Project group Number	**Group N° 9**
Project Acronym	
Project title	Improving Indoor Air Quality knowledge base through the development of pollutant-activity-specific matrix
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1. EXECUTIVE SUMMARY

The purpose of this project is to improve indoor air quality knowledge base through development of pollutant-activity-specific matrix. Indoor Air quality is a rising concern in various enclosed environment. A significant number of pollutants may be found indoor coming from human activities, building construction, furniture, household products, heating system, and outdoor air. The classroom and restaurant in IMT Atlantique, Nantes, France, is taken in consideration for this case study. Predicting and analyzing possible types and source of pollutants in potentially contaminated indoor environment is the key principle for this project. In order to fulfill the objectives of the project, the methodology used is scientific and evidence based which allow to gather the indoor air pollutants found in a classroom and the restaurant of the university. This project develops a generic matrix for the toxic compounds which are subdivided in classes according to their similar features. For this case, the chemical classes used by the Agency for Toxic Substances and Disease Registry have been chosen. There are 14 categories of hazardous substances such as benzidines, aromatic amines; dioxins furans, PCBs; halogenated pesticides; hydrocarbons; inorganic substances; metals, elements; nitrosamines, ethers, alcohols; organophosphates and carbamates, etc. The appropriate references are used to determine the qualitative scale in order to determine the likeliness of presence of those substances in the air. The pollutants are classified by scale from 1 to 5 in certain categories depending their concentration and presence in the classroom and restaurant. The developed matrix presents the sources of the pollutant in the classroom and restaurant linked with the specific pollutants.

2. CONTEXT, POSITION AND OBJECTIVES OF THE PROJECT

2.1. CONTEXT, SCIENTIFIC, SOCIAL AND ECONOMIC ISSUES

According to World Health Organization, the air pollution is recognized as important risk factors for human health. Despite the development of income of the countries, people are exposed to air pollutants both outdoors and indoors most of the time (world Health Organization, 2010). Furthermore, indoor air quality is very important because people spend around 90% of their time indoors in office buildings, residences, day-care centers, schools, retirement homes and other special environments.

Indoor air pollution affects population groups that are particularly vulnerable owing to their health status or age. There they are exposed, on one hand, to pollutants generated outdoors that penetrate to the indoor environment and on the other hand, to pollutants produced indoors as a result of the activities that take place inside the closed environments, for example space heating, cooking, smoking or pollutants emitted from products used for cleaning.

To differentiate between Indoor and outdoor Air Quality, is necessary to define the boundaries between those two concepts. According to Environmental Protection Agency, air quality indoors refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants (Environmental Protection Agency, 2017).

Despite of the fact that multiple organizations have acknowledge the importance of indoor air quality in human health, efforts on analyzing and studying the health effects of indoor air pollution has lagged behind that on outdoor air pollution for a number of different reasons. These includes among many other factors, the feasibility of monitoring concentrations of outdoor air pollutants on a large scale compare to the impracticability of monitoring pollution indoors; the need to take care of the high levels of outdoor air pollutants associated with both coal smoke and photochemical smog; the fact that the science and policy communities have focused on the public health impacts of air pollution in wealthy developed countries, while often disregarding the larger burden of disease due to indoor air pollution from solid fuel burning in the developing world

Finally, in order to address the current situation of indoor pollution, is important to understand that the management of indoor air quality requires approaches different from those used for outdoor air.

2.2. POSITION OF THE PROJECT

This project is proposed as a response to the lack of studies and information which link indoor air pollutant and the indoor sources. Specifically, in school environments such as classrooms and cafeterias that are the environments in which students spend most of their time during their student life. For the case study, the facilities of IMT Atlantique, Nantes, France, is taken in consideration.

However, international organization such as World Health organization and United States Environmental Protection Agency carried out studies and promote initiatives to address the growing problem of indoor air quality on an international level. This research, can complement the available reports by establishing a new guideline for next studies. As part of the aims of this project is to implement a new approach to assess the problem of indoor air pollution. A smart and innovative approach will be applied, it is based on the use of pollutant-activity-specific matrix. Understanding and predicting possible sources and types of pollutants in these crowded closed environments is the key principle for the research.

2.3. STATE OF THE ART

There are many sources of indoor air pollution in any school and home environment. Potential sources of indoor air quality contaminants are interior building materials, office furniture, and equipment. Interior building materials including carpets, carpet padding, paints, sealants and caulking, adhesives, floor and ceiling tiles, cabinets, molding, composite wood products, and other wood work can contain contaminants that are gradually emitted (off-gassed) throughout the life of the material. (Environmental Protection Agency, 2017). Other sources, related to activities carried out in the environment, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping. High pollutant concentrations can remain in the air for long periods after some of these activities (Environmental Protection Agency, 2017). Table 2.1 presents typical sources of indoor air pollutants.

Table 2.1. Typical Sources of Indoor Air Pollutants (Environmental Protection Agency, 2017)

Outdoor Sources	Building Equipment	Components/ Furnishing	Other Potential Indoor Sources
Polluted Outdoor Air · Pollen, dust, mold spores · Industrial emissions Vehicle and non-road engine emissions (cars, buses, trucks, lawn and garden equipment	**HVAC Equipment** · Mold growth in drip pans, ductwork, coils, and humidifiers · Improper venting of combustion products · Dust or debris in ductwork	**Components** · Mold growth on or in soiled or water-damaged materials · Dry drain traps that allow the passage of sewer gas · Materials containing VOCs, inorganic compounds, or damaged asbestos · Materials that produce particles (dust)	· Science laboratory supplies · Vocational art supplies · Copy/print areas · Food prep areas · Smoking lounges · Cleaning materials · Emissions from trash · Pesticides · Odors and VOCs from paint, chalk, adhesives · Occupants with communicable diseases · Dry-erase markers and similar pens · Insects and other pests · Personal care products · Stored gasoline and lawn and garden equipment
Nearby Sources · Loading docks · Odors from dumpsters · Unsanitary debris or building exhausts near outdoor air **Underground Sources** · Radon · Pesticides · Leakage from underground storage tanks	**Non HVAC Equipment** · Emissions from office equipment (volatile organic compounds (VOCs), ozone) · Emissions from shop, lab, and cleaning equipment	**Furnishing** · Emissions from new furnishings and floorings · Mold growth on or in soiled or water-damaged furnishings	

The indoor air quality contaminants include volatile and semi-volatile organic compounds (VOCs and SVOCS, respectively), and small particulate substances that act as eye or throat irritants. Additional Indoor Air Quality contaminants can originate with office furniture, room dividers, and photocopiers. (United States Environmental Protection Agency, 2017). In table 2.2 some of the products used at home or work that can release VOCs into the air when used and stored are presented.

Table 2.2 Origin of VOC emission in indoor environments (New York State's Department of Health, 2013)

Examples of Household Products	**Possible VOC Ingredients**
Fuel containers or devices using gasoline, kerosene, fuel oil and products with petroleum distillates: paint thinner, oil-based stains and paint, aerosol or liquid insect pest products, mineral spirits, furniture polishes	BTEX (benzene, toluene, ethylbenzene, xylene), hexane, cyclohexane, 1,2,4-trimethylbenzene
Personal care products: nail polish, nail polish remover, colognes, perfumes, rubbing alcohol, hair spray	Acetone, ethyl alcohol, isopropyl alcohol, methacrylates (methyl or ethyl), ethyl acetate
Dry cleaned clothes, spot removers, fabric/ leather cleaners	Tetrachloroethene (perchloroethene (PERC), trichloroethene (TCE))
Citrus (orange) oil or pine oil cleaners, solvents and some odor masking products	d-limonene (citrus odor), a-pinene (pine odor), isoprene
PVC cement and primer, various adhesives, contact cement, model cement	Tetrahydrofuran, cyclohexane, methyl ethyl ketone (MEK), toluene, acetone, hexane, 1,1,1-trichloroethane, methyl-iso - buthyl ketone (MIBK)

Paint stripper, adhesive (glue) removers	Methylene chloride, toluene, older products may contain carbon tetrachloride
Degreasers, aerosol penetrating oils, brake cleaner, carburetor cleaner, commercial	Methylene chloride, PERC, TCE, toluene, xylenes, methyl ethyl ketone, 1,1,1-trichloroethane
Moth balls, moth flakes, deodorizers, air fresheners	1,4-dichlorobenzene, naphthalene
Refrigerant from air conditioners, freezers, refrigerators, dehumidifiers	Freons (trichlorofluoromethane, dichlorodifluoromethane)
Aerosol spray products for some paints, cosmetics, automotive products, leather treatments, pesticides	Heptane, butane, pentane
Upholstered furniture, carpets, plywood, pressed wood products	Formaldehyde

The School Indoor Pollution & Health Observatory Network in Europe (SINPHONIE) carried out on the effectiveness of remedial measures in Europe show that schools frequently have Indoor Air Quality problems because of poor building construction and maintenance, poor cleaning, poor ventilation and the activities that can cause pollution sources (Eva Scobod, Isabella Anessi, 2014). The studies also demonstrate that pollution at school is complex and variable and has clear impacts on health. The methodology developed within the framework of SINPHONIE is based on a statistical analysis of the measurements of traffic related pollutants both outdoors and indoors. The experimental data were taken from the number of schools in two countries (Greece and Portugal). The table 2.3 presents the pollutant concentration by measuring sample taken from the number of schools.

Table 2.3 Table of indoor and outdoor concentration ratio for chemical, physical and comfort parameters (rI/O) (Eva Scobod, Isabella Anessi, 2014)

Parameters	The number of schools	Indoor Mean Concentration	Outdoor Mean Concentration	I/O Ratio Mean
Formaldehyde	105	15.2 mg/m3	3.0 mg/m3	7.4
Benzene	100	4.0 mg/m3	2.7 mg/m3	1.5
Naphthalene	33	2.2 mg/m3	0.9 mg/m3	3.7
Limonene	40	36.2 mg/m3	1.5 mg/m3	44.5
NO2	106	13.9 mg/m3	22.4 mg/m3	0.8
PM 2.5	96	45.3 mg/m3	39.9 mg/m3	1.4
Ozone	90	8.1 mg/m3	71.0 mg/m3	0.1
CO	56	0.9 ppm	0.5 ppm	6.0
CO2	97	1.47 ppm	445.7 ppm	3.5
T3CE (Trichloroethylene)	13	3.4 mg/m3	0.2 mg/m3	20.4
T4CE (Tetrachloroethylene)	26	1.2 mg/m3	0.5 mg/m3	1.4

2.4. OBJECTIVES, ORIGINALITY AND INNOVATIVE NATURE OF THE PROJECT

Indoor Air quality is a rising concern in various enclosed environment. A significant number of pollutants may be found indoor coming from ambient air (outdoor), building materials, furniture, household products, heating system, and human activities. Detecting and analyzing pollutants in potentially contaminated indoor environment is a key component of the general policy for risk assessment and site management. So the main objectives of this project are:

1. Develop a generic matrix for the toxic compounds which are subdivided in classes according to their similar features (structure, uses, physical properties etc.). For this case, the chemical classes used by the Agency for Toxic Substances and Disease Registry have been chosen. Hazardous substances are classified in 14 categories as follow:
    - Benzidines, Aromatic amines
    - Dioxins, Furans, PCBs
    - Halogenated pesticides
    - Hydrocarbons
    - Inorganic substances
    - Metals, Elements
    - Nitrosamines, Ethers, Alcohols
    - Organophosphates and carbamates
    - Pesticide
    - Phenols, Phenoxy acids
    - Phthalates
    - Radionuclides
    - Volatile organic compounds
    - Warfare and terrorism agents
2. Identify for various activities / products / historical construction materials the substances likely to be emitted in the indoor air.
3. Synthesize the findings in a pollutants-activity-specific matrix with appropriate references by determining a qualitative scale to determine the likeliness of presence of these substances in the air.
4. Identify from the general matrix developed above, the contaminants likely to be present in a classroom and restaurant at IMT Atlantique, link the sources with specific pollutants.

3. METHODOLOGY

3.1. SCIENTIFIC METHODOLOGY

In aim to fulfil the objectives of the project the scientific methodology will be evidence based with and qualitative evaluation criteria, which allow to gather the indoor air pollutants found in a specific classroom and the restaurant of the same university. The observation, classification and bibliography research of the studied elements gave the approach of data collection presented in next section. Steps or tasks of the experiment are given and follow as next:

1. Literature review of similar previous studies.
   a. Individual scientific papers and article research.
   b. Gathering and share information about the different documents and information found.
2. Start the bibliographic investigation of each pollutant, allergen, toxic and volatile compound that can be generated, released or brought in indoor conditions. To develop a possible indoor air quality study.
3. Listing in a spreadsheet system program the items, and the materials that they are made of. The list is done in a horizontal organigram format that allow the user/s to perfectly identify the composition of each item.

Note: if the materials or pollutants are repeated between the items, the information will be the same in each case, but for having a complete file, it will be copy-pasted in each repeated row.

   a. Establish the first pollutant list with the 14 typical family of pollutants.
   b. If necessary the CAS number of each compound will be displaced in the matrix.
4. The selection of the sites to analyze was done considering certain conditions to be relevant for the study and creation of the matrix. This choice of the two places to examine, was done taking into high consideration the following parameters:
   a. Elevated frequency of people or living species in general.
   b. Daily or regular use.
   c. Capacity of more than forty persons.
   d. High permanence of people

e. Activities performed in-site.

For accomplish of the previous reasons and ease access to the installations the choices presented in this report are situated in Institute Mines-Telecom (before École des Mines de Nantes):

a. Classroom: Amphitheatre Carnot (A104)

b. Restaurant: Restaurant Universitaire IMT (managed by SODEXO)

5. The establishment of two teams is done to try randomness in analysis, compare results and avoid missing objects and/or pollutants. Each team must have done the following activities on the two chambers and then exchange chamber without sharing information about the results found. This was made the same day, so weather conditions, temperature, humidity, and other factors are not considered on the experiment.

a. Exterior surrounding visit of the chamber if possible to consider the access points, ventilations, and emergency exits.

b. Write the list of the objects found inside the room.

c. Listing the activities fulfil inside the room or the ones outside that can affect the interior spaces.

d. For each object assign the material/s that it contains.

e. Discuss within the subgroup about each object and material, therefore will be no missing item.

f. Exchange chamber with the other subgroup and repeat tasks a to e.

After both subgroups finished their analysis, they share the information and compare. If they agree the results are computed; if they don't agree they repeat the experiment or go in-site to verify the item or material of confusion.

6. Listing in the same format the activities done affecting the interior of the chamber, and linking the possible pollutants, chemical compounds, etc. that could be involved and in contact with the living beings in there.

a. If the pollutant is repeated the note of step four is considered as well.

7. Proposing new pollutants not mention before but discussed and considered by the team as important and usually found in previously mention environments.

8. Collective preparation of matrix structure for presenting the data.

a. The matrix must present the links material and pollutants in an easy and understandable structure.

b. The pollutants will be classified by numbers from 1 to 5 in certain categories depending their concentration and presence in the room.

c. The bibliographic reference of each number will be display as super indices inside brackets.

9. Final matrix filling and sending for tutor's approval.
10. While waiting for approval. Start the preparation of poster structure and basic data.
11. In case of approval proceed to finish poster and prepare presentation.

In the other case redo the matrix with specifications of the tutor and continue with poster and presentation.

3.2. PROJECT MANAGEMENT

The project is performed with the tutoring of professor Adrien Bouzonville and his enterprise ATMOTERRA; being him in top of our organizational structure. The organization of our team is as follow:

Figure 3.1 Organizational Structure Project 9

Roles and responsibilities:

Team Leader (MORENO MAXINEZ Lorena):

- Lead the team in each phase of the project by assigning tasks.
- Making sure that every member is informed about the results or new tasks.
- Organize meeting with the tutor and send him the results of the investigations.

Secretary (CARCELLI Laura):

- Responsible of minutes of meetings with the professor.
- Remind the deadlines and the time table to fulfill.
- Gather the information about the hours worked in the project and the carbon footprint asked by the tutor.

Convener (RAHMIYATI Luftia):

- Collecting the final information of all group members and adapting the format for the deliveries.

Mediator (BARRANCO FABRE Adrian):

- Function of mediator between the team members during the meetings and between the discussions with the tutor.

All team members will work as well in the part of the project assigned by the team leader.

Project Gant Chart:

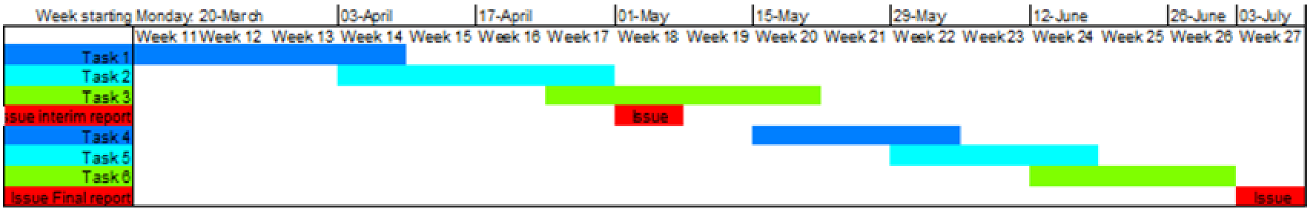

Figure 3.2 Gant Chart

Table 3.1 Tasks for Gant Chart

Task 1	Literature review for previous studies
Task 2	Identify the possible pollutant sources
Task 3	Link the sources with specific pollutants and chemical compounds/by composition
Task 4	First draft of indoor pollutant matrix
Task 5	Case study in the school environment IMTA
Task 6	Presentation and Poster of the results in Project 2

4. EXPLOITATION OF RESULTS

The final matrix is presented in this section, however since the data obtained is very extended, the results will be presented in a complementary excel file that will be attached: Matrix_GeneralCase.XLS.

Some of the results are presented from tables 4.3 to table 4.6, the activities, objects and construction materials existing in the classroom and in the cafeteria, is an example of the results that can be consulted in the excel file. In table 4.7 some references are presented. The complete results can be found in the excel.

In table 4.1 the final classification for families of pollutants is presented, because several pollutants have different chemical characteristics, some families such as particles, alcohols and others were added to the general classification of 14 families.

Table 4.1 Classification of pollutant families

Family Number	Classification
1	Benzidines/ Aromatic amines
2	Dioxins, Furans, PCBs
3	Halogenated pesticides
4	Hydrocarbons
5	Inorganic substances
6	Metals Elements
7	Nitrosamines ethers alcohols
8	Organophosphates and carbamates
9	Pesticides (chemicals used for killing pests, such as rodents, insects, or plants)
10	Phenols/phenoxy acids
11	Phthalates
12	Radionuclides (radioactive materials)
13	Volatile organic compounds
14	Warfare and Terrorism Agents (used in acts of war or terror)
15	Particles
16	Alcohols
17	Salts
18	Others

In table 4.2 the qualitative sale used to determine which pollutants are most likely to be present in indoor air inside the IMT-Atlantique facilities can be observed. For the pollutants that have been studied before by organizations such as Environmental Protection Agency of the USA, for example the VOC's, information was available confirming presence in indoor air coming from sources such as wood and paints. For these pollutants where information was available, the scale was between 4-5 depending the amount and number of papers confirming its presence.

Table 4.2 Qualitative scale

Scale	Description
1	Absence of the compound in the source
2	Likely to be present in the source
3	Presence of the compound in small quantities
4	Presence of the compound in the source confirmed by one study
5	Presence of the compound in the source confirmed by more than two studies

Table 4.3 Matrix of pollutants related to activities in a classroom

Classroom				Acitivities						
1st Family	2nd Family	Pollutant	CAS Number [1]	Teaching	Breathing	Writting on the board	Projector Use	Heating system use	Ventilation system use	Room Cleaning
4	13	Benzene	71-43-2			2 [2]				
10		Cresols	1319-77-3			2 [2]				5[22]
13		Acetone	67-64-1			2 [2]				
13		Formaldehyde	50-00-0					2 [5]		
13		Hexanal	66-25-1				4[4]			
13		Heptanal	111-71-7				4[4]			
13		Octanal	124-13-0				4[4]			
13		Trichlorofluoromethane	75-69-4							4[7][8]
13		Dichlorodifluoromethane	75-71-8							4[7][8]
13		Butane	106-97-8							4[7][8]
13		Pentane	109-66-0							4[7][8]
13		Heptane	142-82-5							4[7][8]
13		d-limonene (citrus odor)	5989-27-5							4[7][8]
13		a-pinene (pine odor)	80-56-8							4[7][8]
13		isoprene	78-79-5							4[7][8]
15		Plant pollen		2					3 [5]	
15		Human & animal hairs		2					3 [5]	
15		Paper fiber							3 [5]	
15		Spores							3 [5]	
15		Cockroach allergens							3 [5]	
15		Fabric fibers		2					3 [24]	
15		Pet danders		2					3 [5]	
16		Methyl Alcohol	67-56-1							2 [6][8]
16		ethylene glycol	107-21-1							2 [6][8]
16		propylene glycol	57-55-6							2 [6][8]
16		Ethanol	64-17-5			2 [2]				
16		Isopropanol	67-63-0			2 [2]				4 [6][8]
17		Calcium Carbonate	471-34-1			2 [3]				
18		Carbon Dioxide	124-38-9	3	3	3			4 [5]	
18		Carbon monoxide	630-08-0						4 [5]	
18		Ozone	10028-15-6						4 [5]	
18		Sulfor Oxide	7446-09-05						4 [5]	
18		Nitrogen Oxides (NOx)	10102-43-9						4 [5]	
18		Water vapor	7732-18-5	3	3	3	3	3	2	
18		Butylated hydroxdytoluene	128-37-0							3 [6]
18		Sodium hypochlorite	128-37-0							3 [6]
18		Heat		3			3	3		

Table 4.4 Matrix of pollutants related to objects in a classroom 1

Classroom					Objects								
1st Family	**2nd Family**	**3th Family**	**Pollutant**	**CAS Number [1]**	**Green board**	**White board**	**Chalk**	**Marker**	**Board Eraser**	**Tables**	**Chairs**	**Projector**	**Notebook**
4	13		Benzene	71-43-2	3[7][15]	2 [2]		2 [2]	2 [2]	3[7][15]	3[7][15]		
4			Naphthalene	91-20-3	3[15]					3[15]	3[15]		
4	13		n-Hexane	110-54-3	3[14][12]					3[14][12]	3[14][12]		
4	13		Toluene	108-88-3	5[7][10][11][12]					5[7][10][11][12]	5[7][10][11][12]		
4			Total Petroleum Hydrocarbons	CASID30651	4[10][11][12]					4[10][11][12]	4[10][11][12]		
4	13		Xylenes	1330-20-7	5[10][11][15][12]					5[10][11][15][12]	5[10][11][15][12]		
5			Arsenic	7440-38-2	3[19]					3[19]	3[19]		
5			Chromium	7440-47-3	3[19]					3[19]	3[19]		
5			Copper	7440-50-8	3[19]					3[19]	3[19]		
5			Lead	7439-92-1	3[13]					3[13]	3[13]		
5			Silica	7631-86-9									
7	9	10	Pentachlorophenol	87-86-5	4[17]					4[17]	4[17]		
9			Methylene Chloride	75-09-2	4[7]					4[7]	4[7]		
10			Cresols	1319-77-3	5[22]	2 [2]		2 [2]	2 [2]	5[22]	5[22]		
10			Dinitrocresols	8071-51-0									
10			Dinitrophenols	51-28-5, 329-71-5, 573-56-8									
10			Nitrophenols	100-02-7									
10			Creosote	8021-39-4	5[17][18]					5[17][18]	5[17][18]		
10			Phenol	108-95-2	4[17]					4[17]	4[17]		
13			Acetone	67-64-1	4[9][10][11]	2 [2]		2 [2]	2 [2]	4[9][10][11]	4[9][10][11]		
13			Formaldehyde	50-00-0	4[5][7]					4[5][7]	4[5][7]		
13			Hexanal	66-25-1								4[4]	
13			Heptanal	111-71-7								4[4]	
13			Octanal	124-13-0								4[4]	
13			ethyl acetate	141-78-6									
15			Plant pollen								3[5]		
15			Human & animal hairs								3 [24]		
15			Paper fiber								3[5]		3
15			Spores								3[5]		
15			Cockroach allergens								3 [24]		
15			Fabric fibers								3 [24]		
15			Pet danders								3[5]		
15			Graphite										
15			Clay										
16			Methyl Alcohol	67-56-1	3[10]					3[10]	3[10]		
16			ethylene glycol	107-21-1	3[10]					3[10]	3[10]		
16			propylene glycol	57-55-6	3[10]					3[10]	3[10]		
16			Ethanol	64-17-5	3[10]	2 [2]		2 [2]	2 [2]	3[10]	3[10]		
16			Isopropanol	67-63-0		2 [2]		2 [2]	2 [2]		3		
17			Calcium Carbonate	471-34-1	1[23]		2[3]		2 [3]				
17			Iron Oxide									2	
18			Benzo(a)pyrene	50-32-8	4[16]					4[16]	4[16]		
18			Esters		3[10]					3[10]	3[10]		
18			Heat										

Table 4.5 Matrix of pollutants related to objects in a classroom 2

Classroom					Objects								
1st Family	2nd Family	3th Family	Pollutant	CAS Number [1]	Pen	Pencil	Pencil eraser	Laptop	Window	Courtain	Door	Lamp	People
4	13		Benzene	71-43-2							3[7][15]	3[15]	
4			Naphthalene	91-20-3							3[15]	3[15]	
4	13		n-Hexane	110-54-3							3[14][12]	3[14]	
4	13		Toluene	108-88-3							5[7][10][11][12]		
4			Total Petroleum Hydrocarbons	CASID30651							4[10][11][12]		
4	13		Xylenes	1330-20-7							5[10][11][15][12]		
5			Arsenic	7440-38-2							3[19]		
5			Chromium	7440-47-3							3[19]		
5			Copper	7440-50-8							3[19]		
5			Lead	7439-92-1							3[13]	3[13]	
5			Silica	7631-86-9					3			3	
7	9	10	Pentachlorophenol	87-86-5							4[17]		
9			Methylene Chloride	75-09-2							4[7]	4[7]	
10			Cresols	1319-77-3		2 [2]					5[22]		
10			Dinitrocresols	8071-51-0									
10			Dinitrophenols	51-28-5, 329-71-5, 573-56-8									
10			Nitrophenols	100-02-7									
10			Creosote	8021-39-4							5[17][18]		
10			Phenol	108-95-2							4[17]		
13			Acetone	67-64-1	2 [2]	3					4[9][10][11]		3[7]
13			Formaldehyde	50-00-0							4[5][7]		4[5]
13			Hexanal	66-25-1				4[4]					
13			Heptanal	111-71-7				4[4]					
13			Octanal	124-13-0				4[4]					
13			ethyl acetate	141-78-6									4[7]
15			Plant pollen							3[5]			2[5]
15			Human & animal hairs							3 [24]			2 [24]
15			Paper fiber							3[5]			2[5]
15			Spores							3[5]			2[5]
15			Cockroach allergens							3 [24]			2 [24]
15			Fabric fibers							3 [24]			2 [24]
15			Pet danders							3[5]			2 [24]
15			Graphite			1	1						
15			Clay			1	1						
16			Methyl Alcohol	67-56-1	1						3[10]	3[10]	
16			ethylene glycol	107-21-1							3[10]	3[10]	
16			propylene glycol	57-55-6							3[10]	3[10]	
16			Ethanol	64-17-5	1						3[10]	3[10]	3 [7]
16			Isopropanol	67-63-0									
17			Calcium Carbonate	471-34-1									
17			Iron Oxide					2	2			2	
18			Benzo(a)pyrene	50-32-8							4[16]		
18			Esters								3[10]	3[10]	
18			Heat					3				3	3

Table 4.6 Matrix of pollutants related to construction materials in the cafeteria

Cafeteria			Construction Materials				
1st Family	Pollutant	CAS Number [1]	Cement	Paint	Plaster	Metallic ceiling	Wood
4	Benzene	71-43-2		3[15][33]			3[7]
4	Naphthalene	91-20-3		3[15][33]			
4	n-Hexane	110-54-3		3[14]			3[12]
4	Toluene	108-88-3		5[7][10][11]		1[46][47]	5[7][10][12]
4	Total Petroleum Hydrocarbons	CASID30651		4[10][11]			
4	Xylenes	1330-20-7		5[10][11][15]		1[46][47]	5[7][10][12]
5	Arsenic	7440-38-2					3[19]
5	Chromium	7440-47-3					3[19]
5	Cobalt	7440-48-4				1[46][47]	
5	Copper	7440-50-8					3[19]
5	Lead	7439-92-1		3[13]			3[13]
5	Silica	7631-86-9			1[20]	1[46][47]	
5	Zinc	7440-66-6		3		1[46][47]	
7	Pentachlorophenol	87-86-5					4[17]
9	Methylene Chloride	75-09-2		4[7]		1[46][47]	
10	Cresols	1319-77-3					5[22]
10	Creosote	8021-39-4					5[17][18]
10	Phenol	108-95-2					4[17]
13	Acetone	67-64-1		4[9][10][11]		3[46][47]	4[10][12]
13	Carbon Tetrachloride	56-23-5		4[7]			
13	Formaldehyde	50-00-0		4[5]		3[46][47]	4[7]
13	Styrene	100-42-5				1[46][47]	
16	Methyl Alcohol	67-56-1		3[10]			3[10]
16	ethylene glycol	107-21-1		3[10]			3[10]
16	propylene glycol	57-55-6		3[10]			3[10]
16	Ethanol	64-17-5		3[10]			3[10]
16	Isopropanol	67-63-0		3		1[46][47]	
16	Isopropyl alcohol					1[46][47]	
17	Calcium Carbonate	471-34-1			2[20]	2[46][47]	
17	Calcium Hidroxide	1305-62-0	4 [5][21]		4 [5][20]	2[46][47]	
17	Calcium Sulfate	7778-18-9			2[20]	2[46][47]	
17	Magnesium oxide	1309-48-4			2[20]	2[46][47]	
17	Aluminum oxide		4 [5][21]		4 [5][20]		
17	Calcium oxide		4 [5][21]		4 [5][20]		
17	Silicon dioxide		4 [5][21]				
17	Iron Oxide		4 [5][21]		4 [5][20]	2	
18	Carbon Dioxide	124-38-9			2[20]		
18	Benzo(a)pyrene	50-32-8					4[16]
18	Esters			3[10]			3[10]

Table 4.7 Some references of the Matrix.

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5. DISCUSSION

The compilation of a matrix is needed to be able to assess which activities constitute a major source of pollution and which pollutants are more luckily to be present in a room, either because it has been assessed its presence related to a single activity/object or because it is present in many activities/objects, thus its release is more luckily.

An analysis for each indoor space considered is then required.

1.1. CLASSROOM

In the classroom, the two main activities emitting toxic chemical compounds are the room cleaning and the ventilation system use, for which compounds are ranked as "likely to be present" and "presence confirmed by one study". The other activity which emits a considerable amount of chemicals is writing on the board, related to the usage of pens (discussed later). Five different classes of compounds are present: hydrocarbons, Volatile organic compounds, particles, alcohols, salts and other various compounds. In particular, the classroom results to be full of carbon dioxide and water vapor, but also the release of heat due to the usage of projector, laptop, heating system and lamps is considerable.

Concerning the objects which are used, green board, tables, chairs, door and lamps present the greater number of toxic elements with a big probability of emission in the air which is often confirmed by one or more than two studies. The main pollutants in air are hydrocarbons (benzene, naphthalene, n-Hexane), inorganic substances (lead and methylene chloride), cresols, acetone, formaldehyde, humans and artificial particles (hairs, paper and fabric fibers), alcohols (methyl alcohol, ethylene glycol, propylene glycol, ethanol) and esters.

Finally, construction materials and outdoor air play an important role in the composition of indoor air. The most pollutant ones are paint and wood, which are formed by or treated with a huge amount of dangerous chemicals, principally hydrocarbons, inorganic substances and volatile organic compounds. To note that all compounds used in the construction materials are sure to be released in air, with more than one study to confirm it. Building materials are the cause of the release of hydrocarbons, volatile organic compounds, alcohols and salts.

From the previous analysis it emerges that these three categories are the most luckily ones to be present in gaseous form in a classroom.

1.2. CAFETERIA

In the cafeteria, three are the activities which produce pollutants in the surround air: eating, whose pollutants exhibit a high probability to be present but not confirmed by studies, the ventilation system and the room cleaning, the last one with one study for almost every pollutant confirming its presence in air. Five classes of compounds are present: hydrocarbon (naphthalene only), volatile organic compounds, pesticides, alcohols and various elements such as carbon dioxide, carbon monoxide etc. Particularly, the room is subject to release of heat, water vapor, carbon dioxide, and particles matter such as pet danders, fabric fibers, human hairs are present.

Analyzing the objects used in this room, plastic chairs, tables, doors and lamps contain many toxic compounds whose release in atmosphere can be a threaten, since the materials they are built with are mainly non-natural compounds. The release of almost every pollutant is demonstrated by one or more studies and researches. The variety of categories present in the matrix is in this case wider because the objects in the room are made with a big amount of compounds: hydrocarbons, inorganic substances, pesticides, phenols, volatile organic compounds, particles, alcohols, salts and other compounds.
Compounds such as ethanol, vinyl chloride, acetone, xylenes, naphthalene and benzene are the one utilized in the largest number of objects.

Construction materials also plays an important role in the emission of pollutants: the paint, the materials for metallic ceiling and wood components contains many toxic compounds with different luckily to be present, from “non detectable quantities” to “more studies which confirm the presence”.
These materials mainly contain hydrocarbons (benzene, n-hexane, toluene and xylenes), inorganic substances (lead, silica and zinc), methylene chloride, volatile organic compounds (acetone and formaldehyde), many alcohols, salts and esters.

Finally, external air must be considered: in fact, the cafeteria of the school is located near the car parking and a balcony, where people usually go to smoke. Even if the cafeteria is not directly exposed to these polluters, the opening of the doors and the mix between indoor and outdoor air can increase the pollutants’ concentration in indoor air. three sources are considered, composition of outdoor air, smoke and car’s smog, and among them the most impacting ones are the smoke and the smog. The range of chemicals emitted from these sources is very heterogeneous: they belong to eight different categories which are hydrocarbons, inorganic substances, pesticides, phenols, phthalates, volatile organic compounds, particles and various compounds.

In conclusion, in the cafeteria more categories than in the classroom are present; they are hydrocarbon, volatile organic compounds, pesticides, alcohols, inorganic substances, phenols, particles, salts and other compounds such as different oxides and esters.

6. CONCLUSION

From the analysis of the activities performed and of the objects present in two different rooms and through the compilation of a matrix, it was possible to assess that the main air indoor pollution is caused by hydrocarbons, volatile organic compounds, alcohols and salts coming from the activities which takes place, the objects used for them, the construction materials which have a high rate of toxicity and from outdoor sources.

Furthermore, this study firstly suggests a specific methodology for the collection and the elaboration of data which could be apply for other confined environments; secondly, it constitutes a database thanks to which starting from an activity or an object it is possible to identify the emitted pollutants; finally, it demonstrates the utility of a matrix to represent data in an understandable way: in fact, the matrix can be easily read starting either from a pollutant or from an activity/object and the assigned scale makes possible to immediately understand which are the more critical amounts requiring intervention.

The matrix can also be used with a quantitative evaluation criteria, and not based on literature references and studies, when an on-field sample collection can be carry on: in this case the matrix is filled with quantitative values representing, for example, a concentration.

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