4-2019

The Development of a Health, Safety and Environment Management System for an Integrated Gender Separated Campus in the Middle East Region – A Case Study

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Recommended Citation

Al Wahshi, Fatima Sbait Salmeen, "The Development of a Health, Safety and Environment Management System for an Integrated Gender Separated Campus in the Middle East Region – A Case Study" (2019). *Biology Theses*. 8.
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THE DEVELOPMENT OF A HEALTH, SAFETY AND ENVIRONMENT MANAGEMENT SYSTEM FOR AN INTEGRATED GENDER SEPARATED CAMPUS IN THE MIDDLE EAST REGION – A CASE STUDY

Fatima Sbait Salmeen Al Wahshi

This thesis is submitted in partial fulfilment of the requirements for the degree of
Master of Science in Environmental Sciences

Under the Supervision of Professor Thies Thiemann

April 2019

Declaration of Original Work

I, Fatima Sbait Salmeen Al Wahshi, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*The development of a Health, Safety and Environment Management System for an Integrated Gender Separated Campus in the Middle East region – A Case Study*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Professor Thies Thiemann, in the College of Science at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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Abstract

In recent years, concerns regarding health, safety and environmental issues increased. This led to the development of integrated Health, Safety and Environment (HSE) Management Systems in many organizations, including universities. The study of the current HSE management system of the United Arab Emirates University (UAEU) has been conducted as a typical National university in the Middle East Region with the added unique feature of a large integrated campus with gender separation. Emphasis has been given to the E-shared laboratories of the UAEU as the interface between the two sides (male/female) of the campus. The E-shared laboratories incorporate most of the teaching laboratories of the Colleges Food and Agriculture, Engineering and Science, and it is here that most of the chemicals and biological samples of the university can be found. At the same time, the E-shared laboratories present a physical bottle-neck in the movement between campuses, also in emergency situations. Spatial Analysis has been conducted to model crowd behavior in the E4-shared laboratories building in emergency situations. Also, in regard to environmental concerns within the health and safety infrastructure, the waste treatment with silica gel and recycling of silica gel in educational and small research laboratories has been studied.

Keywords: Occupational safety and health, environment, spatial analysis, recycling, Silica gel, chemical inventory, chemical waste, hazardous waste, dye adsorption.

Title and Abstract (in Arabic)

تطوير نظام إدارة الصحة والسلامة والبيئة في حرم جامعي متكامل منفصل عن النوع في منطقة الشرق الأوسط -دراسة حالة

الملخص

في السنوات الأخيرة ، زادت المخاوف المتعلقة بالصحة والسلامة والقضايا البيئية. وقد أدى ذلك إلى تطوير أنظمة الإدارة المتكاملة للصحة والسلامة والبيئة (HSE) في العديد من المؤسسات ، بما في ذلك الجامعات. تم إجراء دراسة نظام إدارة الصحة والسلامة والبيئة الحالي في جامعة الإمارات العربية المتحدة كجامعة وطنية نموذجية في منطقة الشرق الأوسط مع ميزة فريدة من نوعها وهي الحرم الجامعي المتكامل الكبير مع الفصل بين الجنسين. تم التركيز على المختبرات المشتركة في جامعة الإمارات العربية المتحدة كواجهة بين الجانبين (ذكور / إناث) في الحرم الجامعي. تضم المختبرات المشتركة معظم المختبرات التعليمية في كلية الأغذية والزراعة والهندسة والعلوم ، ومن هنا يمكن العثور على معظم المواد الكيميائية والعينات البيولوجية للجامعة. وفي الوقت نفسه ، تعتبر المختبرات المشتركة عنق زجاجة في الحركة في الجامعة ، وكذلك في حالات الطوارئ. تم إجراء التحليل المكاني لضبط سلوك الحشود في مبنى المختبرات المشتركة E4 في حالات الطوارئ. كذلك ، فيما يتعلق بالمخاوف البيئية في البنية التحتية للصحة والسلامة ، تمت دراسة معالجة النفايات بجيل السيليكا وإعادة تدوير هلام السيليكا في المختبرات التعليمية والصغيرة.

مفاهيم البحث الرئيسية: السلامة والصحة المهنية، البيئة، التحليل المكاني، إعادة التدوير، السليكا، سجل جرد الكيماويات، النفايات الكيميائية، المواد الخطرة، صبغ الامتزاز.

Acknowledgements

I would like to thank my supervisor Prof. Thies Thiemann for his valuable guidance, motivation, constant moral support, and being prompt and supportive at all times.

I would like to express sincere thanks to my Co-supervisors, Dr. Khaled Galal and Dr. Abbas Khaleel for their sincere and valuable guidance, generous advice and support and encouragement extended to me.

Special thanks go to my mother, husband, sister who helped me along the way. I am sure they suspected it was endless.

Dedication

To my husband, Saeed who has been a constant source of support and encouragement during the challenges of graduate study and life

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List of Abbreviations

HSEMS	Health, Safety and Environment Management System
ILO	International Labor Organization
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OSHMS	Occupational Safety and Health Management System
WHO	World Health Organization

Chapter 1: Introduction

1.1 Overview

A Health, Safety and Environment management system (HSEMS) is an integrated system, which includes policies, processes and procedures to avoid/mitigate the occurrence of incidents that will affect the workers /students' health and the environment. HSEMS is an important requirement in any organization, including universities and colleges. In fact, over time, there have been many incidents of serious injuries and fatalities among students and instructors at universities (see below). Also, universities’ targets and objectives could be affected by risks related to Occupational Safety and Health and the Environment [1, 2].

1.2 Occupational Safety and Health Management System

Occupational safety and health (OSH) is a field related to the safety and health of people at the work place, and it is applicable to all sorts of jobs and levels of risk. The aim of occupational safety and health plans is to provide employees with a safe and healthy work environment. Also, co-workers, family members, employers, customers, and any others, who could be influenced by the workplace environment might be protected by the OSH [3, 4].

OSH as per the World Health Organization’s (WHO) definition is “occupational health [that] deals with all aspects of safety and health in the workplace and has a strong focus on primary prevention of hazards” [5]. Also, health has been expressed as "a state of complete physical, mental and social well-being and not merely as a state of absence of disease or infirmity." Additionally, Occupational health is an integrative subject of healthcare focused on supporting people pursuing their occupation with more awareness and attention about their health. In other words, in Occupational safety and health, health is all about avoiding any hurts from whichever incidental hazards could happen in the workstation [3, 4, 5].

An Occupational Safety and Health Management System (OSHMS) is a management tool that integrates all Occupational Safety and Health (OSH) management components of a business into one coherent system. The integration of these components allows the business to achieve its objectives efficiently by minimizing occupational Safety and Health risks [6]. Also, many studies show that the OSH management systems not only decrease accidents and injury rates, but also develop the productivity and the business of an organization [7, 8].

In the last decades, the concern of occupational safety and health has been developing hand-in-hand with the growth of wages, mainly in relation to the objectives of trade unions in certain countries [9]. Unfortunately, based on the statistics presented by the International Labor Organization (ILO), still 2.3 million employees die from work-related accidents or diseases and over 313 million workers suffer non-fatal occupational injuries every year [10].

Furthermore, there have been many reasons for developing occupational safety and health laws or regulations, one of them being the continuous increase in the number of workers. In fact, the number of people who provide labor for the manufacture of goods and services has grown from 1.9 billion in 1980 to 3.2 billion in 2011. These numbers do not take into account voluntary and informal workforces. Besides, in less than 300 years industrial and manufacturing systems and entrepreneurial labor and market associations have extended from a minority of countries to a vast majority of countries worldwide. Modifications in the geographic and structural configurations of industrial manufacture related to neoliberal globalization and the ensuing global economic crisis have in several instances enhanced the strength and skills to work, but also increased the hazards to workers due to insufficient safety regulations [9].

Therefore, developments in the industry and other related fields need to be regulated by laws concerning the laborers' health and safety. Going through the history of occupational safety and health is one of the best ways to understand why these laws had been developed. In the nineteenth century, industrial machineries were extremely unsafe. Employees had strong cause to panic from the machines they used daily. Occupational injury and death were a severe danger to laborers' lives and their occupation. Also, laborers did not have any instructions related to safe practices and benefits due to safe operations that we have these days [11].

One of many incidents that happened due to lack of safety regulations and laws that had an impact on later developments was Harry McShane's incident. He was a young American factory employee, 16 years old. He got caught in the strap of an instrument in a spring factory in May of 1908. His arm was dragged off near the shoulder. Also, Harry's right leg was broken over the kneecap, and, regrettably, no reimbursement was paid. Harry McShane's accident raised labor actions and drew the attention of the US American society to the importance of occupational safety and health laws [11].

1.3 Timeline of Occupational Safety and Health

In the following, we will look at the development of OSH laws in four foreign countries (UK, USA, Canada and Japan) that had an early industrial development. Also, the development of OSH laws in the United Arab Emirates is mentioned.

1.3.1 United Kingdom

The United Kingdom is one of the first countries in the world in developing occupational safety and health laws. The current UK OSH laws have been formed over 200 years. The main reason in developing OSH laws was the political reactions to social incidents, resulting from the disturbance of the society by the Industrial Development and from the lack of support from the previous Elizabethan Poor Laws. Also, the United Kingdom was the first nation in using machines in industrial production [12].

In 1760, the industrial revolution started in Abraham Darby's foundries at Coalbrookdale in the Iron Bridge Gorge, Shropshire. There was a rapid growth in UK's economy starting from a population dependent on agriculture to a population partially engaged in industry. The country was at war with Napoleon's France and memories of the distressingly fundamental ideas of the French Rebellion of 1789 were fresh in the anxious thoughts of British political leaders. Among the extensive conflict, demands were being prepared for governmental improvement and fulfilling reasonable demands of the people [12, 13].

At the end of the 18th century, the growing speed of industrial transformation and its focus of labour in factories and mills applying powered technology had carried with it increasing concern about the situations of the laborers and especially children working in such organizations. In 1802, the Act for the Protection of the Health and Morals of Apprentices and others working in the Cotton industry and in other Mills was formed. This is the first Act of the Parliament in the UK proposed to defend the safety of laborers [12]. Further factory acts followed in 1833, 1861, 1864, 1867, 1891 and 1895, successively furthering health and safety requirements and making a periodic safety inspection of certain machineries mandatory [13].

Furthermore, in 1833, the Health and Morals Inspectorate was formed. The Inspectorate was responsible for checking factories to confirm the deterrence of harm to child fabric workers. Also, the Inspectorate was able to formulate new protocols and laws to ensure that the Factories' Act was appropriately followed. Although there were severe conflicts between politicians and managers, the factory inspectors were succeeding with regulations concerning equipment safety and accident reporting [12].

Correspondingly, the formation of a Mines and Collieries Inspectorate was in 1843. They had only limited powers under the Act, but started several actions. For instance, they considered the complaints of the mining community and made endorsements for training managers, broadcasting fatal and severe accidents and making provisions for mine laborers. Between 1844 and 1856, a succession of factory regulations were delivered for the safety of children, young persons and women, comprising the establishment for the fencing of equipment, set hours, meal times and vacations [12, 13].

Before the Quarries Act of 1894, the one and only type of quarry that factory inspectors were allowed to inspect were quarries using steam power. The introduction of the Quarries Act in 1894 reached the powers of the Metalliferous Mines Regulation Act of 1872 and offered inspectors the power to apply provisions of notifying accidents, make Special Rules and undertaking prosecutions in case of infringements of safety laws. This led to the establishment of the Quarry Inspectorate [12].

When looking specifically at early health and safety measures concerning the handling of chemicals, it can be seen that in the Factory Act of 1891 two safety codes covered the chemical industry and, separately, the explosives industry. Especially the manufacturing industry using lead, phosphorus, and arsenic was targeted, with weekly health examinations for workers utilizing white phosphorus. With the Factory Act of 1891, it was clear that a focus should be put on the health effects of the long-time exposure of workers to chemicals. In 1895, a Dangerous Trade Committee was formed to look into this matter. In 1906, the Workmen’s Compensation Act of 1897 was augmented to include compensation for workers affected by lead, arsenic and phosphorus poisoning [13].

In 1937, the first comprehensive code for health and safety applicable for all industries was formulated with the Factories Act of 1937 [13]. The Factories Act 1937 was amended with Factories Act of 1948, which introduced an annual health inspection for young workers. In, 1949, the United Kingdom ratified the ILO Labor Inspection Convention from 1947, which included a passage on labor health and safety [13].

In October 1957, the investigation into a serious incident at the Wind scale nuclear site lead to a suggestion from the United Kingdom Atomic Energy Authority (UKAEA) that a body must be set up with accountability for licensing future civil reactors in the UK. Also, the insurance industry increased pressure to the argument and in 1959 the Nuclear Installations Act was passed, also leading to the formation of the Inspectorate of Nuclear Installations within the Ministry of Power. Moreover, today's Nuclear Installations Inspectorate (NII) connected to external website is responsible for the UK safety regulation of nuclear power stations, defense nuclear facilities, nuclear chemical plants, nuclear safety research, decommissioning and strategy. Later, on 2 April 2007, NII has been responsible for civil nuclear operational security and safeguards matters [12].

In 1985, the mandatory reporting of injuries, diseases and dangerous occurrences as a regulation was started, usually known as 'RIDDOR', and this required an accountable person in each company/industrial site to inform the enforcing authority, when a person had died or suffered from any injuries or had a specific medical condition or where a dangerous occurrence had taken place, linked to a work activity [12].

In June 2000, the Revitalizing Safety and Health Strategy Statement was announced to start a ten-year campaign of the same name. The strategy was announced at a time when many people had been injured at work in the 1990s. The purpose of the revitalization of safety and health strategy was to assist people at work to defend themselves and their businesses, to develop a better quality of life in the workplace and to support employers and employees to make work safer and healthier. Then, measurable objectives were set and revised at regular intervals [12].

Later in 2013, the Health and Safety (Miscellaneous Repeals, Revocations and Amendments) Regulations came into force. These Regulations were intended to cancel a series of redundant and / or out of date legislation, comprising one Act and twelve statutory instruments. Also, HSE has presented these Regulations as part of a procedure of confirming that employers can rapidly recognize their duty to deliver a safe and healthy working environment for employees [12].

Developments in Safety and health laws and regulations in the United Kingdom are ongoing with continual improvements in different fields.

1.3.2 United States of America

The United States of America was a little bit late in developments in occupational safety and health as compared with Britain because of a lack of awareness among individuals. Therefore, only some information is available from times earlier than the 1880s. The Americans changed the path of industrial development taken by the British to match the development to the specific geographic and economic conditions and requirements of the American region. This American system supported the usage of labor saving machines and procedures in order to bring about higher incomes. This was coupled with the massive natural resources of a new continent. These developments happened with an assent of the government that reduced employers’ concerns in regard to safety. Consequently, the Americans changed to production methods that were both extremely productive and very risky, with a lack of concern for the welfare of the workers. As a result, the number of fatalities increased over the years of the late 1800s and early 1900s, particularly in the mining industry [14].

Thus, the American systems produced more coal per employee than the European techniques, but they were far more unsafe, and towards the end of the nineteenth century, the safety degraded significantly, as shown in Table 1.

Table 1: Fatality rates per thousand workers per year [14]

Years	American Anthracite	American Bituminous	Great Britain
1890-1894	3.29	2.52	1.61
1900-1904	3.13	3.53	1.28

Still, there were public attempts to develop safety from the early stages of industrialization. In addition, the United States launched regulations controlling the railroads in the beginning of the 1840s. Nevertheless, while most of the instructions were planned to develop safety, they had little influence and seldom had much impact on working conditions. Correspondingly, the first state mining regulation was initiated in Pennsylvania only in 1869, with the other states shortly following thereafter. Nevertheless, many of the initial regulations were ineffective and safety was observed to worsen after the Civil War (from 1865 onwards) [14].

In the period between 1900 and World War I, a slightly extraordinary band of Progressive improvers, muckraking reporters, businessmen, and workforce unions pushed for alterations in several parts of American life. Also, in 1910 Congress formed the Bureau of Mines in reaction to a sequence of catastrophic and progressively common explosions, the consequences of which were debated by the government since 1908. A sharp increase of expenditure due to accidents caused by compensation laws led to tighter employers' obligations and introduced the modern work safety regulations, which resulted in a long-term decrease in work accidents and injuries. Accident rates started to decrease gradually by about 38 percent in the years between 1926 and 1939 [14].

Still, in the 1960s, economic growth caused injury rates to increase again, and the resulting political pressures led Congress to create the Occupational Safety and Health Administration (OSHA) within the Occupational Safety and Health Act of 1970. Individual states can pursue their own occupational safety and health plans, and as of 2007, 22 states and territories have done so. In 1970, the Mine Safety and Health Management (MSHA) was set up, also, due to lasting problems of mine explosions [14].

1.3.3 Canada

The Workmen's Compensation for Injuries Act of Ontario was introduced in 1886, forming safety principles, for example instructing that there be protectors on machineries. In 1887, the Government of Canada asked the Royal Commission on the Associations of Capital and Labor in Canada to inspect the situation of employed people throughout the Region. When recording the testaments of an appraised 1800 observers, the Commission determined that there was a high level of injury in the workforce, which suffered from harsh working situations. The Commission prepared numerous suggestions for developing OSH by forming principles and authorizing regular checks, proposing the formation of a method for reimbursing victims of industrial accidents regardless of who was had responsibility for the accident, and suggesting that a labor bureau be formed to manage the improvement of OSH rules [15].

Justice William Meredith, who was chosen to a Royal Commission reviewing employees 'reimbursement in 1913, wrote the Meredith Report. The report summarized the rules in which laborers surrender their entitlement to prosecute in swap for reimbursement welfare. Specifically, the Meredith report supported no-fault reimbursement for injured laborers, combined with a monetary liability for the system to be allocated by all managers. The reimbursement was to be overseen by an independent and nonpolitical leading panel, with an exclusive authority, where the leading panel is the decision-maker and final authority for all entitlements. Moreover, in 1919, the Association of Workers' Compensation Board of Canada (AWBC) was established as a public association to assist the sharing of information between Workers' Compensation Boards and Commissions. In the beginning of the twentieth century, every state in Canada had initiated labors reimbursement panels, and each authority in Canada had distributed decrees to control fire safety and accident reporting in factories [15].

Furthermore, in 1974, the Ontario government developed the Royal Commission for the Safety and Health of Laborers in Mines, which stated the right to reject unsafe work with no fear of punishment, the right to contribute in recognizing and amending safety and health problems and the right to recognize the hazards in the workplace. These rights remain a significant foundation for the present OSH programs, procedures and laws in Canada [15].

1.3.4 Japan

In 1713, Yojokun in "A Teaching of Wellness, EkikenKaibara" conducted research on the relationship between work and disease. He realized that mineworkers frequently died within a period of three years of starting work, often through pneumoconiosis, triggered by breathing in mine smog, dust and ash and as a consequence of long working days in the mines. At that time, there was still no culture of safety and health to prevent health problems related to work [16].

From 1868 to 1912, the Japanese government created several state maintained industries under a considered policy of national industrialization. The Factories Act of 1911 was the first law agreed to in Japan with the purpose of defending laborers, and it came into force in 1916. Its main anticipation was to forbid women and youths from working at night [16].

Later, in 1905, the Mining Law was ratified, which carried regulations for the mining industry consistent with the country's forest industry, agriculture and fishing activities. Also, special war time regulations were adopted when the country joined the Pacific War in World War II. After the war, in 1964, the Factories Act and Mining Law were resuscitated [16].

The Ministry of Labor was initiated in 1947, and in the same year, the state developed a professional government agency that was devoted solely to managing work policies. After the 1950s, occupational diseases and industrial accidents increased alongside the fast development of the heavy industry. Probably the two most famous industrial accidents and with the most far-reaching consequences were the cadmium poisoning in the Toyama district, starting from 1912, due to mining activities, leading to the Itai-itai disease, which affected some hundreds of people, and the so-called "Minamata" incident in 1956 in Kumamoto prefecture, where about 2250 people were affected by methyl mercury, formed from mercury released by Chisso Corporation. A similar accident had happened in Niigata. Therefore, in order to solve that problem, the "Primary Industrial Accident Prevention Plan" was developed. Then, between 1955 and 1960 numerous protection laws, a medical examination system, and preventive regulations were announced [16].

Furthermore, with the aim of encouraging businesses to take the initiative in conducting safety and health management programs, the Law regarding the Organization for Industrial Accident Prevention was agreed upon in 1964. At the core of this law was the establishment of the Japan Industrial Safety and Health Association (JISHA), in addition to the formation of five industry-based safety and health associations [16]. Nevertheless, health and safety concerns regarding industrial activities continued with the release of significant amounts of the toxic sulfur dioxide by petrochemical industries in Yokkaichi in Mie Prefecture in the 1960s and 1970s. In 1972, the Industrial Safety and Health Law was enacted to provide protection for workers. This legal framework also sets forth the regulations regarding the manufacturing and import of chemicals. In addition, the Chemical Substance Control Law (CSCL), the Law for PRTR and Promotion of Chemical Management (PRTR Law) and the Poisonous and Deleterious Substances Control Law (PDSCL) regulate the handling of chemicals. These regulations are continuously augmented with the advent of new chemicals or new understanding of the toxicology of existing chemicals [17]. Thus, an amendment to the Industrial Safety and Health Law in 2016 made it compulsory for companies to conduct risk assessments for those substances which require a material safety data sheet (MSDS = safety data sheet [SDS]).

By law (Industrial Safety and Health Law of 2005 and prior), every workplace also has to have a risk assessment in place and has to plan and execute measures to reduce risk. However, it has been found that only in 20.4% of the workplaces had such a risk assessment been implemented [18].

The Japanese public has also become concerned about nuclear safety with the accidental radiation exposure of 100 workers in a nuclear facility in 1981 (Tsuruga) and of 118 workers in 1999, two of whom died (Tokaimura) and the Fukushima incident of 2011. These events will have lasting effects on the Japanese society and will most likely spur new safety regulations concerning nuclear and radioactive materials.

1.3.5 United Arab Emirates

The United Arab Emirates (UAE) was formed in December 1971. The country is a federation of seven emirates. The fundamental emirates are Abu Dhabi, Ajman, Dubai, Fujairah, Ras Al-Khaimah, Sharjah, and Umm al-Quwain [19]. UAE is a fast developing country comprised of a population of different nationalities with different levels of education, religious beliefs and cultural customs [20].

Due to the economic and industrial revolution in the UAE, especially of Abu Dhabi and Dubai, expatriate laborers are employed from all over the world in order to fulfill the need for manpower. Therefore, the government noticed the importance to have a labor law in order to manage and control all the issues related to workers, including occupational health and safety issues. Hence, in 1980, the Federal Law No. 8 for Regulating Labor Relations was formed. Moreover, there are additional regulations applying to laborers associated to some of the free zones in the UAE, for example the Jebel Ali Free Zone [21].

In Dubai, the Free Zone Industrial Operations Control Department was established in 1992 for managing the safety and health issues in the free zones, such as the Jebel Ali Free Zone [22].

Furthermore, in February 2010, the Abu Dhabi Occupational Safety and Health Center (OSHAD) was initiated to monitor the performance of an inclusive and integrated management system for occupational safety and health (OSH) and to manage all OSH matters in Abu Dhabi Emirate as well as to ensure a decrease in incidents, injuries and illnesses and to provide laborers with a safe and healthy workplace [23].

1.3.6 Overview of the Introduction of the Most Important Health and Safety laws in Selected Countries

<u>United Kingdom (UK)</u>

1760: The industrial revolution started in Abraham Darby's foundries at Coalbrookdale in the Iron Bridge Gorge, Shropshire.

1802: The Act for the Protection of the Health and Morals of Apprentices and others working in the Cotton industry and in other Mills was formed.

1833: The Health and Morals Inspectorate was formed.

1843: The formation of a Mines and Collieries Inspectorate.

1895: A Dangerous Trade Committee was formed.

1937: The first comprehensive code for health and safety applicable for all industries was formulated.

1949: The United Kingdom ratified the ILO Labor Inspection Convention.

1985: The mandatory reporting of injuries, diseases and dangerous occurrences as a regulation was started.

2000, The Revitalizing Safety and Health Strategy Statement was announced to start a ten-year campaign.

2013: The Health and Safety (Miscellaneous Repeals, Revocations and Amendments) Regulations came into force.

United States (US)

1840: The United States launched regulations controlling the railroads.

1869: The first state mining regulation was initiated in Pennsylvania only.

1910: Congress formed the Bureau of Mines.

1960s: Economic growth caused injury rates to increase again, and the resulting political pressures led Congress to create the Occupational Safety and Health Administration (OSHA) within the Occupational Safety and Health Act of 1970.

1970: The Mine Safety and Health Management (MSHA) was set up.

2007: Individual states can pursue their own occupational safety and health plans.

Canada

1886: The Workmen's Compensation for Injuries Act of Ontario was introduced.

1887: The Royal Commission on the Associations of Capital and Labor in Canada inspection on the situation of employed people throughout the Region.

1913: Justice William Meredith, who was chosen to a Royal Commission reviewing employees 'reimbursement, wrote the Meredith Report.

1919: The Association of Workers' Compensation Board of Canada (AWBC) was established.

1974: The Ontario government developed the Royal Commission for the Safety and Health of Laborers in Mines.

Japan

1713: Yojokun conducted research on the relationship between work and disease.

1911: The Factories Act was the first law agreed to in Japan with the purpose of defending laborers, and it came into force in 1916.

1947: The Ministry of Labor was initiated.

1955-1960: Numerous protection laws, a medical examination system, and preventive regulations were announced.

1964: The Factories Act and Mining Law were resuscitated.

1964: The Law regarding the Organization for Industrial Accident Prevention was agreed.

2005: Industrial Safety and Health Law

2016: An amendment to the Industrial Safety and Health Law.

<u>United Arab Emirates (UAE)</u>

1980: The Federal Law No. 8 for Regulating Labor Relations was formed.

1992: The Free Zone Industrial Operations Control Department was established.

2010: The Abu Dhabi Occupational Safety and Health Center (OSHAD) was initiated.

1.4 OHSAS 18001 and ISO 45001

The Occupational Health and Safety Assessment Series (OHSAS) 18000 is an international occupational health and safety management system requirement. OHSAS includes two parts, 18001 and 18002, along with a number of other publications. The main purpose of the standard is to assist an organization to manage and control its occupational safety and health risks. Also, OHSAS 18001 was cooperatively established by a number of world leading national standard bodies, specialist organizations and certification bodies, as a reaction to an extensive request for a known assessment and certification standard that can be followed. Moreover, just as most of the other management system standards, OHSAS 18001 is intended to be based on the principle of the Plan-Do-Check-Improve (PDCI) cycle. Planning for hazard identification, risk assessment as well as the determination of controls are main requirements of an Occupational Safety and health system. Correspondingly, in the standard it is clear that the requirements of occupational safety and health must apply to all personnel who work for, or on behalf of the organization and must apply to all the organization’s activities [24].

ISO 45001, which is established based on OHSAS 18001, was announced in March 2018 and is expected by the International Organization for Standardization to replace OHSAS 18001 over the next three years [25].

1.5 Environmental Management Systems

An Environmental Management System (EMS) is a set of processes and practices that assist an organization to decrease its environmental impact and improve its operational productivity [25]. The Environmental Management System offers an outline that aids a company to accomplish its environmental objectives throughout a reliable management of its processes. Also, the EMS itself does not determine a level of environmental implementation that must be accomplished; each company’s Environmental Management System is personalized to the company’s industry and targets [26].

1.5.1 Timeline of the Environmental Management System

Earlier, more than three decades ago, scholars and policy activists in the United States discussed what combination of charitable measures, economic inducements, and governmental protocols represent the best way to manage pollutant emissions and other environmental influences. Before 1970, the leading method was incentives along with regulations in certain states. In 1970, this method was observed to be insufficient, and a sequence of main novel federal regulatory decrees recognized technology-based license requirements and necessary limitations of air and water emissions and set up requirements for minimum waste treatment [27]. Furthermore, the communities’ uproar because of the pollution of Lake Erie due to the release of waste from a pulp mill of the Hammermill Paper Company led to the launch of the United States Environmental Protection Agency (EPA) in 1970 [28].

In 1984, the leakage of the poisonous gas methyl isocyanate from a pesticide plant in Bhopal, India, significantly augmented worries about how chemical corporations handled their processes in regard to environment and safety, mainly in third world countries. The release of the toxic gas methyl isocyanate (MIC) from the Union Carbide India Limited (UCIL) plant in Bhopal, India, caused the deaths of thousands of employees and neighbors of the plant and led to serious injuries in hundreds of thousands of others. Ultimately, the Union Carbide Corporation, the parent company of UCIL, agreed to pay $470 million to the Indian government to be allocated to claimants as a reimbursement [28].

In order to avoid the recurrence of the Bhopal tragedy, environmental management systems were recognized over the next several years. In 1988, the American Chemistry Council (ACC) launched Responsible Care to assist member companies in the development of their environmental performance and the health of the neighborhoods, which they controlled. Then, in 1992, the British Standard Institute (BSI) issued the world’s first environmental management system standards, BS 7750, a standard for environmental control in the manufacturing and services sector. During the next year, the Eco-Management and Audit Scheme (EMAS) was launched to permit industrial sector companies working in the European Union to voluntarily contribute to an environmental management scheme to determine the obligation towards a liable environmental stewardship. Later in 1996, the International Organization for Standardization (ISO) established The International Organization for Standardization (ISO) 14001, a worldwide registration scheme that was compatible with BS 7750 and EMAS [28].

1.6 ISO 14001

The International Organization for Standardization (ISO) 14001 is a certifiable standard associated with environmental management; it is almost the same as the quality management systems standard ISO 9001. The main purpose of ISO 14001 is to help organizations in controlling and expanding their operations that influence the environment to fulfill relevant laws and regulations [28]. Moreover, ISO 14001 has now been in existence for several years. The requirements of ISO 14001 are set out in clause 4 of the standard under six main headings; 4.1 General requirements, 4.2. Environmental policy, 4.3. Planning, 4.4. Implementation and operations, 4.5. Checking and corrective actions, 4.6. Management Review [29].

1.7 OSH in Universities around the World

The main purpose of universities is to provide education and risks associated to OSH might have a negative effect on their targets and objectives. Some of such accidents were studied by Wu et al. [2] by using employees' surveys from 100 colleges and universities in Taiwan, where the accidents in laboratories were considered as a significant issue. Research laboratories are locations where students learn skills or confirm scientific theories. Regrettably, there are accidents in labs which may be prevented if employers reflect safety matters in experimental lab management. Some of the accidents are so dangerous that they can cause injuries and deaths of the students or the teachers. It is efficient to apply the viewpoint of applied psychology to control the safety as an associate to engineering measures as the safety performance of several organizations does not cross the plateau phase [1, 2].

Wu et al. [2] clarified that the working environment of the University has both organizational factors and individual factors whose efficiency are based on the performance and communication between principal (eg., senior administration), faculty and staff and students. In general, organizational aspects of the working environment are size, ownership, safety manager, safety committee, and location. Nevertheless, individual aspects that need to be factored in can be gender, age, job tenure, title, experience, safety training of the individual(s) involved, and the work site itself. A good safety structure of an organization makes organizational factors important [1, 2].

Correspondingly, continuous career development and experience are important individual factors. Views of employees can change within the sectors. Wu et al. [2] from the outcomes of their study on safety in universities, viewed the existence of a safety committee as very important, as a safety committee was found to have a positive influence on the safety of that university. Also, a safety committee offers the chance to employees to contribute in safety planning together with the management. Additional results of the study regarding accident experiences indicate that workers who have never confronted any accident have a higher perception of safety hazards than others [1, 2].

1.7.1 National Associations of Universities OSH around the World

Several universities in the world have joined associations regarding Occupational safety and health. The United States of America, the United Kingdom and Australia have associations associated with safety and health in universities. All associations have a core objective to share information about OSH and endorse this information sharing [1].

1.7.2 Australasian University Safety Association (AUSA)

AUSA is an association of professionals and institutes, which are related to a university or any kind of educational organization working for occupational safety and health in the Australasian territory. The purpose of AUSA is to endorse the sharing of information on safety, health, environment and associated sections between the experts working for it in universities. Also, the association promotes and works at universities for strive to follow identical guidelines towards OSH problems. Members of AUSA are Universities and related institutes in addition to individual professionals who are associated with this sector and work for OSH. The first constitution of AUSA was launched in 1999 [1].

1.7.2.1 Universities within AUSA

The University of Melbourne has a shared management system for Environment, Health & Safety (EHS) with health and safety responsibilities for its staff, students and visitors. Policy and Guidance were established and Safety MAP certification was achieved for OSH. Achievements and performance are yearly circulated in the University of Melbourne Annual Report. Also, it has EHS Committees which are intended to manage, communicate and provide particular advice on EHS issues. These committees comprise the Occupational Health & Safety Committee (OHSC), EHS Coordinators and EHS Working Groups. To confirm the working of EHS system, audits are accomplished together internally by departments and externally for certification. Guidance lectures concerning chemical management, usage of permits, office ergonomics and travelling and working off-campus are given to make faculty and students aware of promote OSH. Also, EHS has an incident reporting and emergency response system [1, 30].

The University of Sydney has a commitment to the safety and health of its employees, students and visitors with OSH policies, procedures and guidelines to conform with legislations and to support Australian Standards. It mostly concentrates on office ergonomics, laboratory and chemical safety and emergency and incidents handling. Also, OSH management includes housekeeping and risk management guidelines. The main noticeable aspect is self-audit. As of 2018, University of Sydney is not certified for its OSH [1, 31].

The Australian National University targets to be a leader in OSH and injury management and dedicated its OSH policy to offer a safe work and study environment to its staff, students, contractors and visitors. It mostly includes the management of hazards in general, specifically radiation, noise and electrical safety and mental health. It is not a certified management system [1, 32].

1.7.3 Universities Safety and Health Association (USHA)

USHA is a UK based association, which is working for the promotion of safety and health in higher education since the 1970s with a present strength of 150 university members. The main goal of USHA is to be a center for the exchange of information associated with health and safety in higher education and for the inspiration of safety practitioners. One of the motivating steps from USHA is the issuance of safety awards, for the excellent work of 33 staff and students concerning the development and endorsement of health and safety within the higher education sector [1].

1.7.3.1 Universities within the Universities Safety and Health Association (USHA)

The University of Oxford has an Occupational Health Service, which assists the university to achieve the laws of safety and health and at the same time has become a part of its Risk management program. OSH is for university staff, students and visitors. Also, it has policies and guidelines on OSH, which includes office and laboratory ergonomics. The OSH program mostly concentrates on health at Work, health service for overseas visitors and emergency procedures. Health at work includes mental health (alcohol, drugs, stress), computer ergonomics, work related hazards and OSH for medical students. The Oxfords' OSH program is not certified [1, 33].

The Imperial College London has a safety management system (SMS) to deliver health and safety to its staff, students, visitors and contractors. SMS structure is managed from the top level of Council/Rector to heads of departments to the level of each individual with the help of a safety committee. Also, the university has a distinct policy on health and safety and has numerous guidelines, which include almost all features from work and hazards safety to accident and emergency response. SMS has a software based audit system called iCheck Audit System. SMS is in line with the guidelines of Successful Health and Safety Management [1, 34].

The University College London has an Occupational Health team working for psychological and physical health and safety under Occupational Health Service with Human recourses department. Besides to health guidance and monitoring health triggers, OSH does screening for an employee and driver to confirm safe people for safe work [1, 35].

1.7.4 Campus Safety, Health, and Environmental Management Association (CSHEMA)

CSHEMA is a USA based organization, which was launched in 1954 as a Campus Safety Association. Just as AUSA and USHA, CSHEMA proposes a framework to share health, safety and environmental (HSE) information between education and research communities. Furthermore, CSHEMA offers rewards and a scholarship program to encourage students to continue studies in HSE and to motivate professionals of HSE to practice innovative problem solving. CSHEMA has more than 1000 HSE professional members in the USA and worldwide [1].

1.7.4.1 Universities of CSHEMA

Harvard University has a safety and health management system in compliance with Occupational Safety and Health Administration (OSHA). Its target is to remove hazards and decrease risks for employees, faculty and students. The structure of the management system covers three levels – the University level, the School level and the level of the individual - in order to deliver improvements at all levels based on training and committees. This safety and health management system is working alongside the environmental protection system in managing laboratory, radiation, fire and public health safety [1, 36].

The University of Chicago has an Environment, Health & Safety (EHS) program which targets to deliver a healthy, safe, and environmentally educationally stimulating environment with the assistance of its students, faculty, and staff and with its visitors'support. It has a distinct group of policies for Occupation Health and Occupation Safety. The aim of the policies on Occupation Health is the physical wellbeing of the workers. Occupational Safety targets to reduce or eliminate hazardous conditions. This EHS is not certified [1, 37].

Yale University has an office of Environmental Health and Safety, which has the objective to decrease injuries, accidents and negative environmental influence of its operations in corporation with students, faculty and staff. All policies are in line with OSHA standards. Noticeable aspects are EHS Rewards and Recognition and a Combined Health and Safety Committee, with a representation of all people. It mostly includes laboratory, physical and chemical safety and manages several sorts of risks [1, 38].

1.8 Health and Safety in Educational Laboratories – Health Effects of Selected Chemicals

One of the recent statistical outcomes showed that the loss due to accidents can be assessed to be about 70 billion dollars per year, worldwide. Risks may be everywhere and accidents can happen anytime, but the loss due to an accident can be alleviated through an applicable risk management program. Major accidents can cause a loss of many human lives, create massive environmental damage, and lead to enormous material losses, and often this obviously happens due an ineffective risk management program. Correspondingly, studies show that for an organization or educational center with a strong emergency response system, the damage can be decreased by 6% as compared to the same organization/ educational center with a poor emergency system. Emergency planning as a portion of the emergency system is a supervisory document to lay out a fast, organized and operative rescue in an emergency response to a disaster or major accident [39].

Academic laboratories include teaching, service laboratory functions and research, usually combined with the movement of personnel between the laboratories and functions as required. This variety of laboratory operations poses a challenge when setting up the safety management. Also, the individual academic laboratories are very different in scope and activities [40]. While there are several standard safety systems installed in academic laboratories (see above), there are still numerous accidents that are reported from them. These accidents have the potential to do serious injury to personnel; can lead to major equipment damage, to structural damage, the loss of valuable scientific documents and to a disturbance of the educational operation. Correspondingly, the past few years have seen an extensive range of serious accidents with a number of fatalities, damages to the infrastructure and economic losses the educational centers [39, 40].

Furthermore, there have been several accidents reported due to fires that broke out during demonstrations in academic laboratories that caused severe injuries and burns to students and teachers. Several such incidents happened when methanol was used in demonstrations. The demonstrations included heating a metal salt in a small plate in methanol. These incidents all have a shared factor. The teacher working on the demonstration tried to use additional methanol from a large bottle to do the demonstration again. Then, the vapors from the bottle came in contact with a source of ignition, usually the hot surface of the heating plate and a flash fire resulted as the vapors rapidly ignited and extended across the room catching on fire members of the audience [41]. Therefore, it is very important during the academic preparation of future chemistry teachers to educate them in health and safety issues and provide them with all knowledge and information on this topic. Such planning is an insurance against any serious injuries and risks which can affect the health and cause material damages [42].

Students choosing science as part of their formal education are required to take part in laboratory classes. These practical sessions assist students to test the theory learned in more details and can develop their interest in the subject area. Therefore, laboratory classes are considered to be a significant part of the curriculum. One of the sciences is chemistry in which often hazardous chemicals are used widely during lab sessions. In these classes, students are using chemicals of diverse types and properties. Although the chemicals that students use on a daily basis have numerous benefits, they can also be hazardous to the health and environment [43].

Therefore, providing opportunities to students for running experiments should be accompanied by a sufficient awareness about chemicals and other hazardous substances and laboratory safety in general. Besides, paying attention to possible hazards of chemicals in the science laboratory is required for teachers. Teachers take a significant part to support students to keep safe when handling hazardous chemicals and to encourage the safe habits in the laboratory session. This includes the storage and disposal of chemicals and the proper handling of chemicals. Importantly, students must obey all the recommendations provided by teachers [44].

Moreover, personal protective equipment (PPE) including lab coats are a primary measure of protection in a laboratory environment when used in combination with other controls. Nevertheless, in numerous university laboratories there is a lack of suitable lab coats and sometimes they are not available or not specifically worn while working with hazardous materials. Therefore, this lack of appropriate PPE led to urgent calls for action at universities after the tragic death of University of

California, Los Angeles (UCLA) researcher Sheri Sangji in early 2009. Sangji was carrying a plastic syringe with the pyrophoric chemical tert-butyllithium when the needle came out, resulting in an instantaneous fire. Unfortunately, Sangji, who was not wearing a lab coat, suffered second and third degree burns, causing her death, 18 days later. It was considered that a flame-resistant lab coat could have avoided the extremely acute burns [45].

Following the UCLA incident, the Massachusetts Institute of Technology (MIT) policy for lab coats states ‘‘At a minimum, a laboratory coat or equivalent protective clothing is required for work with particularly hazardous substances, unsealed radioactive materials, and biological agents at BL2 or greater’’[45].

Typical accidents have also involved refrigerators with non-protected motors that made it possible for chemical fumes to ignite and cause laboratory fires. One such fire destroyed a laboratory at Pohang, South Korea. Another accident happed in Tehran in 1996, when an explosion in a biochemistry laboratory at Tarbiat Modarres University caused the death of a person and the loss of laboratory equipment [28]. These accidents led to more comprehensive safety inspections regarding electrical equipment.

Lately, infectious diseases have been found to be more common among occupational diseases. This finding of occupational infectious diseases had a ripple effect in the field of occupational medicine and industrial hygiene. Occupational biohazards are infectious agents or hazardous biological materials that have a damaging influence on workers’ health, both directly through infections or indirectly through the destruction of the working environment. Infectious agents can be samples of a microorganism or medical waste, a virus, or a toxin from a biological source [46].

Furthermore, occupational infectious diseases are normally discovered as part of a systemic infection that can include the respiratory organs in immune-compromised workers. Biological hazards at work, their diagnosis, and treatment has been discussed a lot. Recognized etiological sources of the disease are growing and comprise occupational factors. Additionally, two major groups of biological agents are considered as occupational biohazards: (1) agents causing zoonoses and other infectious diseases that could be spread by impulse or insect vectors, across numerous exposure routes; and (2) allergenic and/or toxic agents creating bio aerosols, producing occupational diseases of the respiratory tract and skin [46].

Furthermore, inspection programs are important in order to check on the efficient implementation of the safety procedures in the educational laboratories. Forty-two U.S. colleges and universities have completed an online laboratory safety inspection benchmarking survey. The results from the benchmarking survey have provided laboratory safety programs with the capability to evaluate baseline, define gaps and to acquire enhancement strategies [47].

Also, many universities conducted surveys regarding health and safety in the laboratories. One of those surveys has been conducted at the University of Indonesia, which included 51 laboratories of the faculty of medicine. The findings showed that 4% of the laboratories had a score above 70%, which indicates that they applied a good university standard for laboratory chemical safety, health and security; however, only 33% of the laboratories were in overall fulfillment of the university’s standard. Also, between 50–70% of the laboratories had a compliance of less than 50%. The recommendation after this survey was that regular laboratory chemical safety, health, security inspections should be organized, and corrective actions applied with constant enhancement through the safety, health & security management system [48].

Another survey was conducted at Khon Kaen University in Thailand, which included classes of fourth-year undergraduate students at the faculty of education who studied a chemistry laboratory instruction course. The main goal of this survey was to inspect the understanding of safety signs by Thai undergraduate students. The results showed that most of the students were confused about the meaning of safety signs. Furthermore, they had difficulties in identifying chemicals usually found in school science laboratories such as sodium. The outcome of this survey provided basic knowledge in regard to learning and teaching in the course to enhance students' awareness of the appropriate handling, storing and discarding of hazardous materials [49].

Another survey compared academic, governmental and industrial researchers' opinions about numerous safety features within their work environments. The results from this study suggested that the safety training in any research environment is a significant feature of laboratory safety by providing researchers with the confidence to run experiments without harming themselves, their co-workers, and their environment [50]. Also, the disparity between researchers' awareness of their own risk and what they think their institution identifies is their risk in the laboratory might possibly cause accidents because of researchers under-evaluating their risk. Therefore, it is important that throughout the safety training, risk levels are obviously expressed. Moreover, industrial labs showed the best operative safety culture, where the safety culture in academic labs is less well recognized as compared to the safety culture in government and industrial research labs. In academia, active participation of the lab supervisor in safety understanding positively affects safety performance as can be seen in the decrease of the number of accidents in the lab and in a direct relationship with the compliance in regard to PPE. Therefore, it is recommended to increase the awareness of the lab supervisors’ part in academic institutions with respect to their important effect on the researchers’ safety [50].

In fact, researchers in chemistry and biology are exposed along their careers to a huge variety of chemical agents at low concentrations in air. Hence, a study has been conducted at two universities in Spain, where the main goal was to determine the relationship between the long-term exposure to chemical agents and the rise in the predominance of the Multiple Chemical Sensitivity (MCS) in university researchers in chemical laboratories. Multiple Chemical Sensitivity (MCS) is a developmental disease that is described by the gradual loss of tolerance to the environmental presence of various chemical agents such as perfumes, colognes, cleaning products, air-fresheners, solvents or hydrocarbon containing fuels. Due to some limitations mentioned in this study, the acquired results differ with one of the main causes of MCS, which depends on the presence of oversensitive people, who give a reaction after continued exposures to quantities less than the required ones to produce the usual non-stochastic results [51].

On the other hand, the health and safety of pregnant women is an important issue to consider in the laboratory working area. Pregnancy has been always considered as a probably serious window of exposure to a variety of chemicals. Certain chemicals might interrupt fetal brain growth, causing an alteration in postnatal behavior. These include chemicals, whose hazards have been recognized for millennia, for instance, lead, which has been recognized as being neurotoxic for a long time, and others, for which the first data on neurotoxicity in offspring date stem only from the previous few years such as bisphenol A, phthalates, polybrominated diphenyl ethers, polycyclic aromatic hydrocarbons, perfluoroalkyl acids, and others, for example, methylmercury and other mercury derived compounds [52]. Also, some studies founded that mercury exposure at the primary stages of pregnancy could be a risk that leads to children of low birth weight. As the mercury in maternal blood can promptly go through the placenta, pregnant women and women of reproductive age must keep away from mercury or decrease as much as possible their exposure to mercury [53].

Moreover, a very large number of chemicals are generated and consumed around the world, and some of them can have harmful effects on the reproductive health of employees. Exposure to toxicants before and after conception can influence parents, fetuses, and newborns. Pregnant women always have concerns about three of the very popular occupational health risks that are tobacco smoke, the quality of indoor air and video display terminals. Nevertheless, there are other more troubling influences. Even copper has been recognized as a reproductive toxicant since it disturbs the motility of human sperm *in vitro*. Also, studies have shown that maternal injection of silver nanoparticles (AgNPs) delayed physical growth and decreased cognitive performance in offspring [54].

Some studies on humans and in animal experiments show that polybrominated diphenyl ethers (PBDEs) could harmfully disturb the male reproductive function. The study also displayed the harmful influence of organochlorine pesticides on the growth of the female reproductive system in the period of puberty. Although the severe toxicity of pesticides has been well recognized, comparatively little is known regarding the consequences of chronic pesticide exposure on health. Also, research into how exposure to “endocrine disruptor chemicals” influences human health has gained great attention among scientists as these toxins are so common in the work environment and can have long-term influences on mental and physical health. Their study demonstrated the complex action of a di(2-ethylhexyl) phthalate/polychlorinated biphenyl mixture and its impacts on the male reproductive system, representing the necessity for more studies on the reproductive hazards of combined endocrine disruptors. Bisphenol A (BPA) has been linked to a drop in sperm quality. Carcinogens/mutagens can cause a health hazard to the mother and fetus during pregnancy and might have long-term consequences on newborns [54].

1.9 Biosafety Levels in Laboratories

In the early twenty first century, the biotechnology became one of the fast developing areas of cutting-edge engineering and science. This quick progress and technological development has offered great social profits worldwide, for instance in enhancements to public health, energy and agriculture development. International society already controls risks in biotechnology research throughout the principles of biosafety [55]. The biosafety lab is a specialized research laboratory that deals with infectious agents [56]. In addition, instructors need to be aware of the risks in using microorganisms in the laboratory and should use the best practices to reduce the risk to students and the public [57].

In universities, activities in laboratories practiced need the requirement for safety standards, as the human factor is expected the sources of accidents in laboratories, educational programs in biosafety become essential to the inhibition of risks. Nevertheless, for an education program become effective is required that the operators are completely knowledgeable about the biosafety concepts, also to able to practice them appropriately to confirm the safety of all academics, professionals and the environment [58, 59].

The protections needed by laboratorial activities are identified as biosafety levels. Biological safety levels are categorized from one to four and are designated based on the organisms or agents on which the research or work is being operated. Each level up builds on the preceding level, adding limitations and barriers [56].

Biosafety Level 1 is appropriate for work including well-categorized agents, which is not known to reliably cause disease in immune competent adult humans, and show insignificant possible hazard to laboratory personnel and the environment. BSL-1 laboratories are not essentially separated from the overall traffic designs in the building. Typically, work is conducted on open bench tops by regular microbiological practices. Also, there is no need for a special containment equipment or facility design, nevertheless might be used as determined by suitable risk assessment. In addition, laboratory workers should have specific training in the procedures applied in the laboratory and should be overseen by a expert with training in microbiology or an associated science [56].

Biosafety Level 2 develops upon BSL-1. BSL-2 is proper for work comprising agents that pose modest hazards to workers and the environment. It varies from BSL-1 in that; laboratory workers have particular training in dealing with pathogenic agents and are overseen by scientists experienced in handling infectious agents and related procedures. Another difference is that entrance to the laboratory is limited when work is being conducted. Then, all procedures in which infectious aerosols or splashes might be produced are conducted in any physical containment equipment [56].

Biosafety Level 3 is appropriate to diagnostic, clinical, teaching, research or production facilities where work is accomplished with exotic or indigenous agents that might cause acute or possibly lethal disease throughout the inhalation route of exposure. Laboratory workers should obtain a special training in dealing with pathogenic and possibly lethal agents, and must be overseen by scientists capable in handling infectious agents and related procedures [56].

Biosafety Level 4 is mandatory for work with exotic and dangerous agents that present a high individual risk of aerosol-transmitted laboratory infections and serious disease that is often fatal, for which there are no vaccines or medications, or an associated agent with unknown risk of transmission. Agents with a close or identical antigenic association to agents necessitating BSL-4 containment should be controlled at this level until adequate data are acquired to either confirm continual work at this level, or re-designate the level. Also, laboratory staff should have definite training in usage extremely hazardous infectious agents. Laboratory staff should recognize the primary and secondary containment meanings of standard and different practices, laboratory design characteristics and containment equipment. All laboratory staff and administrators should be experienced in usage agents and procedures needing BSL-4 containment [56]. On Maqam Campus, there are only laboratories that correspond to biosafety level 1.

1.10 OSH at the United Arab Emirates University (UAEU) and Formulation of the Scope of this Study

In recent years, in the Middle East region, there has been an obvious focus on occupational health, safety and the environment. Therefore Health, Safety and Environment (HSE) concerns have to be rated above many other priorities.

Emergencies, disasters, accidents and injuries can occur at any time, usually without warning. Being prepared physically and mentally to handle emergencies is an individual as well as an organizational responsibility. Also, staff, visitors, as well as contractors' and subcontractors' health and safety are one of the main concerns of organizations including universities in the region as world-wide [60, 61, 62].

The higher education in the United Arab Emirates is experiencing significant development and improvement, both quantitatively and qualitatively. The Government of Abu Dhabi Emirate is committed to protect and conserve the environment, and to protect and promote human health and safety for all inhabitants of the Emirate. The Department of Education and Knowledge (ADEK) is the regulator for education in Abu Dhabi and therefore is committed to ensure the protection of its environment, resources, and operations within the educational sector in the Emirate of Abu Dhabi [63]. This forces the universities in Abu Dhabi Emirate, which includes United Arab Emirates University (UAEU), to have an operational HSE management system.

The UAEU was founded by the late Sheikh Zayed bin Sultan Al Nahyan in 1976 as the first comprehensive national university in the United Arab Emirates. The UAEU offers a full range of accredited, high-quality graduate and undergraduate programs through nine Colleges: Business and Economics; Education; Engineering; Food and Agriculture; Humanities and Social Sciences; IT; Law; Medicine and Health Sciences; and Science [64]. According to the statistics given in the United Arab Emirates University annual report of 2015-2016, there were 2,219 males and 10,313 females enrolled as undergraduate students at the university, along with 360 males and 587 females in the post- graduate programs [65]. Also, the UAEU has a separate male and female health club that offers a fitness gymnasium and studio, an indoor sports hall, an Olympic sized swimming pool (50m, squash courts), and outdoor tennis courts, basketball, and football fields [66].

The United Arab Emirates University (UAEU) has acquired OHSAS 18001 certification, worldwide known as the International Management System standard issued by the British Standards Institute (BSI). This standard defines the required occupational security and safety requirements to support organizations, including universities, to manage security and safety risks and develop performance in this area. Also, UAEU inspires all students, staff and faculty members to participate in all health and safety activities. This is accomplished through arranging and holding training courses and workshops on in order to support them to achieve their activities safely and decrease the probability of accidents [67].

In this research, the actual implementation of a health and safety infrastructure within the guidelines of the OSHAS health and safety management system at the UAEU was studied with a focus on the E-shared laboratories, specifically the chemistry teaching laboratories in E4. During the time of the thesis study, a health and safety management system was implemented officially by the consulting group Santia, working in house, according to the guidelines and regulations of OHSAS 18001. The thesis studies this process of implementation, looks at the current situation and makes some recommendations.

The E-shared laboratories are a gender-shared educational facility on an otherwise gender-separated campus. The gender-shared facility on an otherwise gender-separated campus makes the facility infrastructure unique in some way as the buildings are entered and exited in different manners depending on whether female or male students occupy the building at the time. Exits are locked or open, again depending on the occupancy of the building at the time. Thus, this thesis can also be seen as a case study of a health and safety management system on a gender-separated campus.

Points that were to be addressed in the thesis were the study of management systems for chemicals, a study of the egress of building E4 with its unique feature of standing on the divide of a gender-separated campus, a study of the faculty's and students' responsiveness to the health and management system and the study of waste management and reduction and how such a waste management would impact the health and safety management.

In this thesis, special emphasis was also to be given to remediation efforts in regard to environmental concerns within the health and safety infrastructure. This includes the recycling of materials to decrease the amount of waste that would need to be extracted from the facility.

Chapter 2: Methods

2.1 Research Design

One of the main objectives of this thesis is to study the spatial layout of the current E4 shared laboratories building, and to assess the escape routes hanged (as hang-outs) as part of the existing Fire Safety and Evacuation Plans of the building.

To achieve this objective, the research utilized space syntax method by using DepthmapX software. DepthmapX is a multi-platform and an open-source spatial analysis software for spatial schemes of various scales. Actually, the program was initially established by Alasdair Turner from the Space Syntax group as Depthmap, now open-source and existing as DepthmapX [68].

DepthmapX operates at a range of scales from buildings and small urban spaces to entire cities. At each scale, the objective of the software is to create a map of spatial elements and link them through relationship for example, intervisibility, adjacency or intersection and therefore completes a graph analysis of the resulting network. Also, the purpose of the analysis is to develop variables which might have experiential or social significance [68].

Two kinds of analysis, Axial Analysis & Visual Graph Analysis [VGA], were implemented to recognize the inherent morphological character of the building's spaces. Also, Agent Based Simulation was applied to expect the design of movement throughout a fire evacuation scenario.

The research studied the results of space syntax and real drill observation in order to plan the guidelines to re (define) the applicable routes.

Another objective is using thermally recycled silica gel in a teaching and small research laboratory. Silica gel of Merck grade 9385 (fine, pore size 60 Å, 230-400 mesh, bp. 2230°C, mp. > 1600°C) was used in the experiments. The thermal treatment of the silica gel during the recycling process was carried out in a Carbolite electrical oven ELF 11-6. For the sieving process of the silica gel after the combustion process, Retsch 180 μm sieves were used. Brunauer-Emmett-Teller (BET) surface area and porosity studies were carried out on Micromeritics TriStar II Plus 2.03 instrument. P-content was measured by ICP-OES with a Varian 720-ES spectrometer. For the organic products separated on the recycled silica gel, melting points were measured on a Stuart SMP 10 melting point apparatus and are uncorrected. Infrared spectra were measured with a Thermo/Nicolet Nexus 470 FT-IR ESP Spectrometer. ^{1}H and ^{13}C NMR spectra were recorded with a Varian 400 NMR spectrometer (^{1}H at 395.7 MHz, ^{13}C at 100.5 MHz). The assignments of the carbon signals were aided by DEPT 90 and DEPT 135 experiments (DEPT = Distortionless Enhancement by Polarisation Transfer). The chemical shifts are relative to TMS (solvent $CDCl_3$, unless otherwise noted). Mass spectra were measured with a JMS-01-SG-2 spectrometer, and with an Agilent QTOF 6540 UHD.

Chapter 3: United Arab Emirates University

The United Arab Emirates University (UAEU) is designed to run under strictly enforced gender segregation at the undergraduate level. Most of the colleges operate on one campus, the new Maqam campus, which was populated in 2010. To the best of our knowledge, it is the largest gender separated campus in the world. The UAEU runs gender-shared facilities, and this requires unique planning in order to maintain segregation. Laboratories are operating within different buildings at the same time with both male and female students, but without crossover. Some laboratories, however, such as the so-called E-shared laboratories are gender-shared buildings, which are available to male and female students at different times. Furthermore, UAEU has separate entrances for males and females, and the IT and administration buildings are separated in the middle, gender-wise. Similarly, the library is designed to have both male and female students in separate areas, with the central library accessible at different times for males and females. The segregation system on such a large campus within one geographic location is very unique and had to be designed with a subtle security that does not impede on the day-to-day operation of teaching and research.

In addition, the day-to-day servicing of the campus is carried out by Khadamat Facilities Management LLC, which is also the estates manager, responsible for the upkeep and maintenance of the campus. Subcontractors are present on campus as well such as Berkeley Services Group, which is involved at least some of the cleaning. Furthermore, other subcontractors take care of landscaping. Further contractors are called in as need arises. In addition to that, there are the usual deliveries and other services such as maintenance services, which leads to a relatively complicated set-up, also in matters health and safety.

The university manages its health and safety through the facilities management department. Khadamat has a separate health and safety division. Berkeley yet again manages its own health and safety issues. On the other hand, UAEU is OHSAS 18001 accredited, which necessitates following rigorous guidelines for setting up and maintaining an Occupational Health and Safety Management System.

In Figure 1 below, we can see the crossover of the male and female students in the library and IT building along with the E- Shared Laboratories. Also, in Figure 2, we can see the movement of service personnel possible between the male and female campus – the accesses shown in Figures 1 and 2 differ by two additional cross-overs, one between the library and the IT building and one at the back side of the E3-shared laboratory building.

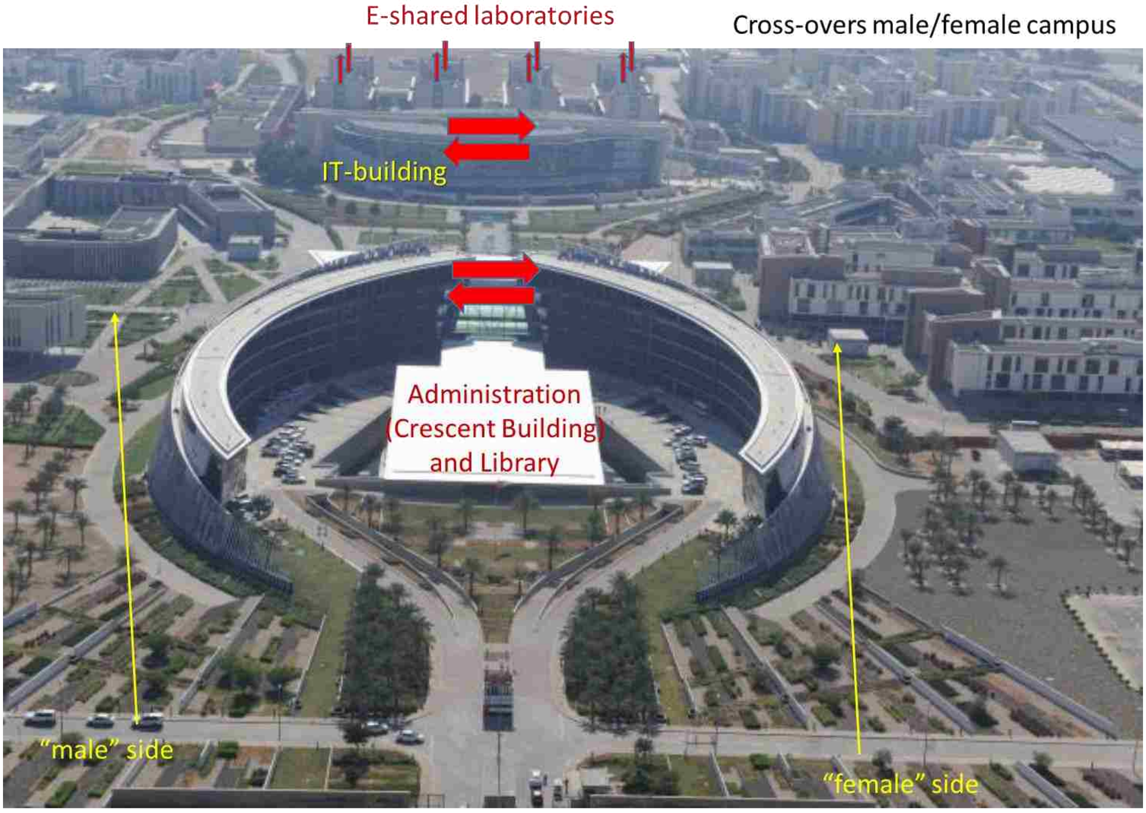

Figure 1: New Maqam campus showing the movement of students and faculty possible between the male and female campus

Figure 2: New Maqam campus showing the movement of service personnel possible between the male and female

3.1 E-shared Laboratory Series

The United Arab Emirates University features five laboratory buildings, named E2-E6, that are on the border between the male and the female side of the campus. The laboratories (Figure 3) are meant for teaching, only. However, in certain laboratories, especially in biology (E3), physics (E3), geology (E4), E4 houses the laboratories of geology (1st and part of the 2nd floor) and chemistry (part of the 2nd floor and the 3rd floor). A floor plan of the building is given in Figures 4, 5 and 6. As can be seen, the building is divided, more or less in the middle, with two magnetically locked-down doors and a central staircase that leads to the first floor and the ground floor with an exit to the courtyard between buildings E4 and E5. The courtyard has no unlocked exits under normal operation conditions. So, the building could house both female and male undergraduate students at the same time with the central connecting doors on all floors locked down. This mode of operation has been tried once successfully in the summer 2016. Normally, however the building is operated on a daily basis either exclusively for females or for male students. At this moment and over the last few years the timetable was such that the male students occupy the building on Sundays and Tuesdays and the female students occupy the building on Mondays, Wednesdays and Thursdays, where Thursday is half day. In those times, the respective outer door leading to the opposite side of the campus (eg., for the men the door to the female campus) is locked down as is the door that leads from outside into the building on the ground floor. There are two elevators, one on each end. There are also two staircases servicing the three floors, one at each end. Additionally, there is a fourth floor that may be reached through the staircases at each end, which is a service floor, featuring the extraction fans, etc.

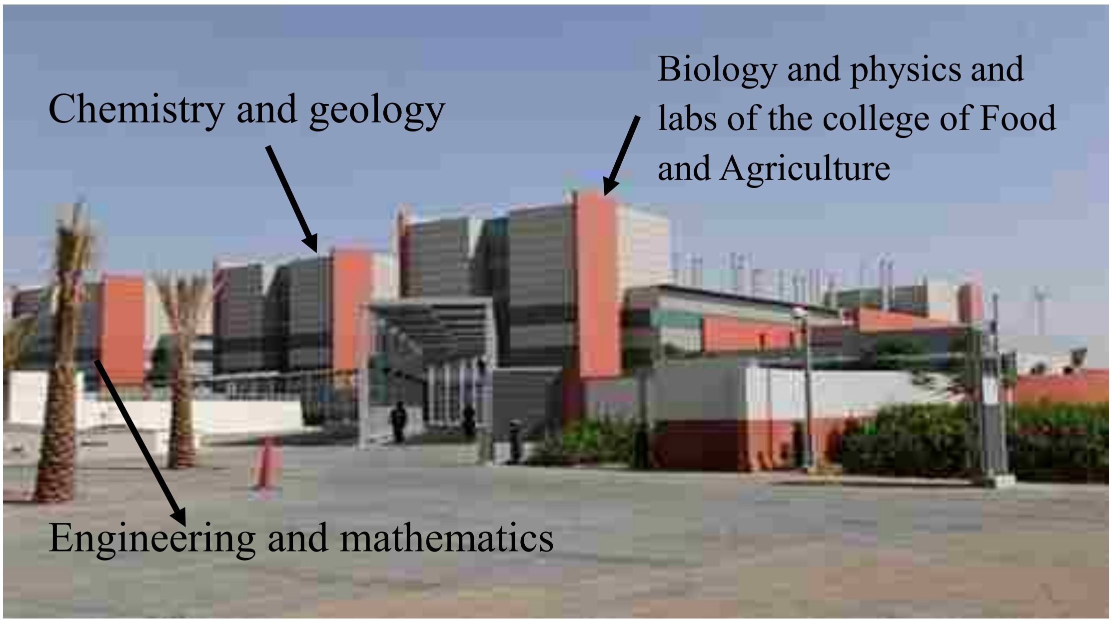

Figure 3 E-shared laboratory series

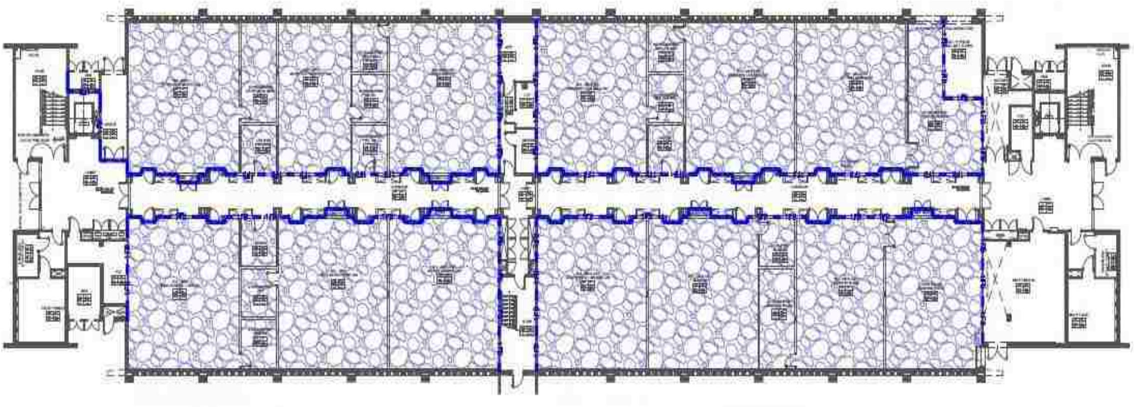

Figure 4: Layout of the ground floor in E4 building

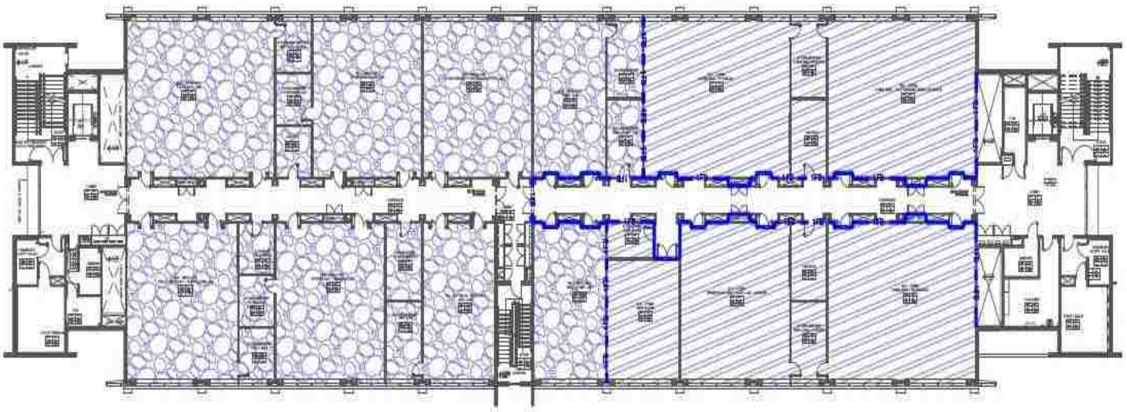

Figure 5: Layout of the first floor in E4 building

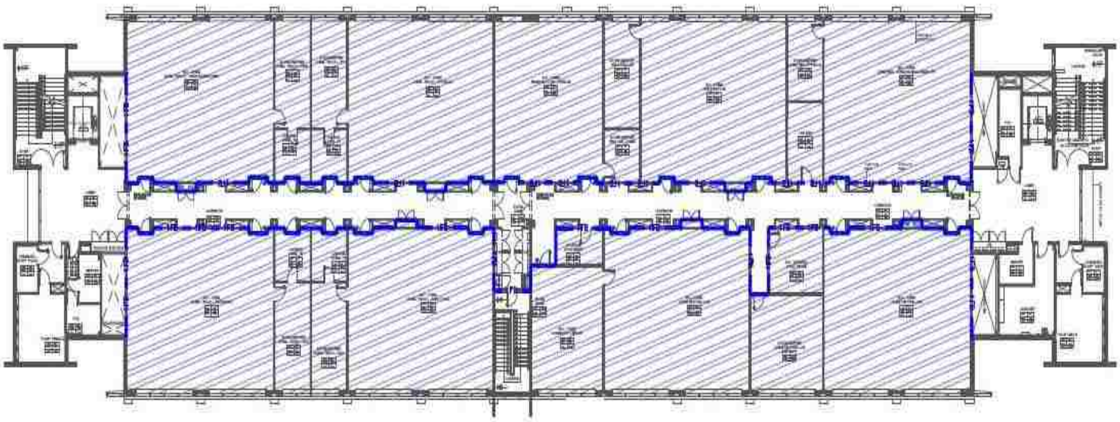

Figure 6: Layout of the second floor in E4 building

The chemistry department has four laboratories on the first floor of E4. They are two General Chemistry teaching laboratories (floor plan, upper right hand side), which are very heavily populated and one Inorganic Chemistry teaching laboratory (floor plan, lower right hand side). The fourth laboratory is serving as a chemistry museum and a demonstration room during school visits to the campus (floor plan, second lab on the lower right sand). In between the laboratories (on each side of the corridor), there is one instructor/staff office and one preparation room/storage facility. There is also a room that was supposed to house a nuclear magnetic resonance spectrometer, but which has been repurposed to be a break room for instructors and staff. On the second floor in E4, the chemistry department has nine laboratories. These are two organic chemistry teaching laboratories, two biochemistry teaching laboratories, one analytical chemistry teaching laboratory, one instrumental analysis teaching laboratory, one physical chemistry teaching laboratory, one instrument room that houses an LC-MS (liquid chromatography – mass spectrometer), an HPLC (a high performance liquid chromatograph), UV-VIS spectrophotometers and an IR (infrared) spectrometer. Finally, there is an undergraduate research laboratory, which is used in undergraduate research projects. Additionally, there is a break room, which is also designated the chemistry library. On one side of the corridor there are three offices for instructors/staff, while on the other side of the corridor there are two offices for instructors/staff as well as a larger and a smaller room which serve four instructors/staff (larger room) and three instructors/staff (smaller room) as offices. There is a preparatory room/storage for every laboratory. All laboratories have two doors. Most of the small offices have two doors, where one door leads into a preparation room and the other into the corridor. The offices on the second floor, named larger and smaller office in this thesis, have only one door and this leads to the corridor. The preparation rooms on the first floor all have two doors leading to the neighboring laboratories on each side. Some of the preparation rooms on the second floor, namely those which are on the same axis as an office, have two doors, one of which leads to the office, the other to the laboratory. One preparation room has only one access door, namely from the Analytical Chemistry teaching laboratory.

Although by the time of the move to the E-shared laboratories of the E-series in 2010 many of the items that one would find on a checklist when setting up a laboratory [69] could already be found, the interiors of the laboratories were only partially finished. Additional, needed water and gas infrastructure for the chemisty teaching laboratories was put in in the summer of 2011. Also, the fume cupboards which had been bought from the Spanish start-up company Flores Valles, initially did not feature water taps or gas outlets – these were also put in in the summer of 2011. Additional fume cupboards were asked for, but the extraction capacity of the fans of E4 was already reached, so that no further fume cupboards could be connected. A stand-alone fume cabinet with air-filtering capability was bought. The corridors have gas cylinder cabinets; however, gas manifolds were missing which did not allow gases to be piped from the cabinets to instruments in the respective laboratories. Storage cabinets especially designed for the storing of chemicals needed to be bought. The laboratories themselves feature a lot of built-in wood. Especially window ledges are made of wood and furniture parts are made out of plywood. Additionally, table top surfaces are partly made from plastic materials. The fear that laboratory material was flammable was unfounded. At the time before moving into the laboratories, material samples were asked for. These were flamed with a hot torch, but none of the materials supported a flame. This indicated a heavy impregnation of the materials with halogen containing flame-retardants. Such flame-retardants pose the risk of emitting halogenated aromatics in case of fire, including dangerous dioxins. The flooring of the laboratories was found to be unsuitable by the end-users at the time of the move to the laboratories in 2010 and this concern was later found to be well founded. In general, laboratory flooring should be abrasion- and chemical-resistant. It should be electrostatic-dissipative. Also, it should be anti-microbial and bacteriostatic and it should be fire-resistant. Typical flooring material can be tiles or sheets made from vinyl, linoleum, ceramic (tiles), rubber, resin coating or linoleum [70]. According to the National Institute of Health regulations, all laboratories under their leadership require a flooring that is chemically resistant according to ASTM F925 standards [71]. The flooring in the laboratories in E4 were found for the most part not to be chemically resistant so that multiple stains have resulted over time. Also, the material used for the lab furniture did not promise a long lifetime. Some of the more common furniture materials are plastic laminate, metal, polypropylene, wood, phenolic resin, and stainless steel [72]. Plastic laminate for lab-bench countertops is attractive because of its low-cost, but it has a short life span [72], and often it is not durable enough to withstand puncture of the material by falling equipment. The material for lab under-bench cupboards is equally important. Initial money saving may lead to numerous repairs and replacements of materials. This especially includes door hinges if chemicals are being stored in the under benches.

3.2 Health and Safety Policy at the UAEU – Set-up of a Health and Safety Management System and University HSE Policy Statement – Historical Overview

In the summer of 2013, an inter-faculty working group was initiated under the auspices of Ms. Klaitham Fares Aldhaheri and Eng. Ali Ahmed (both CDD) with the aim of formulating an overarching health and safety statement for the UAEU. The group members were Prof. Dr. Basel Alsayyed Ahmad (College of Engineering), Mr. Ali Chovuakarran Cheriya Orkkatteri (Health and Safety officer of the Medical College, UAEU at Towwam) and Prof. Dr. Thies Thiemann (College of Science). The working group met a couple of times in the summer of 2013 and drafted a general health and safety statement for the university (Appendix 1). Statements regarding health and safety policies concerning the chemistry laboratories, the biological laboratories, the operation of mechanical and electrical equipment, the use of the sports grounds both in Maqam and the Islamic Institute, operations on the university farm in Al-Foah, field trips (eg., by the department of geology), transport/travel by students and faculty still needed to be written as also the health and safety policies regarding the hostels, which the working group did not have enough information on and no access to (at least to the “female” hostels). Another issue that the working group had difficulty to address was the issue of liability insurance. This can be seen in a larger context, but it can also be viewed at the lab level, where in most countries a person may not start lab work before taking out an insurance policy. Before any of these missing statements were formulated, the working group was disbanded in late September 2013. Later, the general health and safety policy that had been formulated was used in altered form as the general statement on health and policy of the College of Science.

What can be seen in the Organizational Chart of the Health and Safety management and reporting structure at the university level (Organogram) is that the creation of a university health and safety committee was suggested, which would report to the Secretary General at the university level. This mimicked the health and safety working inter-collegial working group in the first years of the new campus occupancy. This structure was never adopted at the university. At the college level a health and safety working committee was suggested on the basis of an existing structure. This structure continues to exist, where at the College of Science it is called the Occupational Health and Safety Committee (2018). In the summer of 2013, the university working group also recommended hiring two full-time health and safety engineers (one for chemical safety, one for biological safety) for the three colleges of Engineering, Science and Food and Agriculture).

The UAEU, which was already working with a health and safety consultant, opted later, from 2015 onwards, to work exclusively through the consultant Santia at university level. The Santia consultant advised the university how to ready itself for OHSAS 18001 accreditation. OHSAS 18001 is a British Standard for occupational health and safety (see above). On September 15th, 2015, the UAEU published a statement of health and safety policy, with the responsible office being the VC for Finance and Administrative Affairs (the Secretary General). In March 2016, the university published an OHSAS 18001: 2007 OCCUPATIONAL HEALTH & SAFETY MANAGEMENT CONTROL MANUAL (HSGEN-01-10-00020-1) which was prepared by an employee of Santia consultant.

3.3 Health and Safety Organizational Structure

The organizational structure of the health and safety management system of the UAEU is modeled after a system that many US American universities follow, namely through the Facilities Management Development (FMD, formerly CDD), specifically through its Health and Safety Division (FMDHS), which is overseen by the Secretary General of the university (as VC for Finance and Administrative Affairs). The organizational chart is shown in Appendix 2. In ref. 73, it says: EHS programs in academia often report through the administrative support structures that include direct reporting to facilities, finance, risk management, or business administration lines [73]. However, the same reference also comments that such a management structure is not without its risks: The contribution of research administration to an institution’s safety culture in academic laboratories is also influenced by a reporting structure that may dilute accountability for safety. In many academic research organizations, the research, development, and compliance programs report to the head of the research organization, while the institutional safety programs, including laboratory safety, report through a different branch of the organization, often through the facilities or financial administration structures. This can lead to a lack of accountability among the safety line management, the facilities management, the academic and research management, and the faculty-led research programs within the laboratories themselves. This bifurcation of organizational reporting can also affect the promotion and furtherance of a safety culture throughout the whole organization. Organizational structure and reporting of the safety support programs need to be in alignment with academic purposes and objectives to provide the most appropriate organizational alignment for a sustainable laboratory safety culture [73].

3.4 Health and Safety Guidelines for the E-shared Laboratories

In mid-May 2011, the Campus Development Department (CDD, now renamed as Facility Development Management [FMD]) and Khadamat (as operator of the new campus in Maqam) jointly published general safety guidelines (Appendix 3). In mid-October 2018, with the end of this thesis, health and safety rules were distributed from the FMD – HS (health and safety division) to students.

3.5 Radioactive Materials, Radiation Sources and Nuclear Material

The department of physics has small amounts of radioactive and nuclear material. In January 2015, it became evident that licenses to handle radioactive materials were running out. Thereupon, the college of science decided to apply separately for licenses to handle radioactive materials and to handle nuclear materials.

The regulations that apply for storage and handling of such materials are the Federal Law Decree No. 9 of 2009, concerning the peaceful uses of nuclear energy and the regulation for the system of accounting for and control of nuclear material and application of additional protocol FANR-REG-10. A radiation protection officer was designated by the college. The radiation protection officer is a nuclear physicist who received additional training to manage the NMA&C system. The materials are stored in E4-0032, a room designated exclusively for the storage of these materials. All materials are shielded by lead screens. Most of the samples comprise only very small amounts of material, where thorium samples (Th-232) are the most significant item in the inventory. The site is visited periodically by the Department of Safeguards of the Federal Authority for Nuclear Regulation (FANR), where the UAEU is deemed to be a LOF (location outside facility). A typical such inspection was on April 18th, 2018, which was categorized a routine inspection. Here, a verification of the accounting and operating records was made and a review of nuclear material accountancy & control (NMAC) and physical inventory taking (PIT) procedures implementation was carried out. Thereafter, a physical verification of the nuclear material was undertaken. In this case, there were no findings. Over the last 2 years, a number of modifications were undertaken to be in agreement with the regulations set by FANR. Most of these were of administrative nature, especially in regard to record keeping, PIT and reporting the findings to FANR. Furthermore, most of the radioactive sources are now under lock in a cabinet within the locked storage facility. As of January, 2019, the College of Science has applied for a renewal of both the license to hold and operate with radioactive substances as well as to hold and operate with nuclear substances. A refresher training will need to be given to the radiation protection officer.

In April and in December 2018, the UAEU was also visited by an IAEA (International Atomic Energy Agency) inspection team, accompanied by a FANR safeguard team. The second visit was to ascertain that no undeclared research with nuclear materials was going on at the UAEU. Both inspections revealed no irregularities with the site. The site is also visited periodically by the Radiation Safety Department of FANR with the last visit in September 2018. For the future use of the site, the installation of a camera to monitor the only access to the room, which is from the courtyard between buildings E4/E5, is deemed necessary. The camera has been ordered. Also, the UAEU will have to come up with a (long-term) plan for the devolvement of those samples that are not used for educational or research purposes (this involves almost all samples except for the Th-232 samples). This will not be easy as there exists no routine pathway to remove nuclear materials from the site in the UAE, especially if they are to be moved to another country for final waste storage. In addition, many of the sources are old and some are missing complete documentation, where some of original suppliers of the sources are no longer in that business.

3.6 Chemical Inventory and Storage of Chemicals in the E-shared Laboratories

As a requirement of the Civil Defense Abu Dhabi, a chemical inventory was established for each laboratory in the E-Series in 2011 (end)/2012 (beginning). The inventory used NFPA classification (NFPA diamond – classification 0-4) to categorize the chemicals as to their hazard. In the E4-shared labs of the department of chemistry two other inventories were carried out, one in the summer of 2015 and one in the summer of 2018. The inventory is in excel format. We studied the change of the chemical inventory of the laboratory E4-2005. The chemical inventory taken in September 2015 showed 498 entries, with 200 different compounds. A further chemical inventory was taken in July 2018. It showed only 399 entries with 239 compounds. Thus, while there was a higher diversity in 2018, there was an overall reduction of 99 entries over the year 2015. However, of the exact entries listed in 2015, 274 (55%) were no longer listed in 2018. This also means that 175 new entries appeared in the time period 2015-2018, which were still listed in 2018. It follows that 55.6% of the chemicals stored in E4-2005 are in fact chemicals that stem from 2015 and earlier. A further room that was analyzed for the movement of chemicals is the preparation room that services the two General Chemistry educational labs existing in the building. It was found that of the 149 original chemicals stored there in 2015, only 72 chemicals (= 48% of the original chemicals) remained. Added were 35 chemicals. Altogether, the number of chemicals decreased to 107. This significant movement of chemicals (eg., through naturally depleting stock, shifting chemicals to other rooms/labs inside E4, shifting chemicals to other rooms/labs outside E4) necessitates a proper documentation. In the Inorganic Chemistry Educational Laboratory, E4-1005, in 2015 there were 130 separately archived chemicals, in 2019 only 89 chemicals (68.5% of the original number). Additionally, there were five new entries, so that only 84 (64.6%) listed chemicals were also listed 4 years earlier. In instrumental analysis, E4-2017, 133 chemicals were listed in 2015; in 2019, only 109 chemicals were listed (82% of the original number), but there was an appreciable exchange of new for old chemicals. Only 63 chemicals of the original chemicals (47%) remained in stock in 2019. That means overall 1 in 2 chemicals was used up in 4 years or shifted to another location, which may include locations outside of E4 such as to F2 (chemistry research laboratories), but also to other departments such as to geology in E4, engineering in E5-7 and to physics in E3. The above-mentioned physical inventory can track these chemicals; however, an electronic tracking system is better suited to do so.

There are a larger number of electronic inventory systems that have been used for the inventorying of chemical stock. Thus, already in 2002, A. Katritzky et al. had developed a chemical inventory system for the Center for Heterocyclic Compounds at the University of Florida that logged in the various chemicals structurally using barcode technology [74]. One of the most common systems used at US American universities is Chem Tracker [75], which was developed by Stanford University and is now licensed to Bio Raft [76]. Other typical chemical inventory softwares are EMS Chemical Inventory Tracking, Chem Inventory [77] and CLAKS (Chemikalien-Lager-und Kataster-System) [78] a chemical database that can also be used an inventory system and that has been developed by Prof. Dr. VolkmarVill (U. Hamburg) and which has been used by the University of Hamburg since 2003.CLAKS is marketed by LCI-systems [79]. A mobile-based QR Code Tag inventory and tracking [80] using barcode identification, which was developed in Malaysia, tracks the position of all chemicals in the inventory in real time. Within this regard, a smart phone app has been developed at the University Pertahanan Nas Malysia [81].

Because of cost containment, UAEU has not yet acquired an electronic inventory system commercially. Apart from the inventory in excel format, mentioned above, we have now developed a hard-copy inventory of the chemicals in the teaching labs as part of the outcome of this thesis, modeled after a system used at Kyushu University, Fukuoka, Japan, where each chemical item (= each container) has its entry on a separate sheet with space for entering each retrieval and use of the chemical (date, amount, user, reason of use).

Looking at the management system of chemicals at university level, it can be seen that there is a lot of redundancy in chemicals over different laboratories in one college and over different colleges. Only recently, has the university through the Facilities Management and Development department at the university with the help of Khadamat been able to transfer chemicals from out-lying campuses that were partially in disuse to the main campus at Maqam. That there is a redundancy in the chemicals has a historical context as the university had acquired a general list of chemicals as basic stock for all colleges in the last decades of the 20th century. While some of these stocks are now expired, it was difficult for the university to move out these chemicals as chemical wastes. The other reason why redundant chemical stocks are kept is because of the relative difficulty of purchasing new chemicals in a timely manner. Previously, there had been meetings between the chemical supplier Sigma-Aldrich (now Merck)/ Labco (local agent) regarding a "collaboration", the last meeting being in April 2016. It was discussed whether it were possible to store chemicals externally in warehouses provided by the agent to lessen the amount/number of chemicals at university laboratories. This could mean that the UAEU would promise to take annually a certain, specified amount of each needed chemical off the hand of the agent. NYU Abu Dhabi, as mentioned by John O'Connor, is facing the same problem and has discussed the resolution of this problem with the agent in the same manner. Momentarily, the agent has been unable to provide even basic chemicals such as the solvents dichloromethane and diethyl ether, that were ordered, in a timely manner, as the agent has no more stocks of these in the UAE and importing them needs two months and more. This affects the running of the teaching laboratories.

At university level, there has been established a working group on the use of hazardous materials, located within the university ethics committee. This group is momentarily headed by Prof. Dr. Thies Thiemann, where it is planned that an online chemical tracking system to inventorize all chemicals within the university will be set up in the very near future.

3.7 Shifting to Safer Chemicals – Sorting out Materials of Exceptional Hazard

The significant annual change in chemical inventory (see above) notwithstanding, many of the chemicals in the stockrooms of the department of chemistry (and for that matter, throughout many laboratories of the UAEU) are older than 20 years and would normally be deemed expired. The cost and difficulty of waste elimination (see below) and the cost of acquiring new chemicals has led to the retaining of old stocks. Nevertheless, different reasons speak for the shifting to safer chemicals in the teaching laboratories [82]: the evident reduction of risk in the teaching laboratory, the easier disposal of wastes after completion of the experiments, and the use of newer methodology, which often goes hand-in-hand with the development of less hazardous chemicals. A negative aspect may be seen in those countries where chemistry graduates are expected to work with very hazardous chemicals in companies and are expected to be trained at the university to handle very toxic or dangerous chemicals. Thus, in 2015 an intense discussion developed in Germany whether experiments with elemental bromine should continue to be conducted in high schools [83]. Although accidents with bromine have happened in German schools leading to injuries among students, the proponents of keeping experiments with bromine in the curriculum maintain that students need to be proficient in handling chemicals, even dangerous ones [72]. In Japanese universities, mercury salts could only be kept in university laboratories under special exemption. A quick look (on Oct. 13th, 2018) at the current chemical inventory of the chemistry teaching laboratories in E4 show 2 bottles of mercury metal and 14 bottles of various mercury(I) and mercury(II) salts.

Also, 13 bottles carrying cadmium salts were found (Oct. 13th, 2018). Nevertheless, there is an effort to phase out the very toxic chemicals replacing them with less toxic chemicals in the experiments, and the chemistry department has started to include green experiments in the laboratory syllabi. Thus, the manual of the course “Organic Chemistry Lab II” now includes an electrophilic bromination of acetanilide, under the circumvention of bromine, using potassium bromide (KBr) with an oxidant (cerium ammonium nitrate [CAN]) (Experiment 9). Also, in the course, a solventless Biginelli reaction is introduced to prepare dihydropyrimidinones (Experiment 10). Nevertheless, a few chemicals that are deemed to be hazardousremain the chemicals of choice for the instructors. Such an example is ethidium bromide, which is used as a fluorescent tag for agarose gel electrophoresis in biochemistry teaching laboratories. SYBR green (SYBR safe) has been proposed as a substitute nucleic acid gel stain. Virtually all intercalating dyes pose some danger. For the instructors, sometimes the relative benefit in health and safety weighs less than the superior other characteristics of the chemical under discussion. Instructors continue using ethidium bromide because of its better visibility in developed electrophoresis plates as compared to other dyes [84].

3.8 Waste Collection and Waste Streams

Khadamat is responsible to collect all non-hazardous wastes. Non-hazardous wastes are collected on a daily basis. The hazardous waste is collected by Khadamat according to the request of the end-user and stored in a room on the ground floor of E6. From there, it is picked up periodically by the waste contractor (momentarily Bridges Environmental Services LLC [85]). The room in E6 is not specifically designed to hold chemicals and while there is a separation of flammable solid and liquid wastes from non-flammable solid and liquid wastes, all of the hazardous chemical wastes are stored in one room. Liquid chemical wastes are picked up either in glass bottles or in plastic containers. They are transported from the end-user laboratory to the storage room in E6 by electric cart.

Non-liquid waste collection in the laboratories is done by depositing the waste in one of the following waste containers: a bin for broken glass, a bin for biological material and a bin for solid chemical waste or solid waste contaminated with chemicals. The bins can be distinguished from each other by their different color and size.

Before biological wastes are placed into the bins, they are autoclaved. Autoclaves exist in E3, E4 and E6. As mentioned above, UAEU Maqam campus currently operates no lab with higher biosafety than L-1. None of the working groups or educational laboratories work with pathogens or infectious substances. Any new research work in that regard would have to pass through the ethical committee, ie., through the hazardous materials committee, where work needing a higher biosafety classification would be disallowed to be carried out on Maqam campus. Biological wastes are taken by medical waste contractors with Khadamat being the mediator.

Additionally, there are bins for used paper and PET (polyethylene terephthalate) bottles. These two are given to recycling [86].

It can be seen easily that the waste separation is not followed as conscientiously as it should be, where the laboratory specialists (laboratory technicians) have said that students continuously mix wastes that should be separated. That this is a more universal problem was indicated by Rudmann et al. [87] who showed in a national survey of US student laboratories (in medical technology) that “chemical wastes are not [always] safely discarded to minimize harmful environmental impact” [88]. In the last two years, seminars on “Health and Safety” have been held for undergraduate students, where the necessity of waste separation was stressed and waste separation was demonstrated during the talk (by Ms. Leina Sweihan, Khadamat). Due to the fact that the attendance of the workshop has not been made mandatory (see below), little betterment from the side of the students has been seen in a diligent waste separation over the last years. Lab coats are a “must” for students to enter the laboratories. Interestingly, students ask to wear gloves for protection, but forget to don safety goggles or take these off once they are working in the laboratory. This may be explained in that students are afraid that chemicals come directly (physically) in contact with them. What is not seen is that chemicals enter the body as readily through the vitreous fluid of the eyes [89] as through the skin.

3.9 Safety Induction

A safety session is given for the students each semester for every chemistry lab course. This represents the first lab unit in each lab course. Oftentimes, the laboratory instructor gives a safety quiz to the students. The course “Professional and Transferable Skills” includes a 3-hour lecture (1 hour per week) on chemical safety and security, ending with a written examination. The Coordinator of the Occupational Health and Safety Committee, a chemical safety officer of the chemistry department and the waste manager of Khadamat gives a health and safety seminar every year. The attendance of the seminar has not yet been made mandatory. 65 students attended the last seminar (in Sept. 2018) Other universities such as the NYU Abu Dhabi possess on-line health and safety sessions for their faculty, staff and students with a mandatory health and safety test online before access to the laboratories is granted. UAEU has not yet developed such an electronic infrastructure, but may need to do this in the very near future. Recently, it has been under discussion in the College of Graduate Studies and with members of the university committee of hazardous chemicals.

3.10 Risk Assessment and Audit

Every unit of the university has been given UAEU forms to utilize for a periodic risk assessment of the laboratories and other spaces. Additional forms have been given for internal accident reporting, and for risk and hazard assessment of any new purchased items. Risk assessment of the laboratories is being carried out on a yearly basis. In the case of accident forms and purchase forms, oftentimes the old forms, preceding the OHSAS accreditation of the university, are still being used. As the university undergoes a periodic external audit in regard to OHSAS 18000 series accreditation, the department and college as university units are centrally involved to provide evidence for the following: OHSAS committee meeting minutes of the college committee, risk assessments carried out periodically, accident reporting, evidence of training, and evidence of continual improvement. Over the last year, only two accident report forms had to be filled out within the E4 labs. Both were minor incidents involving female students. Here, in fact the new accident report forms were used. Copies of the accident report forms were given to the Dean’s office. As the university FMDHS unit has put a focus on licensed first aid training for the staff and faculty members, 10-15% of staff members as well as instructors working in the E4 building were trained in first aid. Evidence for continual improvement is harder to come by. Importantly, financial investment in matters health and safety at the department and college level should be increased in order to ascertain a continual improvement in OHSAS.

In regard to the risk assessment forms, they present a matrix of accident severity by accident likelihood/frequency. The underlying purposes of assessing risks in this way are to make the occupants/users of the spaces (eg., labs) aware of the risks and to find ways to mitigate the risks. Mitigating the risks needs a detailed funded action plan that would need to be put in place [71].

Chapter 4: Waste Management in Educational Laboratories

Waste is usually defined as residing of materials that are no more can be used and which are afterward disposed. Types of waste are different from country to country and might be classified as solid, liquid and gaseous wastes; hazardous and nonhazardous wastes or as commercial, industrial, residential or institutional wastes [90]. Based on the statistics of the World Bank, in 2016, cities in the world produced 2.01 billion tonnes of solid waste, amounting to a footprint of 0.74 kilograms per person per day. Also, the annual waste generation is expected to increase by 70% from 2016 levels to 3.40 billion tonnes in 2050 due to the rapid increase in population growth and urbanization [91]. Therefore, it is necessary that this waste is carefully controlled. Usually, waste management has been the responsibility of the government. Nevertheless, with the rising rate of solid waste generation, awareness and regulations for recycling, recovery and reduction, many organizations have got to participate into one or more features of solid waste management chain [90].

Types of services, which several institutional waste managers offer could be classified into two comprehensive areas: direct waste management services and support services. The direct waste management related services mainly deal with the providing of services for diverse stages of the waste management chain, specifically collection, transportation, pre-treatment, recycling/recovery and disposal. In the other area, which is the support service type, it deals with the providing of services, which indirectly improve the efficiency, and effectiveness of waste management and it covers awareness formation, providing of information, technical expertise along with financing [92].

To the extent that waste management practices are concerned, the main global practices comprise source reduction, product reuse, product recycling, waste accumulation, waste composting, waste incineration along with landfilling /dumping. Each of the waste management procedures poses challenges except the source reduction, which is the ideal method. For example, waste incineration is costly and causes the air pollution along with the greenhouse gas emissions. Also, there is the challenge of disposing of ash. Besides, landfills need land and it should be far away from potential neighboring populations. Waste collection vehicles cause an air pollution [90].

Nowadays, educational laboratories in the world are generating both toxic and nontoxic waste at a high rate [90]. Waste management is one of the most significant environmental features to be studied in the educational institutions. To set up a specific integrated waste management system is one of the extreme challenges for higher educational institutes along with the pre-university educational schools. The existence of waste educational projects and programs helps the development of the awareness and knowledge regarding recycling and municipal waste. Reliable and accessible recycling infrastructure should be in place and must deliver proper information on what is and what is not recyclable [93].

Furthermore, the environmental impact of chemical waste produced by teaching and research is a topic that has been of great concern and discussion for at least two decades. Therefore, there is an extensive need to apply a practice for the handling of chemical waste in educational institutions, which, in mainly laboratory and non-laboratory activities, play a role in the production of small quantities of waste, compared with other organizations, but with most of the waste being extremely toxic.

Certain of this toxic chemical waste is listed by governmental agencies who are worried about the quality of the environment. Examples comprise the disposal of toxic acids, solvents, metals, and chemical and product mixtures, whose toxicity is frequently unidentified. Additionally, it is notable that the composition of waste from research labs always varies depending on each project [94, 95].

As a good practice, one of the Mexican universities established a hazardous waste classification program in 1994. Later, in 2003, a new inclusive program for hazardous waste management was developed to offer an efficient program of collection and classification of hazardous waste produced in laboratories, for the reason of limiting and reducing the quantity of hazardous waste generated in the laboratories. The classification of hazardous waste by type has been beneficial and was rapidly accepted by the student society along with the academic and non-academic staff. Also, the major quantities of produced hazardous waste included liquid acid waste and toxic inorganic materials with corrosive features. The largest amounts of produced solid hazardous waste were fragments of glass saturated with toxic hazardous substances [96].

Numerous studies have been conducted regarding the waste management in educational institutions. For example, a study has conducted an initial assessment of waste management procedures in eleven laboratories of six educational and research institutions in Dar es Salaam, Tanzania. Surveys were given to 52 laboratory employees to measure their awareness of health and environmental hazards of chemical waste and the waste management procedures. Also, a chemical analysis was conducted to define the nature, quantity and composition of waste and then to evaluate the associated risk of environmental contamination and human exposure. The study showed that liquid waste produced by the inspected laboratories has been frequently acidic in nature and contaminated by elements such as copper, chromium and lead, in some cases exceeding the acceptable limits. In general, inadequate waste handling practices were noted in terms of unlabeled waste containers, absence of proper collection plan, inappropriate means of disposal that comprised direct release into the drainage system and open dumping along with the lack of proper records of the waste quantities. The outcomes of this study-increased awareness of the risks related to the chemical waste from this possible source and called for appropriate management of chemical waste, mainly to laboratory scientists and strategy makers. Also, it might have inspired a new generation of environmentally aware researchers [97].

4.1 Waste Management in UAE

Efforts in waste management in the UAE comprise transforming waste to energy, handling wastewater and monitoring the movement of hazardous waste. The same as in all the world’s countries, the quantities of wastes in the UAE have increased in the last decade, because of the population growth and increased economic activities. The majority of the waste ends up in municipal landfills or dumpsites, where organic waste produces a huge quantity of methane, a strong greenhouse gas. Presently, little of the waste is burnt, but the rate of municipal waste recycling has been rising rapidly. Waste management in the country is managed over local authorities. In general, waste matters are controlled through recycling and transforming waste to energy and resources, new techniques and developed waste separation and collection methods [98]. Nevertheless, much of the toxic chemical waste is exported to other countries, including to Europe, which makes the disposal of especially this type of waste expensive.

The UAE Federal Law No. 24 of 1999 on the Protection and Development of the Environment in Article 59 prohibits the “Disposal of hazardous wastes and medical wastes shall be undertaken in accordance with the conditions and criteria specified by the Executive Order. It is prohibited to establish any facilities for the treatment of hazardous wastes without a license issued by the competent Authorities” [99].

4.2 Waste Containment and Recycling in the Laboratory

Laboratory work is an integral part of a student’s science education [100]. To run laboratories is quite expensive. Apart from acquiring new consumables, the extraction of the wastes, especially chemical wastes, often is prohibitive in cost. One way to address this is to carry out experiments at the micro scale, especially in preparations of materials [101, 102]. This will lead to less wastes (and less costs). Many experiments today are already performed at micro scale level. Nevertheless, in organic chemistry, the two main wastes derived from reactions are solvents and silica gel that are utilized in the separation process. These can only be circumvented when either the products of the reaction can be crystallized selectively or when the products are to be separated by preparative gas chromatography. Students in educational laboratories should learn crystallization techniques, but students should also be exposed to more versatile techniques such as column chromatography. Preparative gas chromatography can be very time-consuming, and will be difficult to perform when the laboratory unit is time-limited. This would mean that one would need to continue using preparative column chromatography for the separation of chemical product mixtures. This can be done, if one resorts to the recycling of silica gel and of solvents used.

Another waste issue that needs to be addressed is the disposal of aqueous solutions of metals and of organic dyes. Often, these solutions are accumulating in large quantities, and if not dealt with quickly, tend to be stored as mixtures as further solutions that need to be discarded off are mixed into the older solutions. The mixtures will need to analyzed by an outside laboratory as to their composition which is inhibitedly expensive. Therefore, it is important to get rid of non-mixed aq. solutions as quickly as possible. Metal from metal containing solutions can be adsorbed by different sorbents such as carbon derived from plant or agricultural wastes. To make use of this technique, one would have to desorb the metal, albeit then with a smaller volume of solvent, to be able to recycle the sorbent. Otherwise one would go from a metal contaminated solution of a relatively large volume to a contaminated sorbent of less volume (the sorbent) that one would have to declare as hazardous chemical waste. The desorption is time-consuming, although it has been carried out in our group using activated carbon derived from date palm leaves as sorbent for lead containing aq. solutions [103]. The sorption of dyes on bio wastes such as on activated carbon derived either from date palm leaves [104, 105] or from Jujube fruit kernels [106] leads to a material that would either have to be re-activated by combusting the adsorbed dye in an oven and thus reactivating the carbon or would have to be added to a landfill as hazardous chemical waste. This would lead to the burn-off of an appreciable amount of carbon as well. This recycling can only be carried out a few times as the amount of carbon grows to be less after every recycling and ash content of the material becomes dominant. The way out seems to be using silica gel which is to be recycled anyway (see above) as sorbent. If it withstands the recycling at the temperature needed to burn off the adsorbed organic materials derived from the reactions as well as the solvent used in separation, then it would be able to withstand the temperatures needed to burn off the adsorbed dyes.

Therefore, in this study (study 2) we have focused on 2 items: a.) the recycling of silica gel used in separations of organic products; b.) the recycling of solvents.

Chapter 5: Study 1- The Spatial Analysis of Buildings in Relation to Fire Drills in E4-Shared Laboratories, with Special Reference to Emergency Escape Routes and in Regard to Flow of Persons through the E4-shared Laboratories towards the Male Side of the Campus Leading to other E-series Buildings, F1, F2 and the Exit to the Men's Parking

5.1 Configuration of Space and its Relation to the Evacuation Plan

Understanding the way in which walkers go around their environment is significant for evacuation planning. Two main methods have been established to address the matter of pedestrian movement analysis, modeling and simulation. These are described as, first, the 'configurational analysis' that includes approaches based on representing and measuring features of the spatial configuration or morphology of the environment within which movement takes place, and, second, the 'pedestrian simulation' that covers approaches that pursue to demonstrate the individual pedestrian or the pedestrian population. The first type of methods concentrates on the physical environment, while the second one considers human behavioral matters in which micro-simulations at the level of the building are constructed for fire evacuation and crowding situations. These behavioral methods define the 'route choice behavior' based on fixed pairs of origin-destination for agents, in which perfect paths to the endpoint are usually selected therefore representing a 'programmed movement' [107].

Furthermore, it is significant to consider that movements in case of evacuation are directed by specific evacuation principles, among which the escape route in corresponding floors has a fundamental influence. In general, escape routes, posted as part of the Evacuation Plan, should be the shortest paths. Over and above the inherent morphological features, escape routes regularly follow some special morphological indications such as the location and the number of exits in relation to the layout of the equipments and the configuration of corridors. Generally, recognition of shortest paths will provide an idea of possible movement trails through evacuation in shortest time. On the other hand, the best evacuation trail must correspond with the path of natural movement; the primary corridors, therefore, occupants will never fail to see. In case of significant differences amongst these two kinds of movement, spatial planning would require significant rearrangements [108].

Along with firefighting measures and fire drills, the ‘Spatial Layout’ of a building, particularly its morphology has an important part to confirm the efficiency of fire drills. The Spatial Layout shows the arrangement of fixed building elements such as stairs, aisles, partitions and exit doors along with movable elements, such as machines, equipment, furniture, fixtures and others on the floor plan of the building. As the spatial grid is a producer of movement, the spatial layout of the laboratory building has an important influence on directing all types of movement of the occupants. It is identified that an appropriate spatial layout might assist the process of a fire drill to be more effective, thus, will decrease the vulnerability in a fire incidence [107].

Generally, in computer software packages, such as EVACNET, PEDFLOW, Space-Sensor, MASSE-gress, STEPS, etc., configurational morphological matters are less measured which, certainly, has a huge influence on path choice and evacuation. On the other hand, ‘Space Syntax’ analysis is the top among the configurational methods, which attempts to clarify the configurational properties in explaining the movement patterns [108].

The Space Syntax method was developed in the past three decades by Bill Hillier and his colleagues at the University College London, and it has been applied to the spatial studies of urban spaces and buildings. This method relies on determining configurative spatial relationships of built environments' public spaces and internal spaces in buildings. According to Hillier, Space Syntax is a method for representing spaces and analyzing the networks of space created in the buildings. He added that it is a family of techniques for monitoring how these networks of spaces link to functional patterns, for example, movement, area differentiation, use, and social well-being and malaise. Thus, space syntax has made it probable to create a group of theories about how spatial networks associate generally to the economic, social, and cognitive aspects, which shape them and are influenced by them [109, 110].

The main objective of this analysis is to study the spatial layout of the current E4 shared laboratories building, and to assess the escape routes hanged (as hang-outs) as part of the existing Fire Safety and Evacuation Plans of the building. By comparing the spatial character of the building and its related behavioral aspects, this research will plan the guidelines to (re)define the applicable escape routes.

5.2 Spatial Analysis

Spatial layout generates the open space structure within which the occupants move during evacuation. The arrangement of the building's internal spaces, therefore, has a huge influence on the evacuation process. Consequently, the spatial layouts of the building were analyzed in this research to have an objective idea of the spatial configuration within the building. The Space Syntax method has been implemented here by using DepthmapX software. The DepthmapX is a computer program that analyzes the geometry of spatial configuration within the building. Two kinds of analysis, Axial Analysis & Visual Graph Analysis [VGA], were implemented here to recognize the inherent morphological character of the building's spaces. Also, Agent

Based Simulation was applied to expect the design of movement throughout a fire evacuation scenario [107].

5.3 Axial Analysis

Axial analysis is one of the basic components of Space Syntax. It is an abstraction of the space among rooms and corridors of a building to straight lines drawn throughout it, based on a formal algorithm. Axial lines are described as the longest visibility lines for demonstrating individual linear spaces in buildings. In axial analysis, the value of ‘Integration’ [R=n] of an axial map explains the average depth of each space to all other spaces in the spatial network (a floor of a building). It is a normalized measure of distance from any space of source to all other spaces in the spatial network. Generally, it computes how near a specific space is to all other spaces, and can be observed as the measure of comparative asymmetry or relative depth, two measures within the DepthmapX software [108, 111, 112].

5.4 Visibility Graph Analysis (VGA)

Visibility Graph Analysis is an innovative method of quantifying the spatial structure of buildings. Visibility graphs were first applied by Braaksma in an analysis of airports to recognize the visual and spatial relationship between a variety of facilities that a traveler must find. Visibility graphs, study the range to which any point in a spatial network is observable from any other one. Wherever points are not directly visible, graph measures of a matrix of points can be computed to check how many intervening points are required for one point to see the others [113, 114]. Actually, both the Axial Analysis and the VGA produce integration maps following a similar concept. However, in the Axial Analysis, lines of sight are demonstrated as line drawings where the VGA shows the space as ‘points of a visual field’ in relation to the whole system. DepthmapX software is a good tool commonly used to produce an integration map in the VGA for the escape route. Such an integration map is demonstrated by a color range from red to blue, where the most integrated spaces are shown with a hotter color like red and yellow, and the less associated or separated spaces are represented with a cooler color such as green and blue [108].

5.5 Agent-Based Simulation

To realize the influences of spatial configuration on movement pattern, the agent-based simulation was used. In the agent-based analysis, virtual ‘people’, called agents, are released into the spatial network, where they decide where to go within the network. The agents require a visibility graph to have an idea of the spatial environment. The agent-based simulation, as applied in the DepthmapX program, is based on Turner’s concept of ‘Embodied Space’,in which he described the natural visual interaction between the individual and the spatial environment. It is argued that the agent model is instrumented to obtain a good understanding of the cognitive basis of natural movement and describing navigation and way finding [115].

In the simulation, agents are usually distributed from entry points and permitted to move in the given spatial network. Once analyzing a space’s forward type of vision, the system will display a map representing the paths of movement by agents and their favored choice of path. The movement routes are characterized by colors ranging from red to blue, where the most favored paths are characterized by a hotter color like red and yellow and the less chosen ones are characterized with a cooler color like green and blue [108].

In this research, to simulate the evacuation scenario, the exit doors were selected as entry points and agents were allowed to move within the given spatial configuration. Thus, the whole scenario of the evacuation is considered in a reversed manner; while the agents' movement traces and respective gate counts of generated movements were considered as representative of an evacuation scenario. Additionally, the grid was placed at every 0.33 m, as an approximation to a human step size. Each agent had a 'through vision' having a field of view of 15 bins (about a 170 degree field of view) that has proven to be most effective when compared to natural movement patterns in buildings.

5.6 The Case Study

This research has taken the E4 shared laboratories building to study its spatial layouts and evaluate the existing fire safety and the evacuation plans of the building in relation to its spatial morphological properties.

Functional Layout: The Case study looked at the E4 shared laboratories building at the UAEU, which has a ground floor plus two above grade floors. The building design was originally planned to house business occupancies containing university classrooms and instructional laboratories. The building is currently occupied by multiple departments, some of which require research areas and/or the use of hazardous materials [116].

The shared laboratory building is protected by automatic sprinkler systems. The switch rooms do not have sprinkler protection, are protected by the existence of 2-hour fire barriers separating adjacent spaces of the building. Moreover, the server rooms are protected by clean agent suppression systems instead of automatic sprinkler protection. The building is also protected by standpipe systems containing landing valves and occupant use hose reels placed outside each stair. Also, portable fire extinguishers are allocated throughout each floor. The shared laboratories building is entirely protected by detection devices that will spontaneously inform the building occupants in case of the alarm. The activation of an alarm will allow the continued operation of the corridor ventilation system for 180 seconds prior to shutting down the air-handling units (AHUs) and shutting the fire/smoke dampers. Moreover, the fume hoods inside the laboratories will continue operating upon activation of the alarm. This will decrease the risk of smoke accumulating in the main corridors. The fire alarm system will be activated through smoke detectors, duct detectors, heat detectors, manual pull stations, sprinkler water-flow switches or the activation of a clean agent system. The building Fire Alarm Panels are placed in the main entry lobby of each building. Each of these Fire Alarm Panels contains a handset capable of delivering manual instructions to each area of the building. In the Rolf Jensen & Associates, Inc. (RJA) building survey, the magnetic locked exit doors were specified as a main deficiency. A series of fire protection shortages have been also recognized in this report including; sprinkler barriers, the lack of coverage inside gas storage rooms and the sprinkler hazard classifications [116].

Distribution of Students/Staff inside the building: There are around 100 students, instructors and staff, on average, located in the laboratories during semester weeks. However, the numbers can be different on different weekdays and during different times of the day. Because the UAEU has a gender-separated campus, there are 2 weekdays allocated for male students, and 3-week days allocated for female students to use the shared laboratories. This means that Sundays are relatively quiet, while Mondays, Wednesdays and Thursday mornings are very busy (schedule to change). Therefore, the fire drill was repeated twice, once for both genders using the same building.

Figure 7 shows the central corridor on the 2nd floor of building E4, with lab entries branching off, and the central door (orange panel) leading (straight ahead) to the other half of the building and to the central emergency exit (at right).

Also, Figure 8 shows the locked down double door serving as the exit towards the female side of the campus. The exit leads directly to a vestibule that gives access to an elevator and a staircase (2nd floor, E4-building).

Figure 7: Visual of the central corridor on the 2nd floor of building E4

Figure 8: View of a locked down double door (2nd floor, E4-building)

Evacuation Plan: The Fire Safety and Emergency Evacuation Plans (Figure 9) were posted on the walls in the entrance lobby and near the entry doors on each floor. The Evacuation Plan shows the complete instructions of the approved Egress System, plotting the Escape Routes towards the exit doors and representing the location of emergency firefighting equipments.

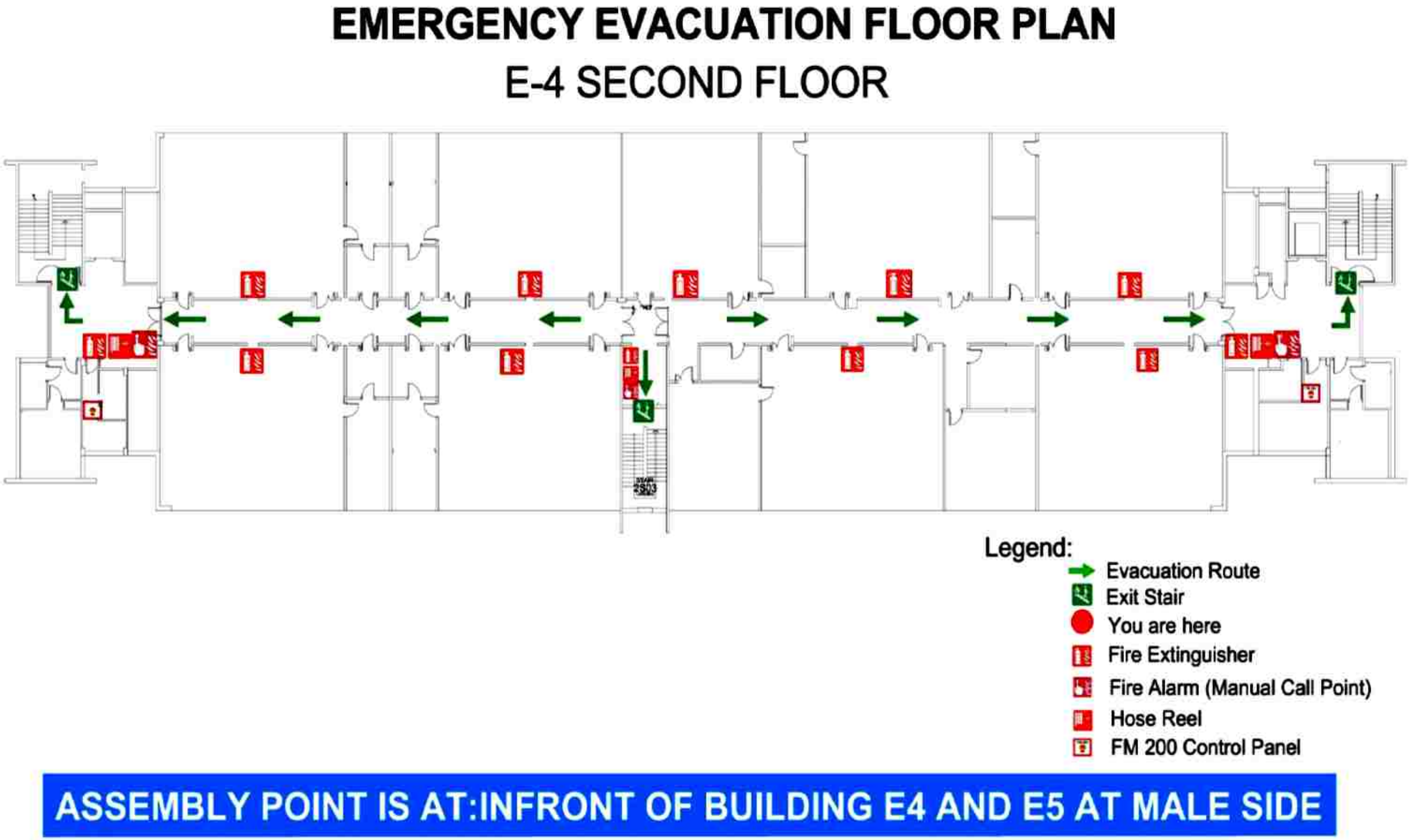

Figure 9: Evacuation plan with escape route posted on the wall

Escape Route: The escape pathway or Emergency Evacuation route is constituted of one evenly spaced corridor inside each floor in the E4 building (Figures 10-12) below and it is connected to three exit stairs as shown in the emergency evacuation floor plan. However, at UAEU as a gender separated campus, the doors on one end of the building are usually being alternately closed for male/female students, so that there are only two exits (stairs), not three, left for the students to use in case of fire. The third exit is kept closed and can only be opened by access cards with authorized personnel only. Still, it is supposed that in case of fire, the closed door will be automatically opened and, thus, the three exits are considered functional in case of an evacuation.

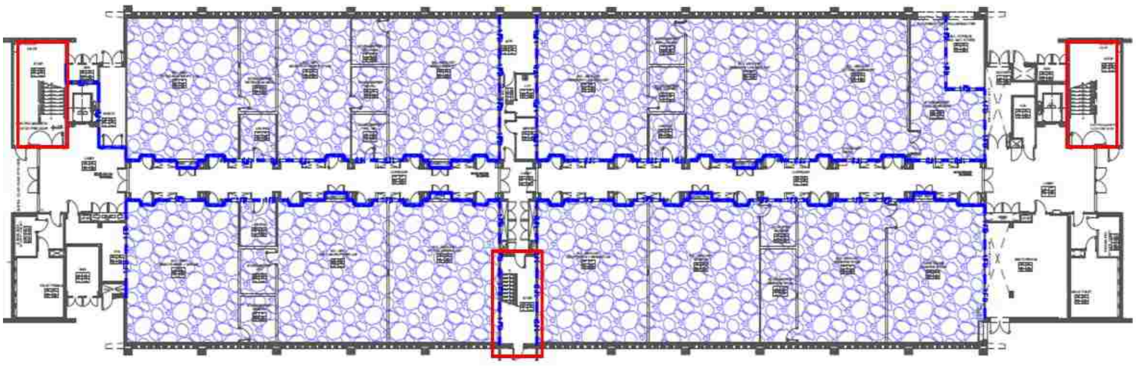

Figure 10: Layout of the ground floor in E4 building

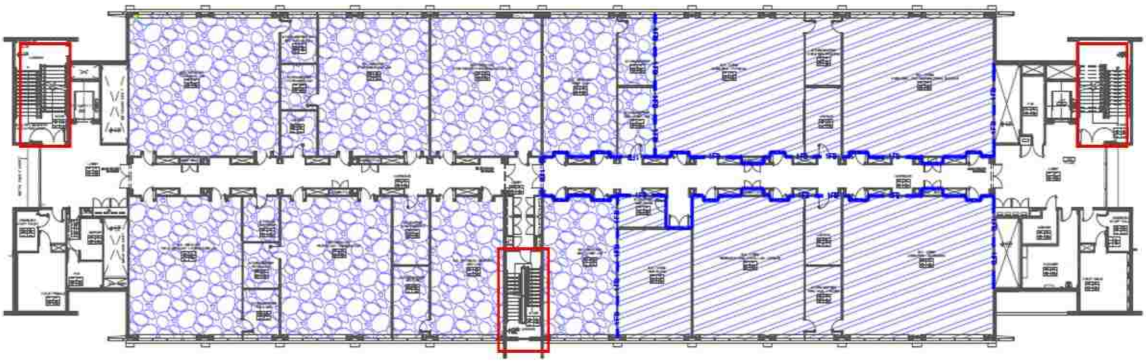

Figure 11: Layout of the first floor in E4 building

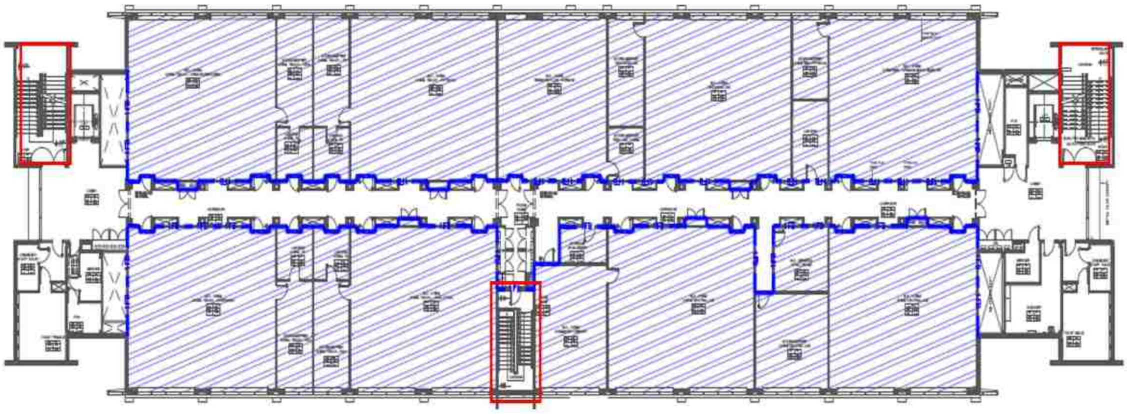

Figure 12: Layout of the second floor in E4 building

Spatial Analysis: The Axial Analysis of the E4 laboratory building spaces gives a general morphological understanding of the floors plans. The All Line Map (Figure 13) consists of axial lines of which 20% integration core [2 high value lines] defined the accessibility pattern of the spaces of each particular floor. As illustrated, the highest integrated line was located on the transverse aisle located at the middle of the floor. Based on the theory of Space Syntax, inference can be illustrated that in case of internal movements from every point to every other point, the students/staff would have picked this lane for internal circulation.

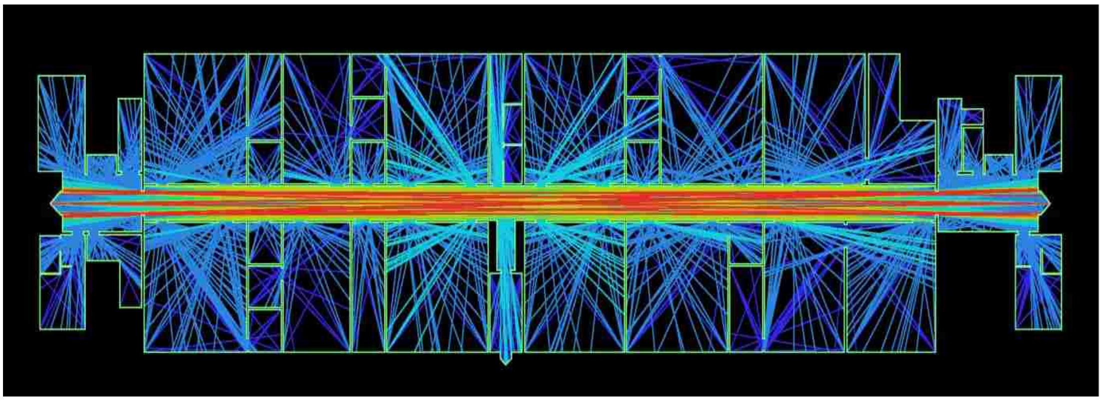

Figure 13: Axial analysis_ integration (R=n) (ground floor)

Furthermore, The Integration pattern in the Visibility Graph Analysis presented that the transverse aisle was is the most ‘integrated’ space. The Integration value decreases significantly close to the exit-doors of the stairs (Figure 14-21.

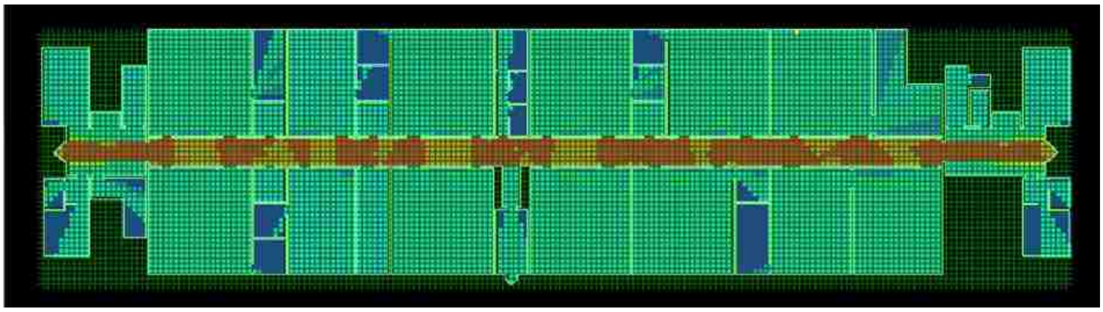

Figure 14: Visual graph analysis_integration (ground floor)

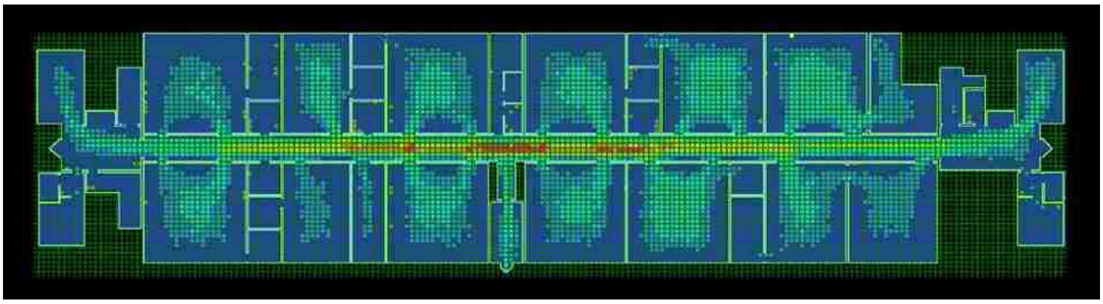

Figure 15: Visual graph analysis_ gate counts (ground floor)

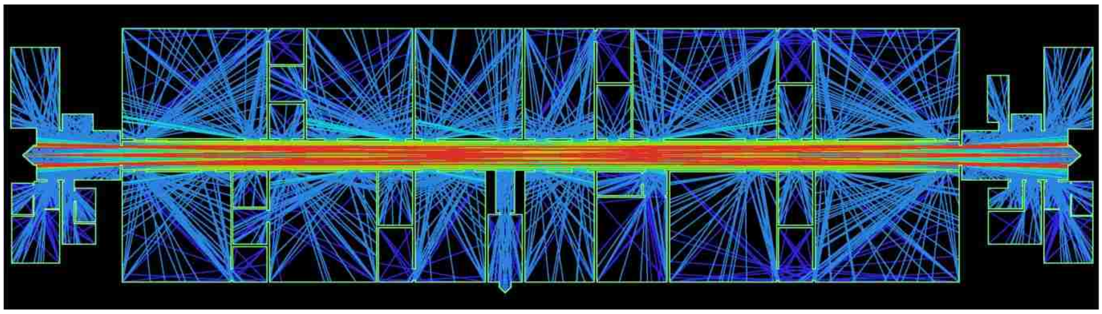

Figure 16: Axial analysis_ integration (R=n) (first floor)

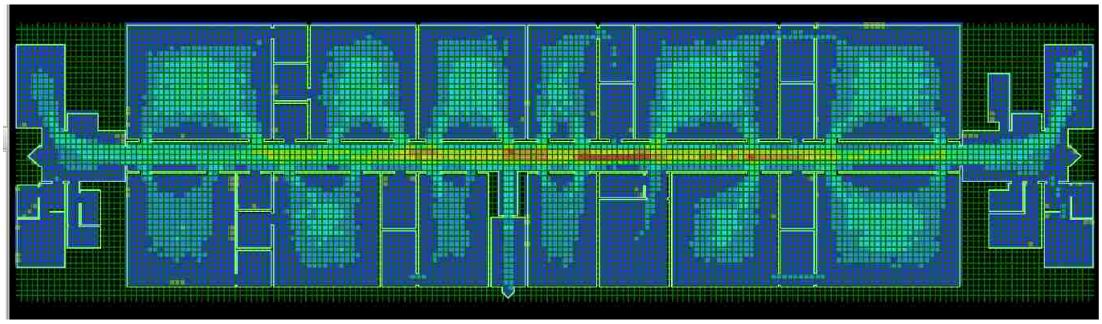

Figure 17: Visual graph analysis_ gate counts (first floor)

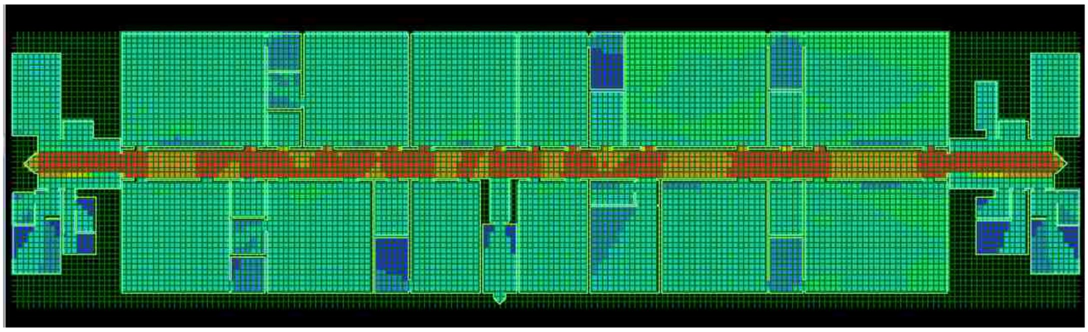

Figure 18: Visual graph analysis_ integration (first floor)

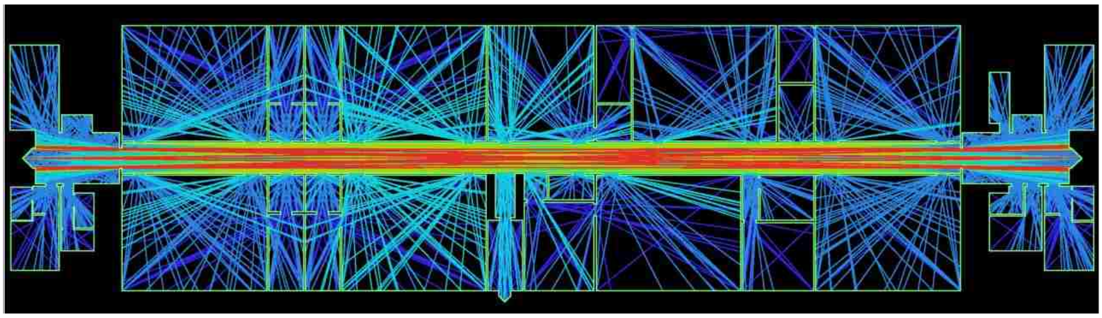

Figure 19: Axial analysis_ integration (R=n) (second floor)

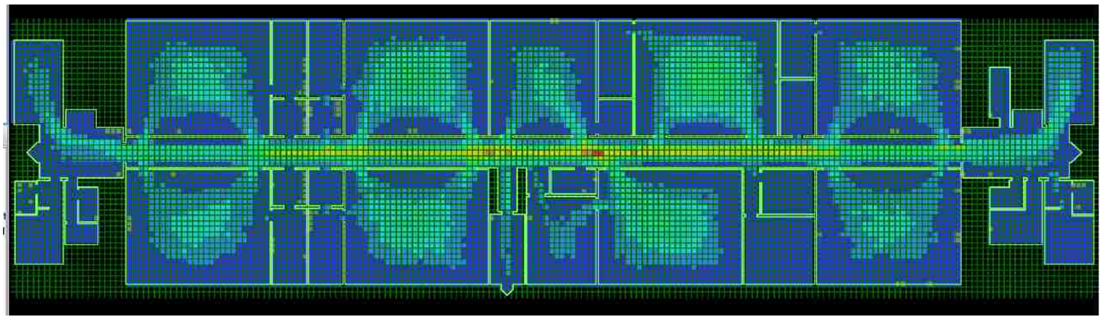

Figure 20: Visual graph analysis_ gate counts (second floor)

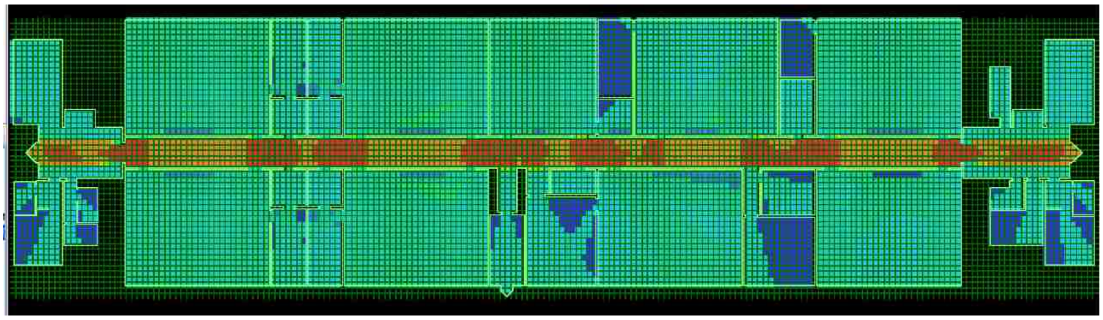

Figure 21: Visual graph analysis_ integration (second floor)

For Agent Based Simulation, agents were released from three exit-doors into the corridor space. The density of distribution of students/staff in different areas, which was uneven in this case, could not be considered in the simulation assumed here. Consequently, simulation outcomes may not correspond to the actual scenario; though it would give some sign of possible favored paths during evacuation based on the spatial layout of the E4 building.

The results of this spatial analysis recognizes the weakness of the three exit doors because of their poor Integration values, in DepthmapX. Although, the transverse primary aisle showed high accessibility having a high level of integration, it has a low accessibility to the three exit doors. In addition, the analysis shows the difference between the side (main) and the middle egress doors on the ground floor, as the main escape for ground floor users, and the escape staircases on the first and second floors as the main means of escape in these upper floors.

On the other hand, a fire drill which was conducted on 8th October 2018 at 10:30 am for female students was observed in this building to represent the behavioral pattern of the students/staff in an objective method to define the underlying relation between the building morphology on the one hand, and the emergency evacuation, on the other hand.

Based on the Emergency Evacuation Drill Report of E4 building for females, which is provided by the Facilities management of the UAE University, there was no mention of the preferable exits as there are two operational exits only and the security officers guided the students/instructors to the assembly point nearest one of the exits (Figures 22 and 23). Personal observation, though, showed that the middle staircase is rarely used during these fire drills. The general evaluation of the drill was not acceptable due to the time taken for complete evacuation of the building.

Figure 22: Exit out of the E4-building (female side)

Figure 23: Assembly point (female side)

In this case study, Evacuation Trails showed that during emergency evacuation, major movement towards the exits would take place along a transverse aisle. However, these trails only represent the natural movement over places based on the configuration of the layout of the circulation aisles and their corresponding relation to the exits specially, the stairs.

Based on both sets of results (space syntax and real drill observation) and the personal observation of the fire drill, it can be concluded that the intermediate escape door and stairs should be more emphasized as the analysis showed the intensive presence in front of it, especially if one of the side end doors for male/female students remains closed during the fire alarm.

Chapter 6: Study 2- Recycling in University Chemical Laboratories in the E4-Building at the United Arab Emirates University

6.1 Recycling of Silica Gel

In organic synthetic chemistry, silica gel is used extensively as the stationary phase in column chromatographic separations of reaction mixtures. Often times, the used silica gel is declared as waste and not re-used. When chemicals remain adsorbed on the silica gel, it needs to be treated as hazardous chemical waste in most countries. Both the waste disposal of spent silica gel and the acquisition of new silica gel is costly, looking at the financial as well as the environmental aspect. There has been an ongoing discussion [117-120] on the usefulness of recycling silica gel as stationary phase material, where oftentimes the recycling suggested consists of eluting and thereby removing adsorbed substances with polar solvents such as with ethyl acetate and methanol, followed by water and drying the silica gel in an oven at 800°C [117] or oxidative treatment, eg., with an aq. solution of $KMnO_4$ and H_2SO_4, with subsequent washings with oxalic acid and deionized water, followed by heat treatment at 120°C [117] or with a treatment of an aq. solution of H_2O_2 and subsequently deionized water, followed by heat treatment at 120°C [117]or by H_2O_2 – solar light [118]. It has been noted that silica gel will lose adsorbed water at its surface already below 150°C and that silanol groups will convert to siloxanes at above 300°C [121-123] and that this may lead to structural instability [120] and thus to a lower separation properties of the heat-treated silica. Also, it has been warned against using such recycled silica gel for the work-up untested reactions in research. Nevertheless, in view of the costs incurred of discarding used silica gel as wastes, the recycling of silica gel in educational and small research laboratories may have to re-addressed. Here, we have studied the possibility of recycling silica gel by simple heating to 600°C in an oven, thereby combusting the organic residues that remain adsorbed to the silica gel at the end of the column chromatographic separation. The current work also looks at the use of multiple recycled silica gel. Typically, after the column chromatography of a reaction mixture over silica gel Merck grade 9385 the solvent loaded silica gel was versed onto a glass filter and air dried with suction, where remaining solvent was collected in a vacuum flask. The dried silica gel was entered into a crucible and pre-heated in a Carbolite electrical oven at 300°C for 30 min.; thereafter, it was heated at 600°C for 2h, which includes a time interval of approx. 35 min. to reach the temperature plateau at 600°C (see heating response curve, Figure 24). After 2 h, the oven is set back to rt, where it takes approximately 35 min. to reach 300°C (see cooling curve, Figure 25). After cooling to rt, the silica gel is sieved through a 180 μm steel mesh. Experiments have also been carried out at lower (500°C and 550°C) temperature and higher temperatures (700°C). Temperatures lower than 600°C did not lead to complete combustion of the carbonaceous material. On the other hand, thermal gravimetric analyses (TGAs) of most of our carbon containing materials have shown that at 600°C samples combusted completely. Therefore, in order to avoid structural changes to the silica gel and to contain energy use, the authors opted for a thermolysis at 600°C instead of at 800°C, a temperature that is often used for the complete ashing of carbon containing materials.

The sieved silica gel is stored in a container and reused only after 3-4 weeks of resting in order to ensure rehydration of the surface of the silica gel. The particles that remain in the sieve and contain sea-sand, if used as a protective layer during the column chromatography, or salts, if the organic reaction mixture has not been extracted with water prior to the chromatography, are collected, sieved through a 425 μm steel mesh, washed with water and dried. The material that remains in the sieve is sea-sand (if used) that is pure enough to re-use in a subsequent column chromatography.

In fact, after the used solid comprising used silica gel, used sea sand and adsorbed organic materials has been heated at 600°C, the used sea sand which has a larger particle size than the used silica gel can be recycled by sieving the silica gel off it using a 180 µm sieve. The sieving is repeated twice. Thereafter, the material left on the sieve which is comprised for the most part of sea sand is sieved through a 425 µm sieve. This will retain some inorganic materials such as inorganic salts. The sea sand, which has fallen through the sieve is washed diligently with deionized water and dried. It is then ready for reuse.

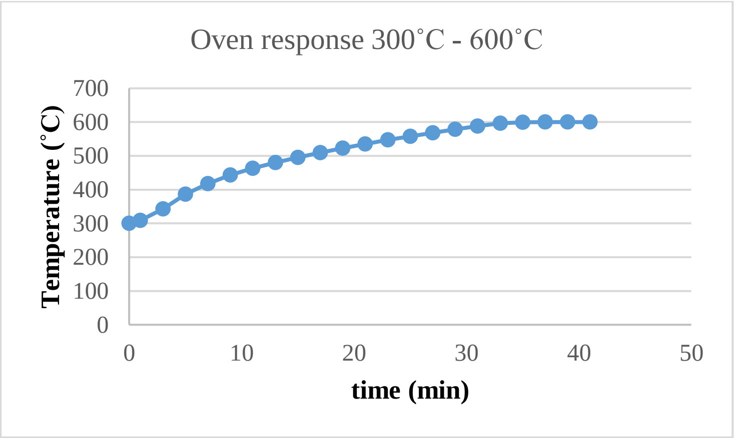

Figure 24: Heating curve of the Carbolite electrical oven (300°C - 600°C) with 100 g silica gel sample

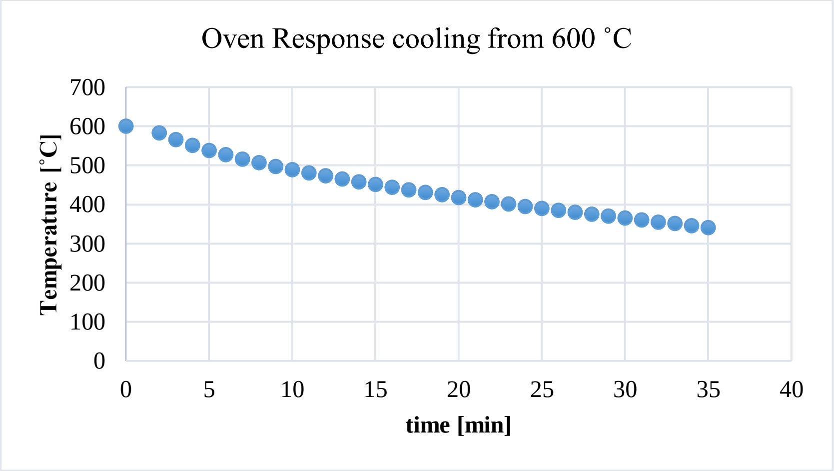

Figure 25: Cooling curve of the Carbolite electrical oven (600°C - 300°C) with 100 g silica gel sample

Preparation of isopropyl 4-hydroxybenzoate(16) using recycled silica gel in the purification step: To triphenylphosphine (PPh_3, 3.78 g, 14.4 mmol) in CH_2Cl_2 (20 mL) was added dropwise bromotrichloromethane ($BrCCl_3$, 3.12 g, 15.7 mmol) and the resulting solution was stirred for 35 min. at rt, during which time it turned dark-yellow. To the solution was added 4-hydroxybenzoic acid(14) (1.71 g, 12.4 mmol), and the mixture was stirred at reflux for 10h. Thereafter, the cooled reaction mixture was concentrated and subjected directly to column chromatography on 5X recycled silica gel (CH_2Cl_2). Thereafter, the fraction comprising the product was extracted with 5w% aq. $NaHCO_3$ (50 mL). The organic phase was dried and concentrated *in vacuo* to give 16 (1.81 g, 81%) as a slowly crystallizing colorless (white) solid, mp. 85°C (Lit. 88°C [124]); IR (KBr/cm^{-1}) ν 3400, 1685, 1610, 1590; 1H NMR (400 MHz, $CDCl_3$) 1.36 (6H, d, ^3J = 6.0 Hz), 5.23 (1H, sept., ^3J = 6.0 Hz), 6.89 (2H, d, ^3J = 7.6 Hz), 6.98 (1H, bs, OH), 7.95 (2H, d, ^3J = 7.6 Hz); ^{13}C NMR (100.5 MHz, $CDCl_3$) 21.2 (2 CH_3), 68.6 (CH), 115.2 (2C, CH), 122.7 (C_{quat}), 131.9 (2C, CH), 160.4 (C_{quat}), 166.8 (C_{quat}, CO).

6.2 Recycling of Silica Gel - Results and Discussion

SEM studies of the original silica gel Merck grade 9385 and for the recycled silica gel (eg., 5 X recycled) show no noticeable difference in size, in shape or morphology. This is supported by Brunauer-Emmett-Teller (BET) surface measurements with a BET surface area of 394.5 m^2/g for the original silica gel, 387.8 m^2/g for 1 X recycled silica gel and 422.3 m^2/g for 2 X recycled silica gel, showing a slight decrease in BET surface area, but then even a slight increase after the second recycling. The average (adsorption) pore diameter (4V/A) decreases, however, from 78.5 Å of the original silica gel over 72.7 Å (for 1 x recycled silica gel) to 65.9 Å (for 2 X recycled silica gel). For the original silica gel Merck grade 9385, only Si and O could be found in the Energy Dispersive X ray Spectroscopy (EDS) measurement. In those instances, where product mixtures were separated which included and left triphenylphosphine oxide on the silica gel after separation, phosphorus content was found on the silica gel in both ICP (P content 960 ppm for 10 X recycled silica gel) and EDS (P content 1.04 w% for 10 X recycled silica gel) measurements. In comparison, the P-content of the commercially bought silica gel Merck grade 9385 was found to be 1.3 ppm (Figure 26). Recently, investigations have appeared on the thermolysis behavior of triarylphosphine oxide, especially when used as building blocks in co-polymers. It is generally thought that the triarylphosphine oxide is converted to phosphoric acid upon combustion and after cooling and hydration [125, 126], where it is likely that amounts of polyphosphoric acids remain, where in our case phosphoric acids can also be esterified with silanol groups.

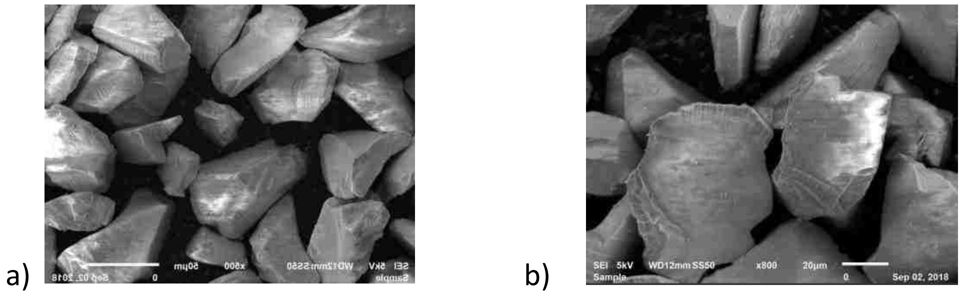

Figure 26: SEM micrograph of commercial silica gel Merck grade 9385 (a. left) and 10X recycled silica gel Merck grade 9385 (b. right)

In those cases where sea-sand was used as a protective covering layer in the column chromatography, both the sodium and sulfur contents in the recycled silica gel rose (to 1.4 w% Na and to 775 ppm S for 10 X recycled silica gel).

Clearly, water will be lost when silica gel is heated. When used as a desiccant, silica gel is recycled at 120°C. At higher temperatures it is known that silanols from siloxanes by ether linkage. Surface siloxane functions in the calcined silica gel are expected to convert back to silanols. This can be expected to happen at room temperature. Using IR- and Raman spectroscopy [127-130], much work has been performed in the literature on the mechanism of the hydroxylation of silica gel surface, where the ring opening of the strained surface siloxanes is thought to be exothermic. We found that after the thermolysis, the recycled silica gel gradually took up water so that by day 8 (at rt) about 7.9 w%, by day 10 (at rt) 9.1 w% of the mass of the silica gel is water, either bound to the surface of the silica gel, inserted into the silica gel by siloxane cleavage or as interstitial water. By day 13 the water content reached 10.1 w%, after which it did not change (Figure 27). This reflects the result of thermogravimetric measurements of commercially acquired silica gel and 5X recycled silica gel, where weight losses of 11.1 w% and 8.1 w%, respectively, were noted upon heating the samples to 600°C.

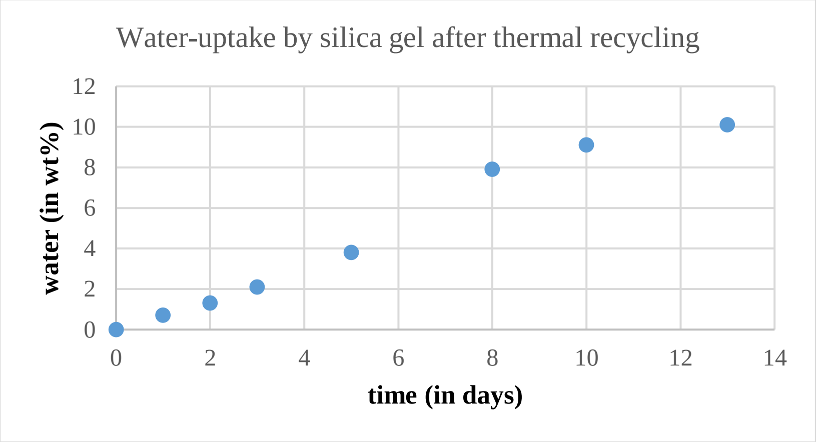

Figure 27: Water-uptake of the silica gel after thermal treatment at 600°C

Typical reactions that have been performed and where the reaction mixtures were separated on recycled silica gel are shown in Figures 27-30. They include two Williamson ether syntheses to methyl 4-ethoxybenzoate (3) (Figure 28) and to the steroidal azobenzene6 with alkenylazobenzene7 as side product (Figure 29) and two reactions that generate triphenylphosphine oxide as a by-product, namely a Wittig reaction to cinnamate10 (Figure 30) and a Appel-type reaction utilizing $BrCCl_3$-PPh_3 as a reagent [131] to azo cinnamate13 (Figure 31). For these reactions, the reaction products could be separated by column chromatography on recycled silica gel to give products in equal yield and purity to the products gained from chromatographic separations with commercial (ie., non-recycled) silica gel.

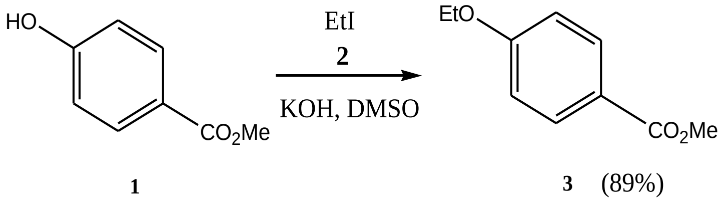

Figure 28: Preparation of methyl 4-ethoxybenzoate (3)

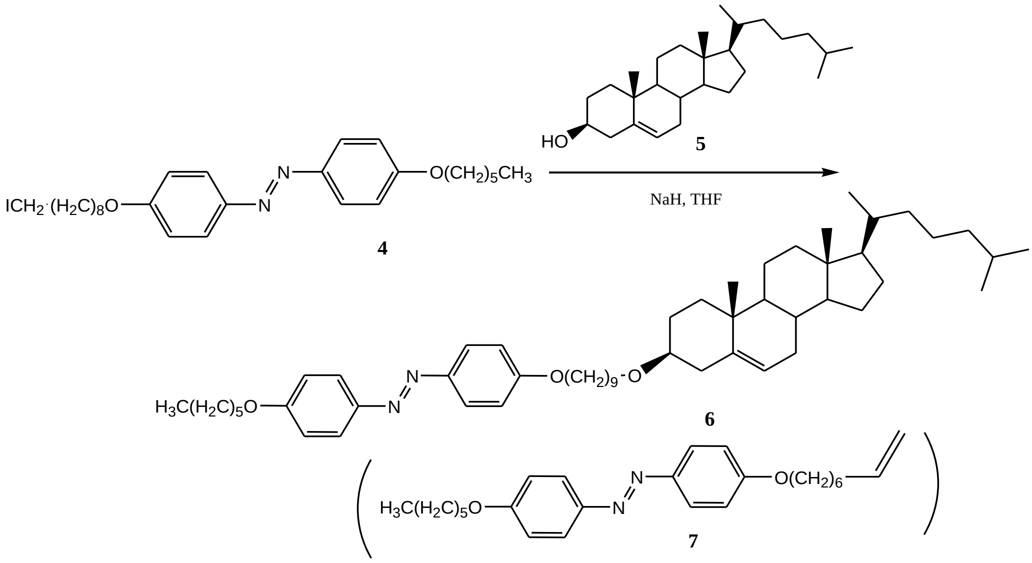

Figure 29: Williamson ether synthesis of steroidal azobenzene6

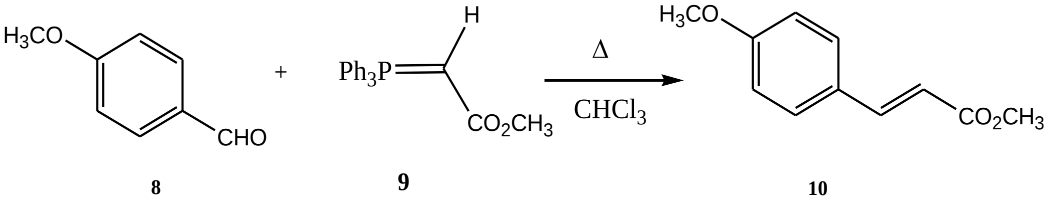

Figure 30: Wittig-olefination to cinnamate10

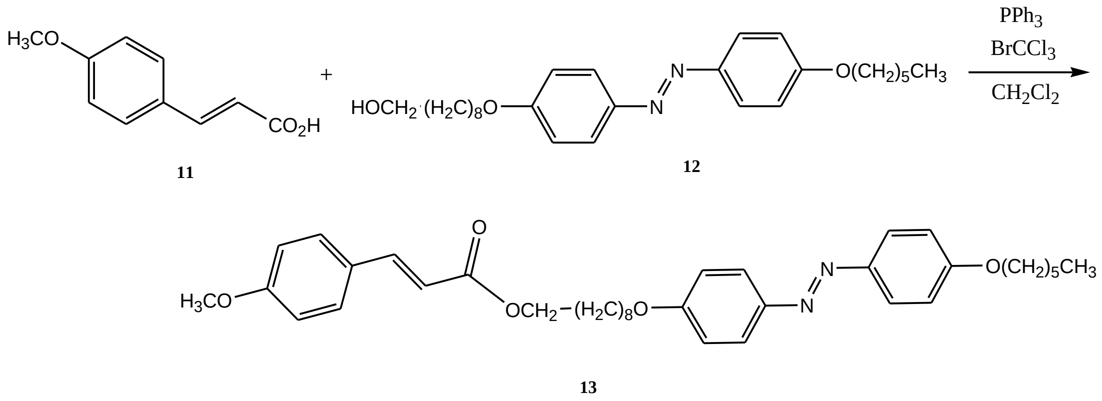

Figure 31: Appel-type reaction using $BrCCl_3$-PPh_3 to azo cinnamate13

An exception was found to be the purification of isopropyl 4-hydroxybenzoate (16) (Figure 32), prepared by Appel-type esterification from 4-hydroxybenzoic acid (14) using PPh_3/$BrCCl_3$ as reagent, where the product partially hydrolyzed on the silica gel during the chromatography. While some hydrolysis was found to occur under identical conditions with commercial silica gel, the yield of the product was by 4% lower using recycled silica gel. The final product could be purified by extraction with aq. $NaHCO_3$ solution of the fraction obtained from the column chromatographic separation.

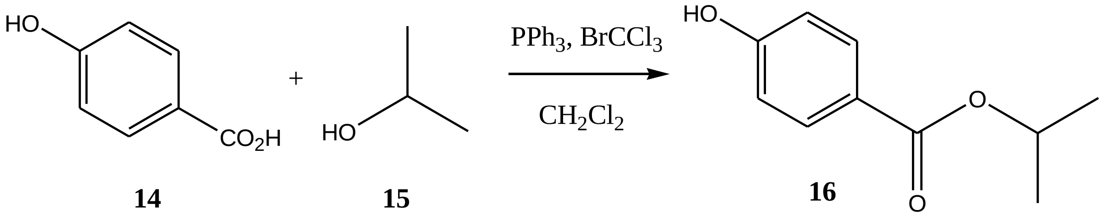

Figure 32: Preparation of 4-hydroxybenzoate (16) by Appel-type esterification using $BrCCl_3$-PPh_3

6.3 Silica Gel Recycling - Environmental Impact Assessment

The industrial cycle of manufacturing silica gels consists mainly of five steps [132]. These steps are raw material acquisition, the synthesis, washing (acid/liquid filtration), drying and finally the storage [132]. For the production of silica gel, the raw materials used are alkali metal silicate solutions and acids (usually sulphuric acid [H_2SO_4]). The manufacturing starts with an addition of H_2SO_4 to an aqueous solution of sodium silicate to form silica gel. The silica is then washed to increase its concentration and to get rid of by products like sodium sulfate (Na_2SO_4). After washing, the silica gel is dried.

For the convenience of study, we can separate these stages into two main stages; the wet stage, and the dry stage. The wet stage represents every step associated with silica gel making, from the use of sodium silicate to washing the silica gel. The dry stage on the other hand, includes the drying of the filter cake [132] and the packaging and storage of the final product. In the wet stage, a lot of water is used especially in the washing step to ensure the purity of silica. The wastewater generated from this stage contains suspended solids and has to be pH treated and purified from Na_2SO_4 before it is released into the sea. In the dry stage (the most energy intensive step), often a lot of water has to be evaporated; it can reach up to 6 tonnes of water for each one tonne of silica gel [132]. For this big amount of water, the dryer used must be very powerful and efficient. Though dependent on the type of silica gel desired by the manufacturers, the dryers used for silica gels need a high temperature inlet and produce a significant amount of CO_2 emissions and dust. Finally, machines do the packaging where the final product is then put in plastic/paper bags (size: 5-25 kg). Needless to say, that these machines also produce waste of dust and emissions to the air.

The following statistics were adapted from a European Commission Report, 2007 [132]. One tonne of silica requires 0.66 tonnes of H_2SO_4, 3.90 tonnes of water glass (as a source aqueous alkali metal solution) and 40 m^3 of water. About 15-24 GJ is consumed for the same amount of silica [132]. The NREU (Non-renewable energy use) for silica gel is 66.0-77.3 (MJ/kg), and the GWP100 (Global warming potential in 100 years) is estimated to be between 3.48-4.12 (kg CO_2-eq/kg) [133]. Other than the energy required for production, treating the waste that comes out at various stages of production can be energy-demanding as well. The solid waste generated is about 29 kg for each tonne of silica on average, which is significantly lower than the waste generated for fumed silica. The treated wastewater generated for one tonne of silica is about 35 m^3 on average. As for the emissions, and according to the European Commission Report 2007 [132], they can be classified to air and water emissions. The drying stage generate large amount of dust, this is of course dependent on the drying technique used. On average, for one tonne of silica 1.3 kg of particles are emitted. Also, if the drying process is generated by natural gas, the emissions of CO and NO_x are estimated to be 0.825 and 0.723 kg respectively on average for each tonne of silica. As for water emissions, they consist mainly of Na_2SO_4 (588 kg/t silica) and other particles. These particles are disposed of in the seas/rivers (6.6 kg particles/t silica excluding Na_2SO_4).

To recycle used silica gel in 120 g batches, we used a Carbolite electrical oven ELF 11-6 that consumes 1kW per hour, making the overall consumption of energy about 60 MJ/kg of silica gel. We were able to cut down on energy by 10% and although this is not much, recycling larger amounts of silica gel can be of apparent value cutting down on energy, further. Then again, the process we use for recycling silica gel eliminates solid wastes and the use of water almost completely.Also, during the recycling process, the silica is not physically moved from the laboratory where it is used. This facilitates logistics and circumvents the energy needs and pollution associated with the transport of the material.

In conclusion, silica gel is used in our laboratories for the separation by adsorption chromatography of organic mixtures obtained from the synthesis of organic materials. We use about 22 kg of silica gel every year for our processes. In previous times, we have not treated silica gel wastes but asked that they be taken away as solid chemical waste. In the last 2 years, we have started to recycle silica gel waste by the simple process described above. As often we are separating organic compounds from triphenylphosphine oxide, it is expected that some amounts of phosphoric and polyphosphoric acids remain on the silica gel and this has been supported by ICP-OES and EDS measurements of the recycled silica gel. Thus far, this has not decreased the quality of the silica gel as chromatographic material. However, that some structural changes of the silica gel do occur can be seen in the decreasing pore diameter (4V/A) and potentially a decrease of water uptake with the number of recycling cycles, so that most likely the silica gel cannot be recycled indefinitely. As of Jan. 27th, 2019, 37.5 kg silica gel from 52.7 kg silica wastes have been recycled from our laboratory that would otherwise have been declared as solid chemical waste. This saved the group 1305 Euro [(list price in Europe) = 5520 AED] in not buying new product (38.7 kg of pure silica gel). The waste disposal (52.7 kg of silica gel waste) would have cost 9770 AED. So, apart from minimizing waste streams, 15290 AED were saved by the procedure. As a final conclusion, it may be said that starting materials for research purposes that are relatively easily separated from their side products can be purified using recycled silica gel. Also, recycled silica gel can be used in educational laboratories to contain wastes and costs.

6.4 Recycling of Solvents

Similar to the discussion of the recycling of silica gel, a recycling of solvents can be discussed. They are by volume the most used consumable producing the by far largest amount of waste. In E4, waste solvents are collected in the individual laboratories, before being brought to E4-2005, where they are collected at a later time from Khadamat Services, who move them to a storage room in E6, where the solvents are collected periodically by Bridges Environmental and moved off-campus. Because of cost and environmental concerns, it has been studied to what extent solvents can be recycled. The targeted solvents include acetone which is used in almost all educational laboratories for cleaning glassware. In addition, the recycling of low boiling solvents used for column chromatography was investigated. This was mainly dichloromethane (CH_2Cl_2) coming from E4-2006, which houses undergraduate research in organic synthetic chemistry, among other things. For many of the separations using column chromatography on silica gel CH_2Cl_2 as solvent (eluent) was suitable without the admixing of other solvents. Because of this, the waste solvent (eluent) could be distilled directly without worrying of changing the composition of the solvent as it distills. For the recycling of used CH_2Cl_2, a simple rotary evaporator was used. CH_2Cl_2 was distilled under vacuum, where a JULABO F-50 chiller was used, set at 4°C. Acetone was distilled in a similar manner. While recycled (distilled) CH_2Cl_2 was pure enough for further use as eluent in chromatography, acetone could only be reused for washing purposes as organic contaminants as well as water enters recycled acetone. On purpose, a fractional distillation at atmospheric pressure using a fractionating column was not used. Some research groups at other universities use/used a continuous distillation apparatus with a heating mantle as the energy source and a separatory distillation column. While the purity of the collected acetone collected at the distillation head (still head) may be higher, there are two disadvantageous: a.) in the distilling flask, more and more impurities gather that over time give off an appreciable odour; b.) a continuous distillation needs to be watched carefully and someone needs to be designated to turn off the distillation at the end of the day. Failing to do so amy result in an accident such as in a fire because of overheating in the distillation flask. Over the time of this research, 22.1 L of acetone and 17.7 L of CH_2Cl_2 were redistilled under vacuum using a rotary evaporator. It has also been tried to distill solvent mixture, where to the CH_2Cl_2, $CHCl_3$, diethyl ether and hexane were added. Use of the distilled solvent as an eluent for column chromatography is then possible, when a solvent is admixed after the recycling to fine tune the polarity of the mixture. Such a recycled solvent mixture should only be used for the separation of known compounds.

6.5 Overall Evaluation of Recycling Efforts as Part of the Occupational Health and Safety Management System

In regard to occupational health and safety, recycling can lead to more risks as this process is in addition to educational processes running in the designated areas. Recycling in-house often leads to more holding containers for chemicals that “clutter” up space and may mean that used chemicals, incl. chemical wastes, are stored for a longer time within the department’s premises. In the present case, this problem was partially solved in that one room was partly dedicated to the recycling of chemicals.

In addition to this, recycling can pose dangers because of the recycling process itself. In order minimize the danger, no acetone recycling by continuous distillation was set up, and acetone was recycled only by distillation through a rotary evaporator. The same is true for the recycling of other solvents such as dichloromethane. Certain recycling efforts were not initiated, although they would save the department/university a lot of costs, such as the recycling of silver nitrate ($AgNO_3$), because of the potential danger of the processes. In the case of $AgNO_3$, this process would be an oxidation of silver residues with nitric acid (HNO_3) which would bring with it the potential danger of an explosion in the case that organic residues would be adhering to the silver wastes.

In all, the university is strongly supporting a campus operation with as much recycling as possible. Khadamat as the campus operator has been leading in the recycling effort as well, however, year by year it becomes more difficult to find ways to improve the percentage of waste recycling. Therefore, recycling of chemical wastes should be looked at more carefully. A recent proposal in this regard is the recycling of zinc chloride. Zinc chloride ($ZnCl_2$, 1500 AED per kg) is produced in the general chemistry educational laboratory, but is discarded there. On the other hand, zinc chloride is used as a reagent in the organic educational laboratory. Here, it is suggested that the zinc chloride produced in the general chemistry laboratory should be purified to such a degree that it can be used in the organic educational laboratory.

Chapter 7: Conclusion

The United Arab Emirates University Maqam Campus represents probably the largest gender-separated campus situated on one site with a demarcation between the female and male parts of the campus, albeit with shared educational laboratory buildings. After an overall appraisal of the occupational health and safety management system and the historical development of the system, the focus was directed towards the E-shared educational laboratory buildings as the interface between male and female parts of the campus. What makes the operation of a gender-separated campus different from the normal operation are the constraints of movement between the two parts of the campus. The use of the building for both genders, where the students are separated by gender, leads to a very busy schedule, with very little time from one laboratory session to the next, leading in certain times to some congestion in certain areas such as near the elevators. The E-shared buildings are locked down to one side and open to the other side at all times, where movement through the locked doors is only possible for card-holders (ie., faculty, staff, Khadamat personnel, Berkley cleaning staff and contractors, but not to undergraduate students or suppliers, such as vendors on delivery runs or visitors). Therefore, one focus of this study was on the evacuation of the E-shared laboratories and the movement of people through the E-shared buildings, including the provision of suitable assembly points. For the study, DepthmapX software was used. The main finding was that the central emergency exit is very important for the evacuation of the people inside the building and that the access to this central escape route should be emphasized more. The spatial analysis shows that there is an appreciable presence of people near that exit in case of an emergency, especially when one of the terminal main doors remains locked down. Visual monitoring of emergency drills noted that there was severe congestion near the side exits, leading from the stair wells directly to the open, as the ventilation system in the building during an emergency leads to a negative pressure difference (inside-outside of the buildings) that does not allow the opening of the main door into the main ground level corridor. Also, it was noted that the assembly points chosen in between the buildings are very close to the buildings and only have small entry gates, where the signage is not clear as signage is missing on the gates leading to the assembly points. It will most likely be difficult to evacuate from those assembly points if the emergency situation deteriorates. The assembly points were most likely chosen in this way as the central exit leads into this inner courtyard, also.

The possibility and risk of recycling materials within the E-series buildings was analyzed, also. Especially recycling of silica gel and waste solvents was studied. It could be seen that recycling was possible, when a laboratory was partially dedicated to this problem. Although the recycling effort can contribute significantly to cost containment, the dedication of one of the laboratories can lead to further congestion in the remaining laboratories. The management of chemicals was seen as a very important issue in this study. In previous times, UAEU operated on three main campuses (one for female students, and two for male students), and this led to keeping multiple containers of the same chemicals at different locations. Many of the chemicals were moved to the Maqam campus. So, a tracking system for chemicals is essential and should be utilized by UAEU in the near future. In this work, a non-electronic database was suggested to keep track of the chemicals in a lab with all additions and removals of the chemicals logged in. This system was initiated in two labs in this study.

As to the general occupational health and safety management system, it could be seen that there has been a shift in the management system administratively away from the colleges towards the central administration (FMDHS), where the interaction between the OHS units of the colleges, Khadamat and central administration is slightly less pronounced than in previous years. Partly this is due to the fact that UAEU is OHSAS 18001 accredited, and because of this the OHS unit with the central administration has been strengthened significantly. As the OHS budget allocation comes from both the central administration and the colleges, procurement does not always seem straightforward.

Critically, the management of very severe emergencies such as earthquakes, where either a quick evacuation of the whole gender separated campus is necessary or an emergency relief center needs to be set-up for the occupants of the campus, needs to be looked at in the future. Nevertheless, as a gender separated campus, the UAEU Maqam campus is well set for dealing with general emergencies and has a dedicated occupational health and management system in place.

7.1 Recommendations

As a consequence of this thesis, the following recommendations can be made:

The evacuation of the E-shared laboratory building should be rethought in such that it should be assured that all exits can be and are used in case of an emergency. The assembly points for the E-shared laboratories (on the female side) should be repositioned, away from the buildings. The assembly points on the male side should be more clearly signposted.

It is of utmost importance that there is a better tracking of chemicals. It is recommended that the university buy software accordingly.

At this point, a general health and safety induction for the students is not compulsory. It is seen that the students do get health and safety training in the individual laboratory courses. Nevertheless, a general induction is recommended. This can be performed online. An examination in health and safety should be given before students may enter the laboratory. This includes graduate students.

As to the health and safety management structure of UAEU, it is recommended to establish a joint health and safety committee with representatives of the different faculties, the administration of the university (especially FMDHS) and Khadamat. This would lead a closer interaction in regard to health and safety among theses 3 entities.

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Appendices

Appendix 1

Health and Safety – General Policy Statement (Draft of June 9th, 2013)

The United Arab Emirates University (UAEU) has the utmost concern and commitment towards the Health and Safety of its employees, students, contractors and all those who are affected by the activities of the University. The provision of a safe working environment is an integral part of the university agenda. The UAEU recognizes that it has a legal duty to provide a safe and healthy working environment on its campuses.

Therefore, the UAEU is committed to a continuous improvement of the working environment through effective administration, education, training, and supervision as well as through infrastructural support. The university philosophy is that “safety is everybody’s responsibility”.

A Senior Management team communicates and promotes this policy and seeks continuous improvement in health, safety & environmental protection (HSE). All managers, faculty members, and other university employees are to demonstrate their commitment towards safety and they are to be equipped with the knowledge, competence, confidence and capacity to deal effectively with HSE issues in support of the UAEU’s wider aims and objectives. All persons on campus must comply with the health and safety regulations of the university

The Key Points and Objectives of the UAEU HSE policy are:

- A positive health & safety culture is supported, where all members of the UAEU are aware of their responsibilities.

- Local as well as applicable international standards in HSE management are to be complied to.
- In all areas, procedures of hazard identification, application of controls and risk minimization are to be in place.
- The UAEU senior administration involves, consults and communicates with all university staff and students on HSE issues.
- The UAEU works in partnership with contractors on HSE issues, where there are shared facilities or activities on the university campuses.
- The UAEU administration monitors and reviews the health & safety performance and provides necessary resources to meet the University health & safety obligations.
- The UAEU asks for the integration of an HSE plan in all the university's new projects.

The overall responsibility for this policy lies with the University Council, which is delegating its authority to the Vice-chancellor for implementation. The University defines and keeps under review the organization it needs to implement and/or maintain the HSE infrastructure mandated by the policy.

The Faculties and administrative units of the university are responsible for the management of HSE activities in their areas of jurisdiction. It is the responsibility of the University HSE department to provide advice and support in all HSE related matters. The University is committed to reviewing its HSE Policy at least once in 5 years and will initiate additional reviews, whenever circumstances require it.

Appendix 2

Organization and responsibilities

The university abides by the legal framework set by the government of the United Arab Emirates such as described in the Labour Law [Federal Law No. (8) of 1980 as amended], the Ministerial Decision No. (32) of 1982 concerning preventive methods to protect employees, the Ministerial Decision No. (4/1) of 1981 concerning hazardous works, and the Ministerial Decision No. (27/1) of 1981 concerning remote areas and locations.

On behalf of the Chancellor of the University and the University Council, the General Secretary's Office has the responsibility to hold intact all regulations and the fulfillment thereof as well as to maintain any and all infrastructure needed for a safe environment for staff and students of the university, including any members of the general public accessing the premises of the university. In particular, the General Secretary's Office in conjunction with the Vice Chancellor's Office will assume the responsibility for:

1.) allocating adequate financial and personnel support for the implementation of the Health and Safety Policy and for keeping a safe environment on all university premises;

2.) designating persons responsible for implementing and maintaining a safe environment at various levels and locations of the university;

3.) monitoring the implementation of the Health and Safety policy and the efforts to keep the university a safe working environment

4.) reviewing the Health and Safety Policy and procedures and the implementation of any mandated changes.

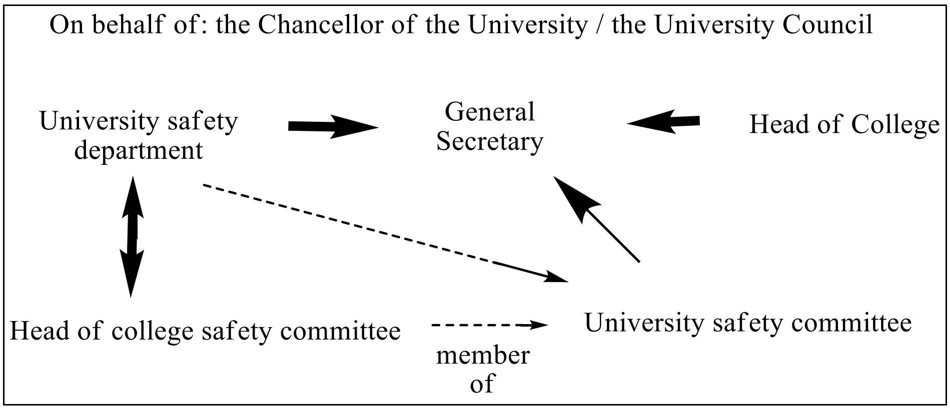

Figure 33: Organizational chart "safety" – university level (suggestion of summer 2016)

The General Secretary's office is to provide one "University Safety Officer", who is to oversee all things concerning "Health and Safety". He/she is to be supported by two-full time safety engineers, and constitutes the "University Safety Department". In matters of "Health and Safety", the General Secretary's office and its "University Safety Department" is to be advised by a university committee, which recruits itself from the safety committees of the individual colleges, the hostels, the transport department, the farms and research centers. The university has a full-time fire marshal for the main campus, named New Maqam campus. All other premises, including outlying campuses, hostels, and farms, have a person delegated as fire marshal. All buildings on the new campus have a person delegated as fire marshal with the responsibility of alerting the civil defense in case of fire or major accident in the respective building.

The head of each college appoints a safety committee for the college, ideally comprised of a member from each department. In items "Health and Safety", each college safety committee member is to advise and report to the Head of the respective Department. Each college has a college safety officer who is also the head of the college safety committee. He is to report to the head of the college. The head of the college and college safety officer ensure that the respective college is knowledgeable and compliant of the University Health and Safety Policy and its regulations. At the same time, each college must have in written form a supporting college Health and Safety Protocol. Both the University Health and Safety Policy and the College Health and Safety Protocol are to be publicized and to be easily accessible to all university staff and university students. It is the responsibility of the head of the college to verify periodically that all safety measures are in place and that funding and other resources for safety measures in the college are adequate. He has to confirm that all accidents within the confines of the college and/or involving his college's students/staff have been recorded in the accident log-book of the college/university and that the dissemination of safety information and safety training of personnel and students are adequate. It is the duty of the head of the college, in conjunction with the college safety officer, to review the college health and safety protocol at regular intervals. It is the duty of the college safety officer to provide for adequate training in "Health and Safety" for students and staff.

Each department designates a departmental safety officer, who is to be member of the college safety committee. The departmental safety officer advises staff/students of safety issues, sees to it that all staff and students comply with the university and college safety regulations, reports on any safety infrastructural deficiencies to the head of the department and/or the head of the college safety committee, and is instrumental in training the staff/students of his department in "Health and Safety" on a regular basis.

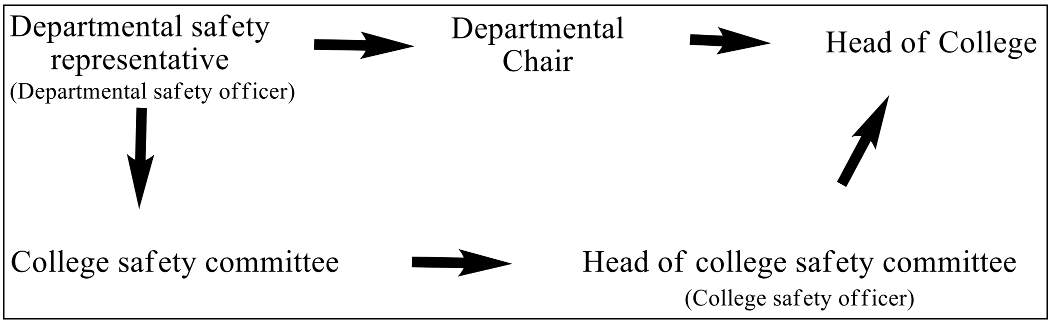

Figure 34: Organogram "safety" at the department and college level (suggestion of summer 2016, in place)

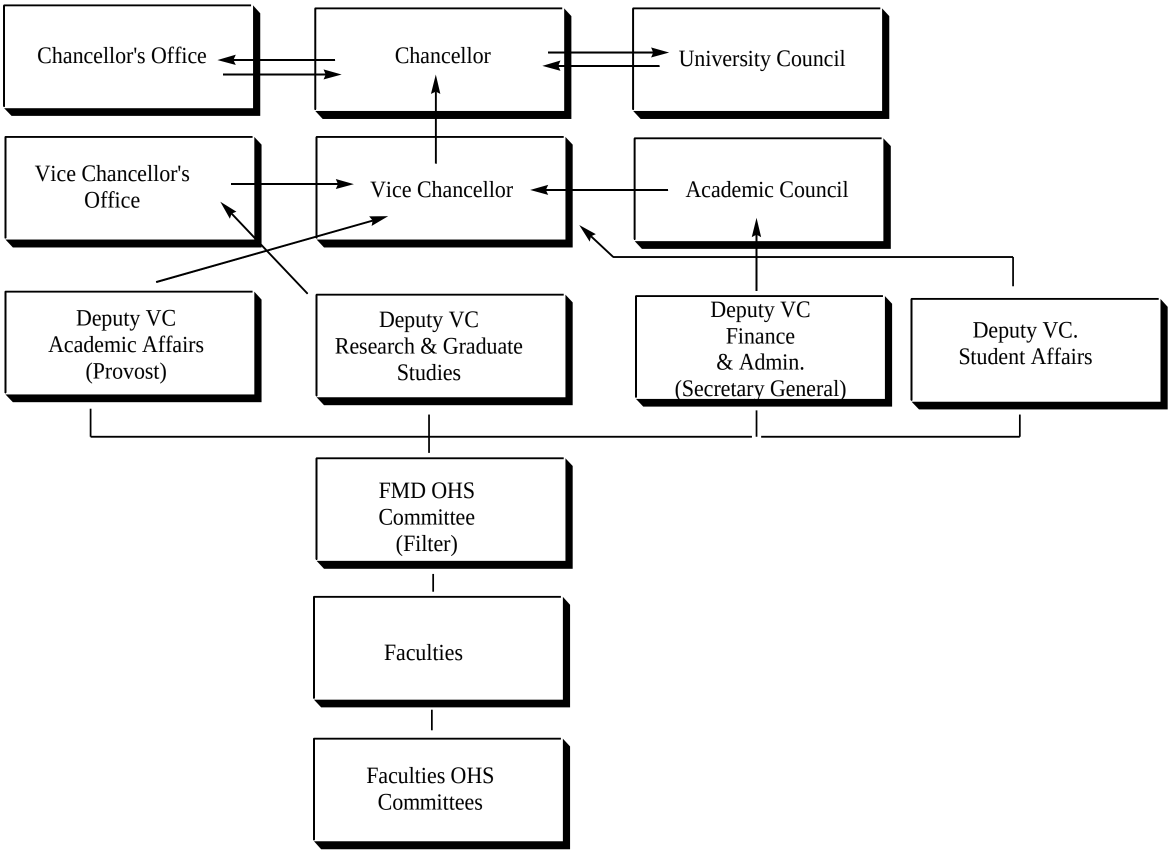

Figure 35: Current organizational chart in regard to occupational health and safety, officially adopted by UAEU

Appendix 3

Late working hours

Heads of schools and conveners of multiple use buildings will decide upon allowed access to parts of the university under their management. This includes the access outside of the normal working hours. University staff arriving at the university outside normal working hours will be registered at the points of entry to the university. University staff on-campus will be asked to register on-line when reaching late working hours. The same rule applies to graduate students. Undergraduate students will be permitted to remain on-campus then, when their hostels are situated on-campus, but are allowed to access work-related areas (laboratories, workshops, classrooms) on campus only with special permission. Security staff has the authority to ask the identity of persons found in the buildings after-hours and check the information against their registration log book.

No after-hour work should be carried out that is dangerous. When working after-hours in workshops or laboratories, persons should best not work singly, or if so, have another person check on them periodically.

Normal working hours on the university campus are designated as:
Sunday – Thursday: 7.30 – 18.00

Evening and weekend working hours are considered as:
Weekdays: 18.00 – 7.30
Fridays and Saturdays
Public holidays

Disabled Persons

Disabled persons who are in need of special infrastructure due to health and safety matters should contact the Head of College or the University Safety Department. Necessary infrastructure would then be implemented, where possible. It is ascertained by the university that quick routes of egress from buildings are available for disabled persons.

Visitors

Visitors are to be registered at the gate of entry. Children will be allowed on the campus during official school visits. School visits must be planned ahead of time, where the head of the department or dean of the faculty has granted permission to an official request by the respective school. Children accompanying their parents are allowed onto the university premises only in exceptional cases. They should not enter workshop or laboratory areas. Exceptions will be made on open days, official school visits and other officially sanctioned work-experience exercises. At all times there is to be a close supervision of the children by university staff. All visitors must follow the university's rules and regulations regarding "health and safety". Pets are not allowed on university premises.

Contractors

Every outside contractor performing work within the University property must accept the full responsibility for complying with the provisions of the University's rules and regulations regarding "health and safety" in addition to all other relevant statutory provisions in respect of the work comprising the contract. The Campus Development Department and/or the "University Safety Department" may advise the contractor of any working method that poses a danger to the safety on campus and will require the contractor to remedy any such dangerous situation without delay.

Hazardous Materials

Staff members and graduate students working with hazardous materials should ascertain that material safety data sheets are available for all compounds in their handling. This includes all materials stored under their management. Written instructions to undergraduate students in their practical work must draw attention to the risks associated with using hazardous substances. Accurate book-keeping of all materials must be maintained. The university keeps electronic records of all chemicals on campus.

Radiation Protection

Any school working with ionizing radiation is to keep exact accounts of radioactive materials, and the registration of workers as well as their radiation monitoring records. For this purpose, all persons working with ionizing radiation will wear a radiation dosimeter, which is to be collected monthly.

The Federal Authority for Nuclear Regulation (FANR) must be informed of any acquisition, sale or move, even within the campus, of nuclear materials (thorium, uranium and plutonium). All radioactive materials are to be registered with FANR. The university will support FANR in its regular monitoring visits.

Fire safety

The university facilities are to be operated according to the Civil Defense Code of Al Ain municipality. The university is equipped with fire fighting material such as with fire extinguishers, fire blankets, sand buckets, etc. The E-shared laboratories are in emergencies fully-sprinkler operated. Emergency exits are to be marked clearly.

Assembly points within the university area are designated, and the access to these is to be shown by adequate signage. An adequate number of posters are to be hung visibly in all areas of the university, detailing emergency numbers and describing emergency procedures. All avenues of egress are to be kept clear. Fire doors within the building should be kept closed, when not in use, and should not be propped open. For a fire emergency, first responders have been designated for each building.

The head of the college, the college safety officer and the university safety officer have to ascertain that the fire-fighting capability of the areas under their management is well maintained and that the identity of the first responders is well-known to all staff and students. The campus development department is responsible for periodic checks of the operational status of the fire-fighting equipment.

Fire drills and emergency evacuation exercises are to be held at least once a year for each building, with the full participation of students and staff. It is advised to hold fire emergency exercises in collaboration with the Civil Defense to enable staff and students to learn the operation of basic fire-fighting equipment.

First aid

In every laboratory and workshop there is to be an adequate first aid kit. The location of such first aid kits is to be marked clearly. In all other facilities of the university the number of first aid kits must not be less than mandated by the regulations of the country (eg., not less than one first aid kit per fifty people of occupancy). In collaboration with the Campus Development Department, individual departments are to identify the person(s) responsible for maintaining the first aid kits in their area of management. The first aid kits in shared areas such as in classrooms will be maintained by the university department of safety.

University nurses are available as first responders in case of an injury. The university is equipped with a small clinic. The contact details of the nurses are to be marked clearly throughout the campus. Apart from cases with very minor injuries, university nurses can be seen as first responders only, and a hospital emergency car is to be called.

Safety training

Undergraduate students, especially newcomers to the university, are deemed uninstructed in safety as where university "health and safety" is concerned. Therefore, an instructional unit in "health and safety" is given for all new-comers by the University Safety Department. Additionally, different colleges have their own safety training programs. These colleges include the College of Engineering, the College of Science, the College of Food and the College of Health and Medical Sciences. Safety workshops are given to the students, at least once a year. These will be given by safety officers of the university, at departmental, college or university level, but also outside expertise is invited. In student laboratories, where hazardous materials or equipment are used, students take a safety-unit in the first period of their lab course. Students will sign that they have understood all instructed safety issues pertaining to the course. Additionally, fire and building evacuation exercises will be held from time to time, but not less than once per half year for each building.

Queries regarding "Health and Safety"

For queries, staff and students should consult their immediate supervisor. Otherwise, the departmental safety officer, the head of safety of the college, the head of college and the university safety department will be ready to answer questions regarding "health and safety", in that order. Additionally, the respective college health and safety protocol and the University guidelines on "Health and Safety" are available on-line.

Reporting of Accidents and Incidents

All accidents and dangerous incidents will be logged electronically into the university's accident report log as soon as possible and will be reported in person to the college safety officer within 24 hours. In case of serious accidents and incidents, the head of college and the university safety officer should be informed as soon as is possible.

Monitoring of health and safety policies and regulations

The college safety committee will inspect regularly all areas of the respective college to ascertain that all governing rules of health and safety are followed throughout the parts under the college's management. A record of inspection and remedial action is kept both with the head of the college safety committee and the university safety department.