYMETHYL AMINOMETHANE C4H11NO3	2
36	PURE D+ XYLOSE C5H10 O5	1	73	TRI-HYDROXYMETHYL AMINOMETHANE HYDROCHLORIDE C4H11NO3HCL	2
37	D-GLUCOSE ANHYDROUS P.A. ACS C6H12O6	1	74	UREA CHN20	3
38	D-GLUCOSE C6H12O6	5	75	BROMOCRESOL GREEN C21H14Br4O5S	2
39	POTASSIUM DICRHOMATE P.A. K2CR2O7	2	76	BASIC MALACHITE GREEN C23H26N2O	1
40	DI-SODIUM EDTA SALT C10H14N2O8 Na2.2H2O	1	77	METHYL RED ACS C15H15N3O2	1
41	PURE YEAST EXTRACT	4	78	CRYSTAL PURPLE	1

				P.A. C25H30ClN3	
41ª	PHENOL (PHENIC ACID) P.A C6H5OH		79	AMMONIUM SULPHATE (NH4)2 SO4 (10/12/2013)	1
41.5	MEAT EXTRACT	1			

Source: Elaborated from data collected.

After recording all the reagents, they were classified as either hazardous according to the Chemical Safety Sheet (CSS) or environmental assets, as listed in Table 3.

Table 3 – Hazardous reagents.

Flask	Hazardous liquid reagent	Quantity [L]	Flask	Hazardous solid reagent	Quantity (L)
1	TOLUENE (TOLEROL) P.A. - ACS	7	5	OXALIC ACID (COOH)2. 2H2O	1
3	HYDROCHLORIDRIC ACID P.A..	4	10ª	AMMONIUM PERSULFATE FOR ELECTROPHORESIS	1
4	HYDROFLUORIC ACID 48% P.A. HF	2	24	PURIFIED ACTIVATED CHARCOAL IN POWDER, P.A.	2
4ª	HYDROFLUORIC ACID 40% P.A .HF	1	26	AMMONIUM CHLORIDE NH4CL	1
8	SULPHURIC ACID P.A.	4	27	BARIUM CHLORIDE DI-HYDRATE P.A. BaCl2 . 2H2O	15
11	NORMAL BUTYL ALCOHOL P.A. - ACS (1-BUTANOL)	1	30	IRON (III) CHLORIDE (ICO)(6 H2O) P.A. FeCl3 . 6H2O	1

16	ISO-AMYLIC ALCOHOL P.A. (93-METHYL 1-BUTANOL)	1	35	SODIUM CHLORIDE CRYSTALS P.A. NaCl	1
18	METHYL ALCOHOL P.A. (METHANOL)	12	39	POTASSIUM DICRHOMATE P.A. K2CR2O7	2
19	CYCLOHEXANE P.A.	8	41[a]	PHENOL (PHENIC ACID) P.A C6H5OH	
20	CHLOROFORM - ACS	1	50	SODIUM HYDROXIDE MICROPEARLS P.A. NaOH	8
21	ETHYL ALCOHOL	8	51[a]	IODATE P.A. I2	1
23	FORMALDEHYDE P.A. -ACS	7	54	AMMONIUM MOLYBDATE P.A. (NH4)6Mo7O24. 4H20	1
24	FORMALDEHYDE P.A	1	56	SILVER NITRATE P.A. AgNO3	1
26	AMMONIUM HYDROXY P.A.	2	56[a]	AMMONIUM OXALATE MONOHYDRATE P.A (NH4)2CRO4. H2O	
31	TOLUENE (TOLEROL) P.A. - ACS	9	64	COPPER (II) SULPHATE (ICO) P.A. CuSO4	3
			65	COPPER SULPHATE P.A. CuSO4	2

Source: Elaborated from data collected

In this laboratory, no flask containing environmental asset was found, thus decreasing the risks in handling the reagents and also to the environment regarding water flows and population's health as they will not be affected by unknown wastes.

4.2. Proper Disposal Procedures of Hazardous Reagents

In the second step of the waste management application, the flasks were labelled as "hazardous reagent" or "environmental asset", including expiration date and amount in use and stored, in order to avoid wastage. It was also defined that, in case of lack of a given reagent in other institution's laboratory, the microbiology laboratory can loan it depending on the chief's authorisation.

The classification of the wastes is shown on the label of each flask, thus avoiding wastage in addition to reducing the storage of reagents and decreasing the amount of residues in case of product's expiration date. This label also advise the user to take care in handling the reagent and about the hazard related to the contact with both flask and material inside it.

When laboratory activities involving the mixture of different types of chemical products are performed, yielding an unknown residual material, this material cannot be disposed without being previously labelled with the name of the reagents for hazard classification according to the ABNT norms.

4.3. Application of the Soft Systems Methodology

The application of SSM was performed from the steps proposed by the methodology.

Step 1: Description of the Problem

It was found that there were many issues related to the problem situation raised. The main problem regarding the proper waste disposal has to do with a poor management of laboratory materials.

It was also observed that the site used to harbour chemical wastes from local laboratories, whose responsibility is of the university's administrative centre, does not serve as storage place for environmental assets or biological residues either, which is the case of the majority of wastes from the microbiology laboratory. In this sense, this laboratory cannot rely on the university to disposal its wastes properly. In addition, the personnel do not know about the existence of a guideline of good disposal practices developed by the Sustainability Office to aid them in such a procedure.

Despite the existence of a hazardous waste management commission, which is run by the Institute of Agro-Sciences (*ICIAG*) at the Federal University of Uberlândia, the actions proposed have not been translated into practical efforts aimed at promoting management of wastes through label application and final destination of laboratory residues. In this commission, the residues not meeting the criteria established by the university's chemical wastes management guide are classified and handled as environmental assets.

In the midst of this rather chaotic scene, the majority of the wastes are incorrectly disposed by the laboratory staff, which not always occurs due to lack of knowledge about the hazardousness of these materials, but also due to lack of good management and follow-up inspection.

Step 2: Description of the Explicit Problem – Hierarchical Level

There is a co-ordinator professor who is responsible for each laboratory at the university by being aware of the practices adopted and by authorising other professionals to use the laboratory. There are also other technicians who account for tasks, ranging from giving continuity to research development processes to organising everything within the laboratory, such as computers, reagents, electrical devices and so on. Moreover, they are the main responsible for making the laboratory staff aware of the importance of a proper waste disposal.

The laboratories are frequently used by students who carry out any type of research. And these students are also responsible for everything occurring in the laboratory despite receiving orientation by professors and technicians.

It is necessary that professors are made aware of the responsibility of working in a biological research laboratory while knowing the reagents available there. Thus, they can take precautions in cases involving hazardous reagents, that is, way of storing them, products which can stay close to the flasks, how to use and handle them properly in order to avoid accidents, and care regarding their disposal.

The co-ordinator professor should ensure that the technicians make inspection of the use, storage and disposal of all wastes, particularly those classified as hazardous.

Step 3: Formulation of Key Definitions

In this step, the definitions existing in the system reveal their main objectives, relationships, attributes, environment and its restrictions, transformation made by the system and the worldview. The mnemonic CATWOE was used as checklist (FEROLLA; PASSADOR; PASSADOR, 2012) as follows:

- *Clients*: every society which is directly affected by the system (in this case, the waste disposal), either beneficially or adversely.

- *Actors*: those who are linked to the system, that is, professors, technicians and students.

- *Transformation*: the main element of the system, with inputs (what occurs in the present) and outputs (what is expected in the future). In the desired transformation, the wastes are classified and then disposed accordingly.

- *Worldview:* it is what needs to be changed from the root definition and its importance. In the root definition, the people involved do not become sensitised by the action or perhaps they become sensitised but cannot adapt the waste processes to their daily work accordingly. There exists a behavioural barrier preventing actors from following the procedures suggested for adequate disposal of hazardous wastes.

- *Owner:* the one who has the control of the situation occurring in the system and power to give orders to be correctly followed. It may be the professor responsible for the laboratory.

- *Environmental restrictions*: problems which may interfere with or make it difficult to achieve what is expected within the main system. Rush in research work, focus on results rather than on complementary elements, autonomy of the senior laboratory technician and lack of follow-up inspection and control on the part of the university are considered as environmental restrictions.

Step 4: Definition of Features for Making the Laboratory Perfect without Preoccupation with Resistances – Entry into the Systemic World

For an ideal place to work with and handle all the residues present in the laboratory, it would be needed to propose an adequate physical space so that all materials can be organised, that is, where they could be correctly separated as acidic reagents, nutrients, basic reagents or hazardous wastes. Also, there should exist a place to store cell-culture dishes individually and another one for disposal of biological material. In addition, it would be necessary to have a good-size workbench large enough for development of experiences and free of objects which might make the work difficult or impede it.

With regard to the quality of work, it would be necessary to have a more ventilated environment and where the most volatile residues could be adequately stored in order to prevent their smell from spreading out, which can harm the health of those people working in the laboratory.

With regard to the empty flasks, they might be reused in the laboratory whenever possible, otherwise they should be immediately discarded in order to neither occupy space nor contaminate the environment, mainly when hazardous wastes are involved.

With regard to liquid wastes, they should be disposed into proper containers instead of the sink, particularly the hazardous mixtures. This procedure should be carried out in partnership with a company providing removal of these wastes from the university environment.

Another way of preserving the environment through management of wastes generated by the laboratory is to find forms to treat them at the university itself. This could be achieved by reserving a place in each laboratory for performing techniques of recycling and reuse of these residues so that they can never be discarded, thus encouraging students to study waste treatment techniques.

Finally, the most important change in the laboratory would involve a wide effort to raise the awareness of students, technicians and professors about the proper use, treatment and disposal of these wastes in their local workplace.

Step 5: Comparison between Items 2 and 4 to Discuss How Ideal Situations Are Confronted with Real Situations – Resistance to Ideas

The major imbalance between what would be ideal and what actually happens in the case of the microbiology laboratory has to do with the physical space, since there is a great difficulty in increasing any area at the university campus when a common site is affected.

The immediate removal of flasks containing hazardous residues would require that the responsible ones are ready to do so at any time, but waste removal companies usually have date and time scheduled for the service. Moreover, should this option be accepted, it is likely that the price charged for the waste removal would be higher as specific employees are needed to solve the institution’s problems.

Another limiting feature is that public servants may often have resistance to changes in their work routine, mainly when tasks are altered and consequently barriers and resistance are created in view of the new procedure.

Step 6: Evaluation of Possible and Desired Changes, Which Can Be Structural and/or Behavioural

Among the possible changes are the following: awareness and education of senior and new employees about the risks of handling these materials as well as disposing laboratory wastes erroneously.

Another possibility is to better distribute the materials used for laboratory research activities so that they are no longer accumulated in the cupboards and the reagents are individually stored in adequate place. In this way, one can prevent these materials from being damaged as usually occurs in places not adequate for storing the flasks.

For the proper disposal of wastes, the storage place should be identified for future disposal by means of labels with residue's name, classification, handling risks and expiration date so that they can be properly discarded or sent to a locale from where they can be later taken for adequate disposal. This is a reality which can be implemented in the analysis laboratory.

Step 7: Proposition of Actions to Change the System

Bio-safety is the prevention and decrease of risks. In the microbiology laboratories, there is an interaction between people, microorganisms, objects and hazardous substances, exposing all the laboratory users to ergonomic, biological and chemical hazards in addition to contaminating the environment.

To improve the laboratory environment on a coherent basis by using the university's resources, it is necessary to implement educational practices, which can begin with training of professors and technicians so that they can convey what they learnt about how to behave in a laboratory. These trainings are aimed to make all the users aware of the laboratory risks which can directly affect those who handle the material and cause damage to the environment.

In addition, it is necessary to implement a waste management system in which chemical, biological and hazardous residues generated from laboratories can be sent to storage places, that is, adequate containers before removal of those materials which can be neither reused nor recycled by the removal service.

It is suggested that an awareness programme including lectures, *in situ* training or even graphic handouts could be developed to stimulate a behavioural change among the laboratory users. Another suggestion to call attention to the importance of such changes is to issue an official report to professors who co-ordinate the laboratories explaining the need to change the procedures. Follow-up inspections of the laboratories periodically could help in the maintenance of the objective sought.

4.4. Replication of this Model to other Institutions

This research model can be applied not only to other laboratories at the university, but also to any other place. To do that, it is enough to define the SSM steps for the place in question by making the problem situation explicit and creating methods of improvement either in hospitals, business offices, restaurants or even at home, that is, any place where there are several activities and people working on a team basis.

5. FINAL CONSIDERATIONS

The objective of the present work was to apply the Soft Systems Methodology (SSM) for management of hazardous wastes present in a laboratory at the Federal University of Uberlandia, including their storage and disposal, in order to identify solutions for these wastes and make those involved in scientific research in the laboratory aware of the problem. This aim has been achieved as viable actions can be taken to change the laboratory procedures regarding the disposal of solid residues.

The correct application of SSM to laboratory procedures can be a way of encouraging all the involved people to improve their work as a team and together they can achieve the final aim of disposing the laboratory hazardous wastes properly.

In addition, the SSM contributes to the formulation and execution of norms and regulations which should be followed in the laboratory so that the users behave seriously and judiciously about all the harms they may cause as a result of any negligence in handling these materials.

With regard to the limitations of our study, it should be noted that only one laboratory was considered. Therefore, one cannot generalise the results found when a greater number of laboratories are to be analysed, including the variety of chemical composites.

It is expected that further studies will investigate laboratories certifications as new opportunities to boost the proper disposal of these materials.