Improving Indoor Air Quality (IAQ) in Kuwaiti Housing Developments at Design, Construction, and Occupancy Stages

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List of Acronyms

KEPA	Kuwait Environment Public Authority
IAQ	Indoor Air Quality
EC	European Commission
HVAC	Heating Ventilation and Air Conditioning
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers.
ACMV	Air Conditioning and Mechanical Ventilation
WHO	World health Organization
M&E	Mechanical and Electrical
OAQ	Out-door Air Quality
IAQM	Indoor Air Quality Management
REF	Research Ethics Framework
ESRC	Economic and Social Research Council
USEPA	United States Environmental Protection Agency
ROI	Return On Investment
ETS	Environmental Tobacco Smoke
SBS	Sick Building Syndrome
BRI	Building Related Illness
IEE	Institute of Environmental Epidemiology
VOCs	Volatile Organic Compounds
VVOC	Very Volatile Organic Compound
SVOCs	Semi-volatile organic compounds
PAHs	Polycyclic Aromatic Hydrocarbons
MVOCs	Microbial Volatile Organic Compounds
COPD	Chronic Obstructive Pulmonary Disease
CVD	Cardio-Vascular Disease
SD	Sustainable Development
PMV	Predicted Mean Vote
AC	Air Conditioning
EPD	Energy Performance Directive
HRV	Heat Recovery Ventilators
MERV	Minimum Efficiency Reporting Value
IPCC	Intergovernmental Panel On Climate Change

GIS	Geographic Information System
ISAAC	International Study of Asthma and Allergies in Childhood
LEED	Leadership in Energy and Environmental Design
IEEE	Institute of Electrical and Electronics Engineers
KIEM	Kuwait Institute of Environmental Management
KISR	Kuwait Municipality, Kuwait Institute of Science and Research
OPR	Owner’s Project Requirements
RIBA	Royal Institute of British Architects
BoD	Basis of Design
BIM	Building Information Modelling
CAD	Computer Aided Design
STC	Save The Children

Abstract

There are many sources of outdoor pollution in Kuwait which then makes natural ventilation a poor mechanism for good Indoor Air Quality (IAQ). Therefore, a mechanical or hybrid ventilation system is necessary. First of all, Kuwait is situated in the northeast of the Arabian Peninsula in Western Asia with a desert weather climate. The prevailing wind is north and northeast and that causes sand storms. Also most of the towns and cities are situated and constructed within the vicinity of many industrial sites, petroleum downstream/upstream facilities (including Kuwait's three refineries, petrochemical complexes, crude oil production points etcetera) and many small industries. Most housing construction projects, as well as schools, commercial and governmental buildings are built in the downwind of the polluted air emitted from such plants, therefore, there is the potential for consequential health effects related to the ambient air. As a result, there is a prevalence of asthma and rhinitis among the schoolchildren in Kuwait. The estimated prevalence of asthma among school children was 22.4% and that of rhinitis was 23% (Abal et al., 2010).

It was evident from a preliminary study that indoor air quality (IAQ) in Kuwait housing is under-researched and there is a clear lack of awareness amongst building stakeholders (Architects and Designers, M&E Engineers, User, etc.) of the harmful effects of chemicals that exist inside buildings. The risk of poor Indoor Air Quality (IAQ) is increased by a lack of proficient knowledge of how numerous factors can contribute to poor IAQ, both during design, construction and after occupancy. As a result, the study set out to: research previous related research studies in the field of IAQ, identify the current status quo of IAQ in Kuwait, conduct a survey (questionnaires and interviews) with Kuwait construction professionals regarding IAQ issues and to find the barriers to implementing IAQ best practice in all stages of the project, and then finally, to develop a framework for achieving good IAQ in Kuwait housing projects.

The findings revealed no documents written for Kuwait, that encompasses codes, standards, regulations and guidance for the implementation of good IAQ in Kuwait housing developments, or a framework for government enforcement of such. It was also revealed that there was a significant lack of awareness of indoor air pollutants and good IAQ both amongst occupants and construction professionals. The analysis also revealed that the status quo in the housing development process did not enable integration amongst the project team and

stakeholders at the design stage, hence team member's valuable input on achieving good IAQ at design stage is lost. Furthermore, the process did not emphasize the following at every stage of the project to ensure good IAQ: commissioning of the ventilation design and installation, which includes value engineering, proper sequencing and scheduling of activities to avoid dust or debris from contaminating the ventilation system, proper documentation and reporting to ensure the owner's project objectives are documented, achieved, checked, and carried over to the next stage.

The findings show that the barriers to achieving good IAQ in Kuwait housing developments are; cost and budget, government enthusiasm, lack of awareness, lack of enforceable codes and standards, lack of design integration, distrust of the competence level of local IAQ companies, habit and age, low level of IAQ education, and lack of training. While, the drivers of good IAQ in Kuwait housing are; the client/end-user, the government, architects, designers, IAQ consultants, construction professional societies, contractors and manufacturers.

The developed and validated framework achieves the aim and objectives of the study by proposing strategies and actions for improving indoor air quality (IAQ) in Kuwaiti housing developments through increased integration, commissioning, proper and adequate sequencing and scheduling, and documentation at design, construction, and occupancy stages. Kuwait Environmental Protection Agency (KEPA), Kuwait Institute of Environmental Management (KIEM), Kuwait Municipality, and Kuwait Institute of Science and Research (KISR) were also suggested as the main bodies to drive the education, awareness, and training, of not only the construction industry but also the general population on good IAQ practices.

1 CHAPTER ONE| INTRODUCTION

1.1 Background to the Research

Kuwait is located in the northeast of the Arabian Peninsula in Western Asia with a desert weather climate. The prevailing wind is north and northeast and that causes sand storms. Also most of the towns and cities are situated and constructed within the vicinity of many industrial sites, petroleum downstream/upstream facilities (including Kuwait's three refineries, petrochemical complexes, crude oil production points etcetera) and many small industries (Al-Salem and Khan, 2008). Most housing construction projects, schools, commercial and governmental buildings are built in the downwind of the polluted air emitted from such plants, therefore, there is the potential for consequential health effects related to the ambient air (Bouhamra, 1996; Bouhamra and Elkilani, 2001; Bouhamra, 2012). This explains the high prevalence of asthma and rhinitis among the schoolchildren in Kuwait. The estimated prevalence of asthma among school children was 22.4% and that of rhinitis was 23% (Abal et al., 2010).

From the literature review, it was evident that indoor air quality (IAQ) in Kuwait buildings is under-researched and there is a clear lack of awareness amongst building stakeholders of the harmful effects of chemicals that exist inside buildings (Khamees and Alamari, 2009). This research proposes a framework that will enable project stakeholders in Kuwait to tackle these issues, because whilst the literature review revealed that there is an abundance of research donw on indoor air quality (IAQ) in developed countries like the USA, the UK, Germany, Canada, and Japan, there is very little research done for the state of Kuwait. Indoor environments consist of seven factors that can impact the health of humans. These factors have been called the "Seven Sisters." The factors comprise of *"indoor air quality, lighting, temperature, sound and vibration (acoustic), electromagnetic fields, flora and fauna, and the psychological and social environment"* (Dumont, 2008a).

Indoor air quality research is a multidisciplinary task, and requires a highly skilled team including scientists from various disciplines such as medicine, chemistry, biology, engineering, architecture, and building sciences (Maroni, 1995). According to a study conducted by the American Lung Association, most people are aware that outdoor air pollution can damage their health, but may not know that indoor air pollution can also have significant economic effects as well (Commission, 1996). The risk of poor Indoor Air Quality

(IAQ) is increased by a lack of proficiency and knowledge of how the numerous factors can contribute to poor IAQ, both during design and construction and after occupancy (Kibert, 2005, Kibert and Grosskopf, 2007). Bluyssen et al (2010), in a study and consultation with different stakeholders (producers of construction products, architects and housing corporations) from the Netherlands, the UK, Denmark, Sweden, France and the Czech Republic, concluded that "*the general awareness of what IAQ is, how to improve it, and who should or can undertake actions, is poor"* (Bluyssen et al, 2010). The gaps were as follows:

- Lack of awareness of IAQ with all stakeholders (i.e. architects, product producers, general public, representatives of end-users), but most of all with the end-user. The end-user needs to acquire a good knowledge of IAQ.
- Lack of proper regulation: as long as appropriate regulation is lacking no one feels responsible.
- Lack of communication between stakeholders of the building process.

According to Mølhave and Krzyzanowski (2003) the World Health Organisation (WHO) 'Working Group' convened in year 2000 to agree on a set of statements on *"The right to healthy indoor air",* derived from fundamental principles in the fields of human rights, biomedical ethics and ecological sustainability. These statements inform the individuals and groups responsible for healthy indoor air about their rights and obligations, and empowered the general public by making people familiar with those rights (WHO, 2000a, Mølhave and Krzyzanowski, 2003).

The European project – Healthy Air is a network project involving six institutions in Europe on actions and activities that address the effects of construction products on indoor air. Different ways to improve indoor air quality were reviewed, ranging from source control to education of occupants on how to manage the built environment to achieve healthy and acceptable indoor air. Through a literature study, organised workshops with scientific experts and building professionals, as well as via interviews with three stakeholder groups: producers of construction products, architects and housing corporations; requirements for information, guidance and actions to improve indoor air quality were identified. These requirements formed the basis of a possible approach to improve indoor air quality: education and awareness, regulations and policies and further research and development (Bluyssen et al., 2010). According to a study to assess people's awareness about indoor air pollutants and the effects on health, the result showed a very low level of awareness among Kuwaiti students, however, teachers did demonstrate more awareness, but the overall result showed a general lack of awareness and knowledge among the participants (Khamees and Alamari, 2009) .

Therefore, it is not only important to create awareness and mitigate against the effects of poor IAQ in existing buildings, it is important to get a 'heads start' right from the project level. All project participants that have some influence on IAQ (Architects and Designers, M&E Engineers, User, etc.) must be involved. When projects are managed and controlled in a manner that eliminates or reduce the possibility of moulds growing, dampness occurring, materials emitting toxics gases in building, out door air quality (OAQ) compromising (IAQ), etcetera; then families can be safe, children would avoid unnecessary exposure to toxic gases, and we would have healthy homes.

1.2 Research Rationale

Indoor air quality is a major contributor to the quality of people's lives and is affected by the presence of many pollutants related to building materials, furnishings, and human activities. This is a very serious problem in most industrial and developed countries around the globe, and Kuwait indoor environment is no exception.

Most Kuwaiti residents are aware that outdoor air pollution can damage their health, but may not know that indoor air pollution can also have significant effects (Khamees and Alamari, 2009). Many people are oblivious about the different indoor generated pollutants that exist within the walls of our homes. Without adequate circulation, humans are exposed to different indoor pollutants that; are trapped within the home, and can cause serious health problems. Kuwait is a hot arid climate, and as such, most people tend to spend a high percentage of their time indoors, thus increasing exposure to indoor air pollutants. In addition, buildings are well sealed from the outside to increase the efficiency of heating and ventilating air conditioning systems (HVAC) for indoor air quality (IAQ) and thermal comfort. This again, increases exposure to built-up indoor air pollutants. IAQ can be defined as the nature of air that affects an occupant's health and wellbeing (Bauhamra and Elkilani, 2001).

In Kuwait, buildings are air tight due to the harsh, hot weather; and to keep them cooled, most buildings recirculate cooled air through a cooling process, which also traps most of the pollutants, preventing them from escaping outside. Additionally, no fresh air supply exists other than insufficient air infiltrating from outside through doors, windows or cracks on wall systems. Therefore, pollutant concentrations could increase to such a level that it is higher than outdoors, adding to this problem there are neither building regulations nor codes which exist to control the pollutants indoors during the architectural design phase nor construction process phase. There are no enforceable indoor air quality standards; therefore, indoor air could be more polluted, indeed many times more than outdoors causing very serious illness and concern (Bouhamra 1996).

Achieving 'good IAQ' in Kuwaiti housing through proper design, construction, and maintenance, is the aim of this research. Good IAQ is defined by the absence of harmful or unpleasant constituents (ASHRAE, 2009). Many poor design decisions can lead to poor IAQ. For example; having inadequate space for mechanical equipment, limiting access for inspection and maintenance, and selection of interior finishes that can lead to high levels of volatile organic compound (VOC) emissions (ASHRAE, 2009). Such decisions are usually made in the early stages of design and are difficult to modify or correct later on. Basic, early, design decisions related to site selection, building orientation, and location of outdoor air intakes and decisions on how the building will be heated, cooled, and ventilated are of critical importance to providing good IAQ (ASHRAE, 2009). If all project stakeholders commit to 'good IAQ' from the early stages of design, and maintain that level of commitment through construction and occupancy then, we will have more high performing and healthy buildings in Kuwait.

1.3 Research Questions

How do we improve IAQ in Kuwaiti Housing Developments at Design, Construction, and Occupancy Stage?

1.4 Aim

The aim is to develop a framework for improving Indoor Air Quality (IAQ) in Kuwaiti Housing Developments at Design, Construction, and Occupancy Stage.

In order to meet the above aim, the following objectives are as follows:

1.5 Objective

1. To explore previous related research studies in the field of IAQ
2. To identify the current status quo in IAQ in Kuwait
3. To conduct a survey with Kuwait construction professionals regarding IAQ issues and to find the barriers to implementing IAQ best practice in all stages of the project.
4. To develop a framework for achieving good IAQ in Kuwait housing development.
5. To refine and validate the framework.

1.6 Justification and Contribution to Knowledge

Indoor air pollution may cause or aggravate illnesses (Daisey et al., 2003, Mendell, 2007), increase mortality (WHO, 2010), and have a major economic and social impact (Fisk and Rosenfeld, 1997, Fisk, 2011). Most people spend 90% of their time indoors: at home, in school, in shopping malls, in offices (Bouhamra 1996). Indoor air research is a multidisciplinary task, highly skilled teams including scientists from various disciplines such as medicine, chemistry, biology, engineering, architecture, and building sciences are generally required (Maroni, 1995). In Kuwait, outdoor air is regulated by the Kuwait environment authority, and studies conducted in Kuwait showed ambient air is polluted many more times in urban areas than the international standard (Bouhamra 1996; (Bouhamra 2012). Additionally, the Kuwait environment authority have specific guidelines for some pollutants in outdoor air and some guidelines for industrial buildings, but no specific indoor air standards nor guidelines (Bouhamra and Elkilani, 2001).

Many countries around the globe have indoor air quality management (IAQM) strategies for housing and school after they have been constructed, and during occupancy (Hall et al., 1995, Beaulieu, 1998, KEPA, 2011). A pilot interview with a few construction professionals in Kuwait revealed that there were no policies in place for monitoring and controlling IAQ in housing developments and belief was that the responsibility for such a policy rests with the ministry of education. They also stated that there was a lack of understand and/or focus on indoor air quality (IAQ) during design, construction and occupancy phases of Kuwaiti residential developments. Given the benefits of good IAQ and the serious problems that could arise from poor IAQ, this study contributes to the body of literature by developing a framework for improving Indoor Air Quality (IAQ) in Kuwaiti Housing Developments at

Pre-Construction, Construction, and Occupancy Stage; and this will be a useful tool for decision makers and key stakeholders on construction projects so that good IAQ can be achieved for the sake of occupants, and owners alike.

1.7 Conceptual Framework

From face value, of the researcher's industry experience and interaction with professionals in the industry in Kuwait and some literature review on indoor air quality improvements on projects, the below conceptual framework appeared to be the process to achieve IAQ improvements on Kuwaiti Housing developments.

Firstly, the research realised that in Kuwait, the problem and barriers of IAQ improvements need to be identified. Secondly, policies and regulations need to be drafted by the Kuwait Municipality, as there is currently no governing document in Kuwait that construction professionals can refer to for standards and regulations. The only accessible documents are international standards such as ASHRAE. Construction professionals in Kuwait need also to be educated and trained in these policy and regulation document so that proper implementation can be achieved. Thirdly, proper implementation would involve inspections from the Kuwait Municipality and also certification of architects and engineers with respect to their knowledge and achievement of good IAQ on their projects. Fourth and lastly, results of good IAQ are documented and fed back into the process as a form of knowledge management for future use.

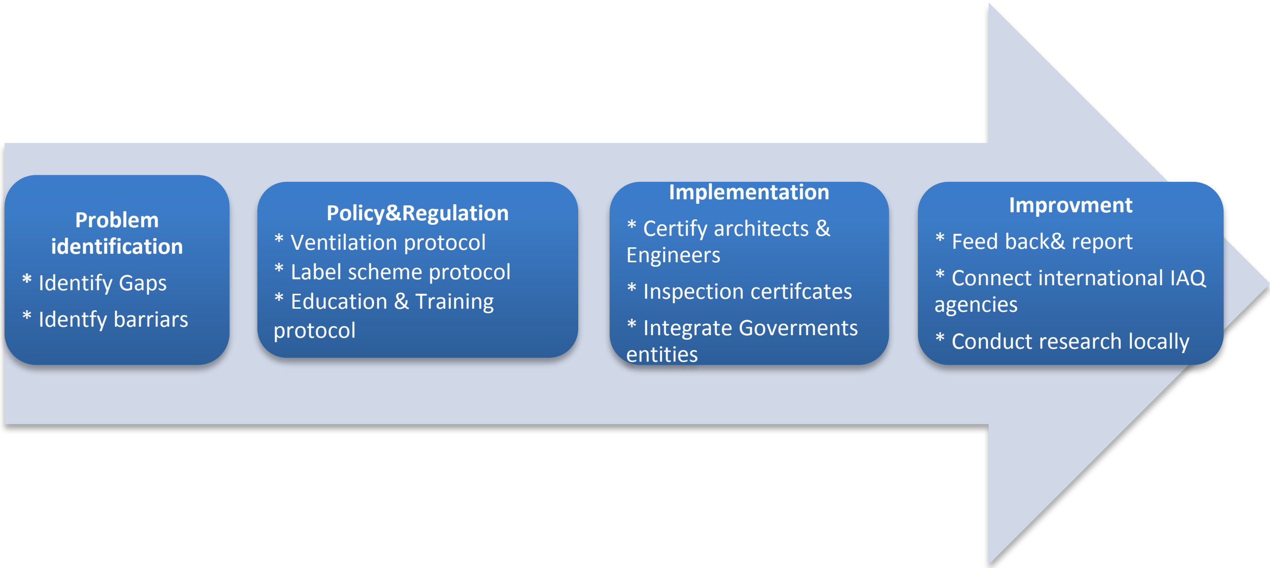


Figure 1.1: Conceptual Framework

1.8 Ethical Issues of the study

It is part of academic research to state the ethics that guided the research. The sample group that were chosen to participate came from a pool of construction professionals whose duties or responsibilities on a housing project affected achievement of good IAQ directly or indirectly in Kuwait. For example, architects and designers, contractor, facilities manager, mechanical and electrical (M&E) engineers, IAQ and HVAC specialists, etcetera. The individuals that participated in the research were assured of the confidentiality or their responses and that they both their names and companies will remain anonymous. The invitation letter for participation included anonymity and confidentiality clauses as well as the brief review of the research, the reason why their participation mattered, and that participation was completely voluntary, which meant they could pull-out at anytime if they did were not happy about it. The participants were also given a rough idea of how long the interview or questionnaire will take to complete should they choose to participate or respond. Finally, the respondents or participants were assured that after the research the data collected will be handle according to the Research Ethics Framework (REF) set out in the Economic and Social Research Council (ESRC, 2010).

1.9 Thesis Guide

The researcher intends to affirm the originality of the research study by stating that the study is the first of its kind to be carried out in the area of improving good IAQ in Kuwait housing developments at design, construction and post construction stages.

Chapter 1: Is the *introduction* to the research background, research justification and rational, the research aims and objective, and research questions. The chapter states the knowledge gap in Kuwait that it intends to fill by developing with the aid of empirical research, a framework for improving the achievement of good IAQ in Kuwait housing developments at design, construction, and post-construction or occupancy stages.

Chapter 2: Gives a general review of literature on indoor air quality (IAQ) around the world, and how it is achieved. The chapter looks at present and previous research works on IAQ conducted on the construction process, i.e. at design construction and post-construction. A broad overview of household pollutants, and effects, are given and discussion on international standards and regulation are also given.

Chapter 3: This chapter gives an overview of the, geographical, and environmental conditions of Kuwait as a whole. This includes the climatic conditions, and the human main activities (refineries, transportation, industrial, etc.) that contribute to the pollution of the environments especially the ambient air surrounding residential and commercial areas. This is important because to a large extent, good IAQ in Kuwait depends on the cleanliness of the outside air, which is used to clean the inside air, since Kuwait residents also depend on natural ventilation.

Chapter 4: This chapter states the chosen research approach or method which justifies the best way to answer the research question achievement of the aims and objectives. The chapter contributes to the strength and validity of the research study as it states the research's philosophical position, research approach, research design, sample selection, data collection and analysis techniques.

Chapter 5: This is the chapter that documents the research's data collection and analysis. Here, the quantitative data (questionnaire information) gathered is presented in the form of tables, graphs, and charts which aided in the understanding and analysis of the data. The qualitative data was coded according to themes, which encapsulates activities the are done at the design, construction, and post-construction stages to improve the achievement of good IAQ on a housing project in Kuwait.

Chapter 6: This chapter documents the development of IAQ framework based on the findings from chapter 5. The framework covers the three phases of a construction project; design, construction, and post-construction (occupancy). The framework is structured around RIBA Plan of Works 2013 (based on a traditional method of procurement) and greatly influenced by ASHRAE (2009) and Kuwait Environment Public Authority (KEPA) (2011). Effective project processes are expected to streamline design, construction and post-construction activities so that the best possible IAQ environment can be achieved. RIBA stages; strategic definition, preparation of brief, concept design, developed design, technical design, construction, and handover, were combined with ASHRAE project processes; using an integrated design approach and solutions, commissioning to ensure that the owner's IAQ requirements are met, and selecting HVAC systems to improve IAQ and reduce the energy impacts of ventilation.

Chapter 7: After the framework was developed, it was necessary to validate it using member checking to ensure the reliability, credibility, comfirmability, transferability, and generalizability of the framework and findings were achieved. In succinct terms, it is the process by which the accuracy of the findings and the framework was to be assessed, and from which the feedback was used to improve the framework.

Chapter 8: Here, the thesis concludes with an overview of the whole thesis and findings. The thesis also gives recommendations on how to better improve the achievement of IAQ in Kuwait housing project.

2 CHAPTER TWO| LITERATURE REVIEW

2.1 Introduction

The Literature review is structured into sections to include definition of Indoor Air Quality (IAQ), sustainable architecture and urban development, building construction, healthy buildings, indoor air quality and occupant wellbeing, illnesses caused by buildings, indoor contaminates, and relationship between indoor air pollution and health.

2.2 What is indoor air quality (IAQ)?

According to the United States Environmental Protection Agency (USEPA) (2016), "Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants." Contrary to popular belief, indoor air can be even more polluted than outdoor air. Most people think of air pollution as something outside -- smog, ozone, haze hanging in the air, or some smell from a chemical factory nearby. But the truth is, the air inside homes, offices, and other buildings can be more polluted than the air outside (Books and Davis, 1992). Common pollutants found in the air inside homes are: lead (in house dust), formaldehyde, fire-retardants, radon, microscopic dust mites from moulds, even volatile chemicals from fragrances used in conventional cleaners. According to Books and Davis (1992), some pollutants are tracked into the home via a new mattress or furniture, carpet cleaners, or a coat of paint on the walls.

Poor Indoor Air Quality (IAQ) is among the top five environmental risks (USEPA, 2016). Improving IAQ in buildings can greatly improve the wellbeing of occupants. Pollutants in a building's air can cause dizziness and headaches as well as aggravate allergies and asthma. While cleaning and vacuuming can improve indoor air, cleaning alone will not solve IAQ problems. Good IAQ carries numerous, valuable benefits. It helps improve the health, productivity of employees and happiness of occupants, decreases absenteeism, increases learning and student performance levels and creates a more positive customer experience (Lennox, 2016). Benefits of good IAQ has also been tied to greater return on investment (ROI) and bottom-line economics (ASHRAE, 2009).

Problems related to poor IAQ have been greatly documented and available for consumption yet many building design and construction decisions are made without taking into consideration the potentially serious consequences of poor IAQ. For as long as man started to systematically building his home, ventilation has been a major design factor. In the last century, the awareness and concerns about IAQ issues has steadily come into the lime light and is a strong factor when designing and constructing any habitable structure. However, according to ASHRAE (2009), *"in most cases IAQ is still not a high-priority design or building management concern compared to function, cost, space, aesthetics, and other attributes such as location and parking."*

2.3 Indoor Air Quality and Occupants' Wellbeing

Indoor allergens and irritants need particular attention in this decades and going forward because we're spending more time indoors, and because modern homes are airtight, these irritants can't easily escape (Books and Davis, 1992). Most people spend about 90% of their time indoors every day – at home, at work or school (Klepeis et al., 2001, Jacobs et al., 2007). This means that a level of occupant's wellbeing, in relation to the indoor air quality, thermal, visual and acoustical comfort has to be achieved.

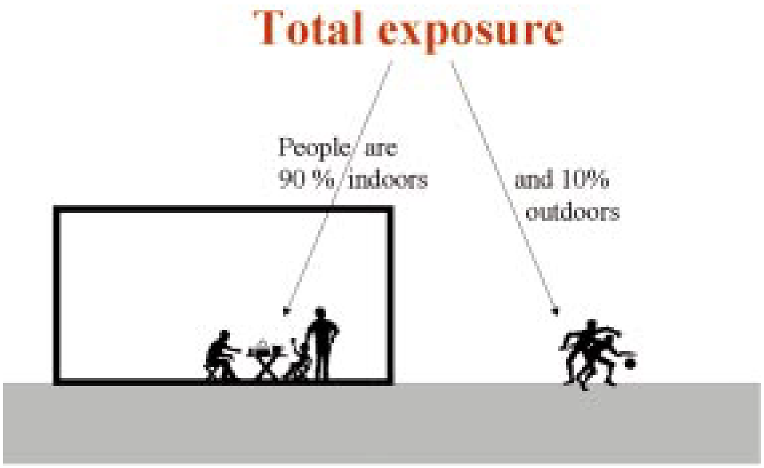


Figure 2.1: Time typically spent indoors and outdoors

Source: European Commission (2003)

Similarly, USEPA tests levels of pollutants are 2 to 5 times higher indoors than outside, regardless of whether the buildings are located in rural or highly industrial areas. Other recent scientific studies have also questioned the quality of air inside our homes and buildings (Waterfurnace, 2016). A typical breakdown of time allocation is shown in Figure 2.2 below.

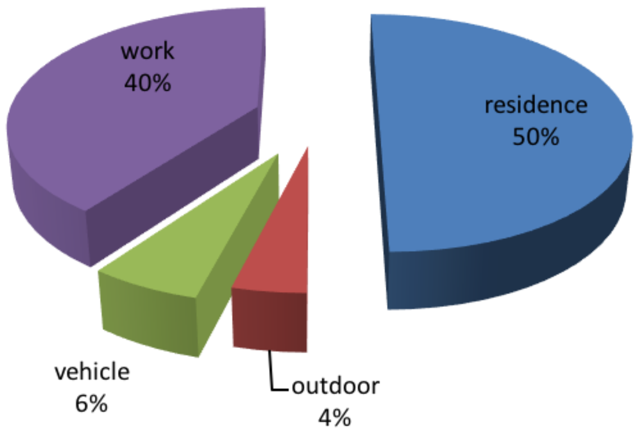


Figure 2.2: Daily time allocation (Source; Jacobs et al., 2007)

The rapid development of new building materials, furnishings, and consumer products over the past 50 years has resulted in a subsequent increase in new chemicals in the built environment (Weschler, 2009). Weschler found that there has been a sudden increase in the number of chemicals manufactured and used in household and building products, including construction materials, interior finishing materials, cleaning agents, furnishings, computers and office equipment, printers and supplies.

People exposed to indoor air pollutants for long periods of time become more susceptible to the effects of indoor air pollution than those who are not. The reality of the types of illness and the amount of fear felt by people is shown in the following figure.

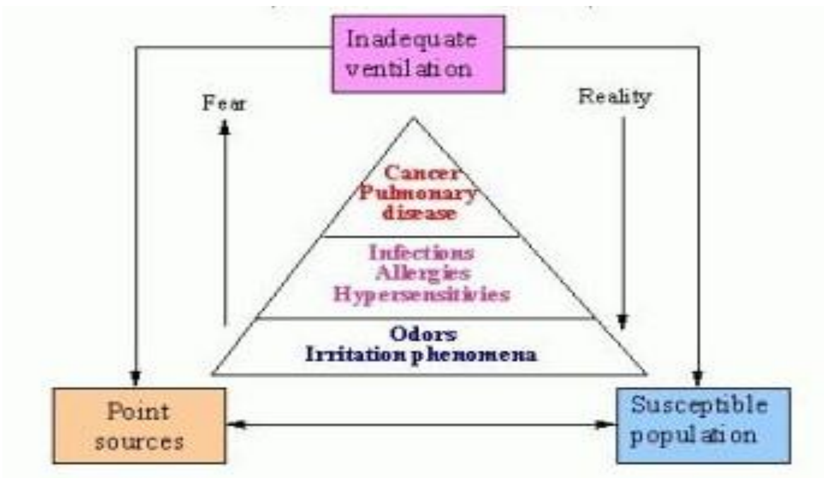


Figure 2.3: Understanding indoor air quality (Brooks and Davis, 1992)

The people most susceptible include; the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

There have been many definitions provided for appropriate indoor air quality (IAQ), one definition describes the absence of air contaminants which may impair the comfort or health of building occupants (Rousseau, 2003). Contaminants can also be defined as chemical, physical or biological contaminants in the breathable air inside a habitable structure or conveyance, including workplaces, schools, offices, homes, and vehicles (Jacobs et al., 2007). Exposure to pollutants may cause a variety of effects ranging in severity from perception of unwanted odours to cancer (EC, 2003). Examples of health effects are dispersal of airborne infectious disease, micro-organisms in air humidifiers causing pneumonia and humidifier fever, mould increasing risk of allergy, and an increased risk of lung cancer through exposure to environmental tobacco smoke (ETS) and radon (Crump et al., 2009; ASHRAE, 2009). Sensory effects include:

- Adverse health effects on sensory systems
- Adverse perceptions such as annoyance reactions and triggering of hypersensitivity reactions
- Sensory warnings of harmful factors such as irritation due to formaldehyde.

It can be seen that there are significant and serious implications of poor IAQ. The sources of indoor air pollution are shown in Table 2.1 below.

Table 2.1: Sources of Indoor Air Pollution (Source: Crowther, 1994)

Type	Agents	Subcategory	Example
Chemical	Inorganic	Gaseous	NO_2, CO, SO_2, O_3, Chlorine
		Particulate	Dust (lead, copper, wood), mineral fibres
	Organic	Toxic	Formaldehyde, solvents (toluene, styrene), pesticides (lindane, Tributyl tin oxide)
		Carcinogenic	Nickel compounds, primers (lead), chromates, vinyl chloride, pesticides (arsenic, creosote)
Biological	Microbes	Viruses	Influenza, colds,
		Bacteria	Legionella pneumophila, Plague
		Fungi, moulds	Spores, toxins, Mycotoxins
	Plants	Seed plants	Pollen
	Arthropods	Mites	Housedust mite faecal Pellets
		Vectors	Protozoa Parasites: malaria, Chagas' disease
		Other Insects	Flies, bugs, Cockroaches
	Others	Rodents Pets	Rats, mice Skin scale, fur, feathers Droppings
Physical	Sensible	Temperature	Hypothermia, heat, stress
		Humidity	Dry mucous membranes
		Light	Circadian
		Sound	Dissynchronisation, glare Noise pollution
	Insensible	Electromagnetism ionising	Radon

Poor indoor air quality is not a new phenomenon. There is more than enough documented evidence from century ago on the issues concerning IAQ. Waterfurnace (2016) reiterates the statement made by the Health Reformer in 1871: *"In the construction of buildings, whether for public purposes or as dwellings, care should be taken to provide good ventilation and plenty of sunlight… school rooms are often faulty in this respect. Neglect of proper ventilation is responsible for much of the drowsiness and dullness that make the teacher's work toilsome and ineffective."* In addition, learning becomes difficult for pupils. The above quotation by the Health Reformer captures the rationale of this research – the need for better design and monitoring during construction to ensure effective and efficient IAQ systems within residential buildings.

Needless to say, there are great economic impacts of poor indoor air quality (IAQ) on countries that fail to do something about it. Such impacts include direct medical costs and lost earnings due to major illness, as well as increased employee sick days and lost productivity while on the job (EC, 2003). However, knowing the exact costs, in terms of money, to the government is complex to calculate. In most cases, it is just estimation because of the difficulty in measuring costs related to social health and behavioural studies in general not only with regards to IAQ. Calculations of the social costs of poor IAQ would need to consider the costs for IAQ induced illness, direct medical costs and disabilities, reduced working efficiency, secondary costs related to discomfort and annoyance caused by deteriorated IAQ as well as the loss of productivity and material and equipment damages (EC, 2003). All these variables make it really hard to ascertain the exact economical cost of poor IAQ to society. The European Commission defined the 'total social cost' of poor IAQ on society as *"a quantitative expression of the impact of deteriorated IAQ on economic activity, health and well being."* But this figure is still very hard and complex to calculate or estimate. However, the figure is said to be immense (EC, 2003). ASHRAE gives an example of the high cost of poor IAQ in their 2009 guidance document. The example can be seen below.

"The costs of poor IAQ can be striking. There have been many lawsuits associated with IAQ problems, though most are settled with no financial details released. However, some publicly disclosed cases have involved legal fees and settlements exceeding $10 million. For example:

- In 1995, Polk County, Florida, recovered $47.8 million in settlements against companies involved in the construction of the county courthouse (including $35 million from the general contractor's insurer), due to moisture and mold associated with building envelope problems. The original construction cost for the building was $35 million, but $45 million was spent to replace the entire building envelope, clean up the mold, and relocate the court system.

- Occupants of a courthouse in Suffolk County, Massachusetts, received a $3 million settlement in 1999 following a series of IAQ problems associated with a combination of inadequate ventilation and fumes from a waterproofing material applied to the occupied building

Numerous IAQ problems have also occurred in private-sector buildings, but these tend to be settled out of court and are therefore not in the public record. As in public buildings, the causes of the problems vary and the settlement costs can be very expensive. A conservative estimate puts the lower bound of litigation costs during the early 2000s well over $500 million annually."

It is alleged that due to some ill-advice and poor judgment on cost-saving exercises in the design, construction, layout and operation of many new builds and retrofits, employers suffer far greater costs from employee's ill health and reduced productivity. The European Commission states that the benefits of good IAQ should be as clear as day, yet, many owners allow their buildings to be plagued with indoor pollutants (poor IAQ) all caused *"by a senseless energy-saving policy, bad HVAC design or malfunctioning installations due to poor maintenance or lack of commissioning. 'Low cost buildings' can cost society and business life much more than they gain from energy or other savings… Improving the indoor air quality in domestic and non-industrial commercial buildings is probably one of the most profitable investment society and the business world can make."* There are many low cost measures that can improve IAQ in residential and work environments. However, most buildings especially office and commercial buildings would require increased energy use to operate the HVAC systems, and also increased maintenance cost to monitor and control IAQ problems effectively and efficiently.

There have been major documentations of the impact of poor IAQ on employee health and productivity. Absenteeism and reduced productivity translates into loss of income for the employer and perhaps cause business failure. Therefore, *good indoor air quality is good business* (Fisk, 1997). Wyom (1993; cited in EC, 2003) gives fourteen impacts of poor IAQ. When these are measured and translated in monetary form the cost is immense.

- Absence from work, from workstation; unavailable on telephone
- Health costs, including sick leave, accidents, injuries
- Observed downtime, interruptions
- Controlled independent judgments of work quality, mood, etc.
- Self-assessments of productivity
- Component skills, task measures, speed, slips, accuracy
- Output form pre-existing work-groups
- Total unit cost per product or service
- Output change in response to graded reward
- Voluntary overtime or extra work
- Cycle time from initiation to completion of discrete process
- Multiple measures at all organizational levels
- Individual measures of performance, health and well being at work
- Time course of measures and rates of change

2.4 Buildings Illnesses

Two expressions have been associated with illnesses caused by poor indoor air quality, such as sick building syndrome (SBS), building related illness (BRI) and environmental sensitivity. These will now be addressed in the next section. SBS varies in a number of ways from building related illness. The symptoms of sick building syndrome are predominantly non-specific, that is they are not readily identifiable to one illness, or one contaminant source. While, BRI as illnesses arising from exposure to indoor contaminants that cause a specific clinical syndrome (Samet, 1993; Spengler and Sexton, 1983)

2.4.1 Sick Building Syndrome

The Institute of Environmental Epidemiology (IEE) (1996) refers to sick building syndrome as an excess of work-related irritations of the skin and mucous membranes and other symptoms (including headache and fatigue) reported by occupants in residences or modern office buildings. The World Health Organisation (WHO) (2010), listed the following symptoms as those most commonly attributed to sick building syndrome:

• Eye, nose and throat irritation;

• Sensation of dry mucous membranes and skin;

• Erythematic;

• Mental fatigue;
• Headaches;
• High frequency of airway infection and coughs;
• Hoarseness, wheezing, itching and unspecified hypersensitivity;
• Nausea and dizziness.

Characteristically, the symptoms of sick building syndrome are prevalent in 20% or more of the building's occupant population, as opposed to building related illness which normally only affects a few occupants (Spengler and Sexton, 1983, Samet, 1993).

2.4.2 Building Related Illnesses

The nature of a building related illness is dependent on the contaminant present within the building. For example, exposure to bio-aerosols can cause illnesses such as humidifier fever and hypersensitivity pneumonitis, whereas exposure to the legionella bacteria precipitates Legionnaires' disease (Spengler and Sexton, 1983, Samet, 1993). These symptoms are not alleviated when the person exits the building. The most effective mitigation strategy for building related illness is to trace the illness to a specific contaminant and remove the source from the building. Identifying these two types of illnesses caused by indoor environments can sometimes create confusion when investigating an air quality problem. An added problem is that both illnesses can be present in the same building, and on some occasions a building related illness may be mistaken for sick building syndrome, or vice versa. These definitions are useful tools in assisting the identification of the problem, yet it is the alleviation of the health and indoor air problems, which are the highest priority, above classification. In contrast, the term "building related illness" (BRI) is used when symptoms of diagnosable illness are identified and can be attributed directly to airborne building contaminants.

2.5 Indoor Contaminants

Table 2.2: Sources and Types of Indoor Air Pollution(Crump et al., 2009)

Source	**Main pollutants**
Outdoor air	SO_2, NOx, ozone, particulates matters, biological particulates, benzene
Combustion of fuel	CO, NOx, VOCs, particulates matters
Tobacco smoke	CO, VOCs, particulates matters
People	CO_2, organic compounds
Building materials	VOCs, formaldehyde, radon, fibres, other particulates, ammonia
Consumer products	VOCs, formaldehyde, pesticides
Furnishings	VOCs, formaldehyde
Office equipment, including HVAC	VOCs, ozone, particulates
Bacteria and fungi	VOCs, biological particulates
Contaminated land	Methane, VOCs, contaminated dusts eg metals
Ground	Radon, moisture
Washing and cleaning	Moisture
Animals (eg. mites, cats)	Allergens

Crump et al, (2009) outline a number of indoor contaminants and their definitions. They are the following:

Volatile Organic Compounds (VOCs) are emitted over periods of weeks or years from construction and furnishing products and have the potential to cause poor air quality. There is a growing interest in release of VOCs from consumer products including electrical goods such as computers and printers as well as cleaning products and air fresheners. ETS contains a complex mixture of organic compounds and while smoking is banned in the workplace and public buildings in many countries, it remains a significant source of airborne pollution in many homes (ASHRAE, 2009).

Formaldehyde: is a very volatile organic compound (VVOC) that has been widely studied because of its release from a range of building and consumer products. Semi-volatile organic compounds (SVOCs) have a relatively low vapour pressure and therefore tend to occur at lower concentrations in indoor air than the more volatile VOCs. They include plasticisers used in polymeric materials such as vinyl floorings and paints, pesticides such as DDT and pentachlorophenol, and polycyclic aromatic hydrocarbons (PAHs) produced during fuel combustion and present in coal tar and in tobacco smoke.

CO2 is a natural constituent of air and only in exceptional circumstances is it present in sufficient amounts to be a danger to health. It can be present in buildings as a result of respiration of people and animals, as a product of combustion and as a component of soil gas. It is widely used as an indicator of ventilation rate and, effectively, as a proxy for body odour.

CO is a colourless, odourless gas, produced by the incomplete combustion of most fuels. Incomplete combustion can occur, e.g. when there is inadequate ventilation to an appliance.

Nitrogen dioxide (NO2) is emitted from gas-fuelled cookers, fires, water heaters and oil fired space heaters.

Sulphur dioxide (SO2) is produced by burning sulphur-containing fuels such as coal and oil. Ozone is primarily a pollutant of ambient air produced by photochemical reaction. It undergoes reaction indoors with surfaces and airborne pollutants to produce new organic compounds and particles. Water vapour is produced by people during activities such as cooking, cleaning and washing, as well as through normal respiration. The amount of water vapour in the air has direct effects on health and comfort and is also important in relation to the occurrence of biological pollutants.

Particle Pollution refers to a mix of very tiny solid and liquid particles that are found in the air, both indoors and outdoors, and which can be harmful to health. It is difficult to assess particle pollution because the particles themselves are different sizes, some are one-tenth the diameter of a strand of hair. Many are even tinier; some are so small they can only be seen with an electron microscope. Because of their size, individual particles cannot be seen, but together they appear as a haze which forms when millions of particles blur the spread of sunlight. This means that humans do not know when particles are being breathed, yet it is so dangerous it can shorten life. The differences in size make a big difference in how they affect health, natural defenses help humans to cough or sneeze larger particles out of our bodies, but those defences don't keep out smaller particles (those that are smaller than 10 microns in diameter, or about one-seventh the diameter of a single human hair). These particles get trapped in the lungs, while the smallest are so minute that they can pass through the lungs into the blood stream.

Researchers categorise particles according to size, grouping them as coarse, fine and ultrafine. Coarse particles fall between 2.5 microns and 10 microns in diameter and are called PM10-2.5. Fine particles are 2.5 microns in diameter or smaller and are called PM2.5.

Ultrafine particles are smaller than 0.1 micron in diameter and are small enough to pass through the lung tissue into the blood stream, circulating like the oxygen molecules themselves. No matter what the size, particles can be harmful to health, although the smaller particles are able to penetrate deeper into the organs (Al-Salem and Khan, 2010).

PM0.1 – particulate matter having a diameter smaller than 0.1 microns (100 nm).

PM10 – particulate matter having a diameter smaller than 10 microns.

PM2.5 – particulate matter having a diameter smaller than 2.5 microns.

The figure below shows sizes of particles as well as sizes of organic or biological components such as sizes of bacteria and viruses.

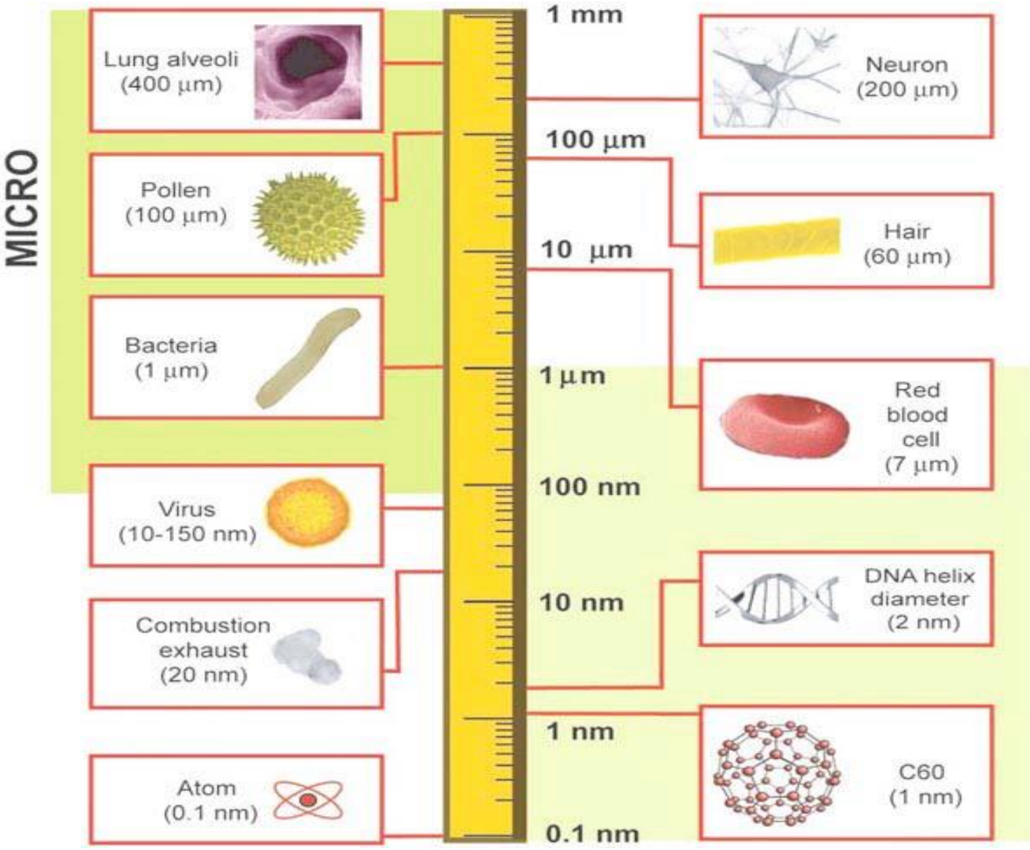


Figure 2.4: Logarithmical length scale showing size of nanomaterials compared to biological components and definition of 'nano' and 'micro' sizes

Source (Buzea et al., 2007).

Recent epidemiological studies have shown a strong correlation between particulate air pollution levels, respiratory and cardiovascular diseases, various cancers, and mortality (Buzea et al., 2007).

There is extensive scientific studies on the sources of indoor pollution including a number of reviews (Crump et al., 2004a, Pluschke, 2004, Fernandes de Oliveira E, 2009, Maroni, 1995, Morawska and Salthammer, 2003, Salthammer, 1999b, Crump, 2002, Bruinen de Bruin et al., 2005, Mendell, 2007), below in the table, showing the most common. Because most people spend most of their time indoors, the health effects due to exposure of both pollutants generated outdoors and those released indoors can be significant. It has been estimated that air pollution reduces the life expectancy of every person in the UK by an average of 7-8 months, with estimated equivalent health costs of up to £20 billion each year (Crump et al., 2004b). According to WHO (2000a), poor IAQ is believed to have an important causative or aggravating influence on the following diseases:

- Allergic and asthma symptoms
- Lung cancer
- Chronic obstructive pulmonary disease (COPD)
- Airborne respiratory infections
- Cardiovascular disease (CVD)
- Odour and irritation (SBS symptoms)
- Stress

Health effects from indoor air pollution vary greatly, depending on the types of pollution present, the concentration of each pollutant, and the relative susceptibility of the person. Some affects are acute such as asthma, hypersensitivity pneumonitis, and headaches; while others are chronic such as cancer, heart disease, COPD (Chronic Obstructive Pulmonary Disease), and others (Waterfurnace, 2016). These will now be explored in more detail.

Allergic and asthma symptoms

Allergic and asthma symptoms are increasing throughout Europe, affecting between 3-8% of the adult population with higher prevalence in infants (Mendell, 2007). Studies have been done in Kuwait which show the rate of prevalence of 16% in children (Behbehani et al., 2000), and another study done in Kuwait shows a higher prevalence at 23% of the children (Khadadah et al., 2009). Fisk et al (2007) state that the cause of allergic diseases is a complex interaction between genetic and environmental factors. For example asthmatic patients are sensitive to allergens present in the indoor environment and are often hyperactive to a number of gasses and particles. 30 to 50% increase respiratory and asthma related illnesses have been associated with building dampness and mould.

Lung cancer

Lung cancer is the most common cause of death from cancer globally. Most are due to bad lifestyle such as - smoking. But it is estimated that 9% are due to radon exposure in the home and 0.5% in males and 4.6% in females are due to exposure to environmental tobacco smoke (ETS). Also evidence suggests some risks have been associated with combustion particles including ultrafine and fine particles in ambient air, diesel exhaust and indoor cooking oil and coal burning (Lewtas, 2007).

COPD

COPD is a chronic respiratory disorder that is usually progressive and associated with an inflammatory response of the lungs to noxious particles or gases (WHO, 2004). It is estimated that the prevalence of clinically relevant COPD in Europe is between 4 and 10% of the adult population. About 70% of COPD related mortality is attributed to cigarette smoking. ETS, biomass combustion fumes, particles in ambient air and long-term exposure to mould/dampness are also attributed to COPD (Burden, 2003).

Airborne infectious diseases

Airborne infectious diseases include Legionnaire’s disease, tuberculosis, flu and SARS (Severe Acute Respiratory Syndrome). Reservoirs of aquatic systems such as cooling towers, evaporative condensers, and humidifiers, have been the source of airborne agents in spread of Legionella and pneumonia. Symptoms of these diseases can be irritated by exposure to ETS and combustion particles (Carrer, 2008, Oliveira Fernandes et al., 1995).

2.6 Benefits of good IAQ

The European Commission (2003) documents a number of benefits for ventilation of future rural and urban building developments in order to provide healthy IAQ and satisfactory indoor comfort for occupants. According to the commission, the present and future generation of occupants will be safe, and productive, because good IAQ will:

- Advance the health and well-being of building occupants
- Optimise energy use and save cost with comfort and productivity
- Minimize indoor and outdoor exposures to pollutants and other agents with adverse health effects
- Decrease life-cycle costs by avoiding adverse health effects, energy waste and unnecessary costs for operation, maintenance and rehabilitation of buildings
- Avoid the use of rare materials and encouraging a sensible recycling of other materials
- Avoid the use of materials and substances hazardous to the environment
- Not cause unwanted side-effects like noise, draught, added air pollutants, or spreading indoor or outdoor generated pollutants
- Help to maintain building and city designs and structures that are vital to social and economic values and social networks among individuals
- Help to preserve historical buildings and environments as well as respecting local architectural traditions in a cautious and aesthetic balance with new building and system designs
- Design and operating buildings and systems so that they make sensible use of climate and natural forces and can be adapted (over centuries) for shifting demands.

2.7 Ventilation in Relation to Pollution Sources

According to European Commission (EC) (2003), indoor air pollution is mainly determined by the outdoor pollution levels, and the ventilation system in relation to the pollution levels.

"The outdoor pollution level; That is,

- The amount of outdoor air 'imported' to the buildings by the different forms of ventilation
- The indoor pollution sources related to the occupants and their activities (cooking, copying,
- etc)
- The pollution from the building itself (building materials, energy systems…)
- The degree of cleaning of incoming outdoor and return indoor air

The role of ventilation in relation to the pollution levels is substantial:

- As far as the indoor pollution levels are concerned, ventilation is on the one hand bringing the outdoor pollutants into the building but on the other hand it is lowering the concentrations of pollutants indoors due to indoor pollution sources.
- Ventilation has also an impact on the outdoor pollution level. Building related pollution sources represent about 40% of the total pollution. Due to the increased thermal insulation levels of buildings, including envelope tightness, the importance of the ventilation related energy use is increasing and may represent up to 50% of the total energy use of a building, particularly for certain typologies such as office buildings"

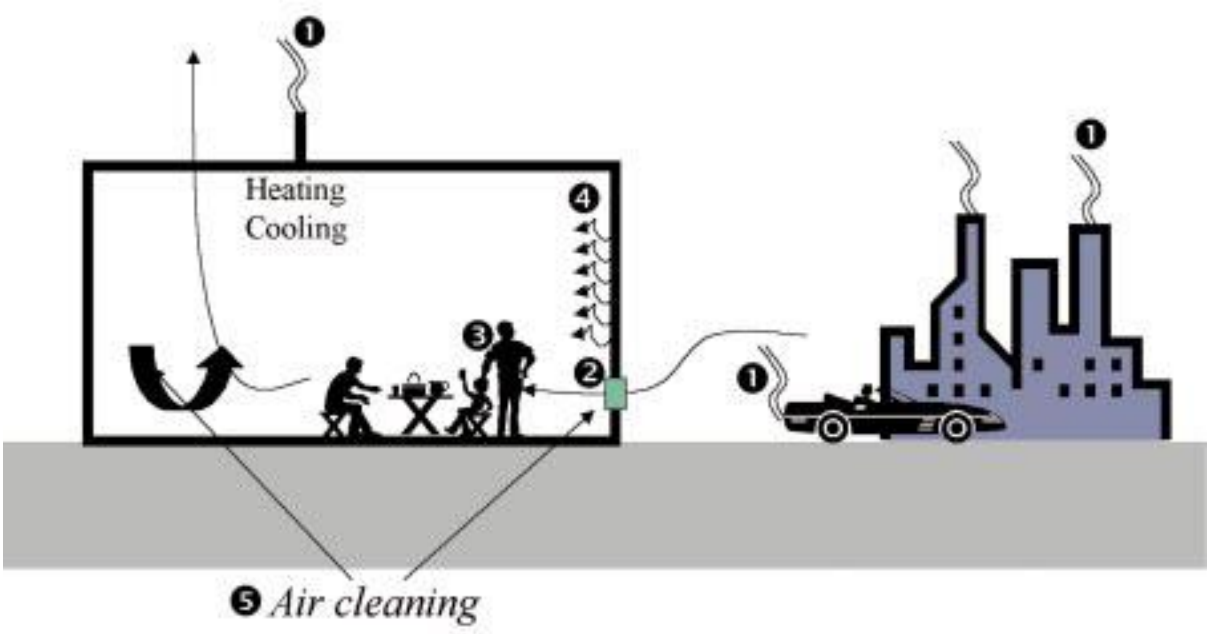


Figure 2.5: Pollution sources for indoor and outdoor air quality (source, EC, 2003)

However, by bringing in outdoor air, in the case of HVAC systems, the distribution ducts collect dust and other particulates, which in time makes the HVAC system a source of air pollution. Therefore, adequate and frequent cleaning must be done to preserve the cleanliness of the air pumped into the building. The illustration also twerps the assumption that outdoor air is cleaner than indoor air. Depending on the location and the nature of the activities done in a given environment, outdoor air could be more polluted than indoor air, which means open ventilation might not be the best option, rather a HVAC system. Although, country side air is said to be more 'clean'.

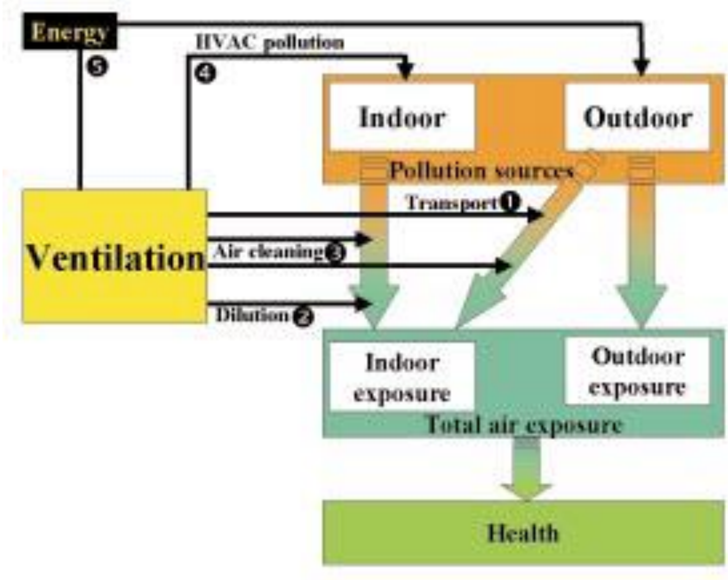


Figure 2.6: The Role of ventilation in relation to total air exposure (Source: EC, 2003)

2.8 Ventilation Systems

Ventilation can be classified into two types; natural ventilation, mechanical ventilation, and the hybrid ventilation systems. The latter is a ventilation system that is a combination of the former two. Natural form of ventilation is the most common type of ventilation found around the world. It is as simple as ventilating a room through openings, where air enters and exits the building or space through envelops; windows and doors. The quality of the indoor air, temperature of the air, and flow rate, depend entirely on the weather condition and of course, outdoor air characteristics. If there is high-pressure wind outside, the flow rate of natural ventilation increases, similarly, if it is summer or winter, the temperature will differ accordingly.

2.8.1 Natural Ventilation systems

There is also a form of natural ventilation that is aided by an exhaust fan, where, the fan extracts the pollutant from the room, while the room is being ventilated by opening windows. But natural ventilation is plagued a lot of limitations. Natural ventilation system does not have particulate filtration; it does not have temperature control, which means, whatever is the outside temperature (cold/hot) that will be the temperature of the air coming in. With natural ventilation, there is no insulation from outdoor noise, and consistent and irrational noise can cause serious health issues to residents, including and not limited to deafness, irritation, and discombobulating residents. Furthermore, natural ventilation systems cannot pressurise or depressurise buildings. And lastly, low ventilation rates in some weather conditions or low ventilation rates dues to buildings with small openings, could result in build up of pollutants that may make the building inhabitable by humans.

2.8.2 Mechanical Ventilation Systems

On the flip side, mechanical ventilation make use of fan powered air supply into the rooms and exhaust fan that takes the air out of the room. The ventilation supply air is sometimes heated by the exhaust air through the aluminium strip found within the HVAC system. These systems are mostly found in countries that do not need cooling systems as much because they are in cold climates. However, cooling and humidification are not possible. Other ventilation systems have heating, cooling and humidifying capability. On the other hand, these ventilation systems are found in countries in hot climate that need systems with cooling capability in order to ensure thermal comfort. Although, mechanical ventilation systems (HVACs) have a lot of advantages, they do have some risks. These include but not limited to; noise generation caused by the fans and pressured air generated by the fans, possible growth of micro bacteria if there is condensed moisture in the system, the components of the systems may become dirty or contaminated over the years of operation and the system may start to release pollutants and smells into the rooms, it is also possible that the dirt could come from unprotected ducts during construction and installation. If the mechanical ventilation system does not have cooling system, the kind found in European countries due their cold climates, at times when temperatures get hotter than usual, such as in unusual summers days, then thermal comfort is not attained using the HVAC system. According to the European Commission (2003) mechanical ventilations systems have been shown to cause adverse effects on residents. The commission states, that the reasons are not well known but could be linked to, but not limited to the following reason; "*air handling system is a source of pollution, moisture in air handling system causes the mould growth, system generates and transfers noise, ventilation air supply is poorly controlled, occupants cannot influence the ventilation."* As a result, surveys have found a puzzling fact in some instances, *"that people report themselves more satisfied with natural ventilation than with air conditioning and mechanically ventilated buildings this is the issue which may have major effect on the whole building design as natural ventilation has to be integrated into the architectural design from the beginning of the design process."*

Figure 2.7 shows a proposed real-time implementation for HVAC control system. "At intervals, also called 'sampling times,' the sample device feeds measured values of the indoor air condition, supply air condition and outdoor air condition to the optimizer. The optimizer then uses the values supplied at every interval to update the values of the controlled variables for the reference of the controller. A hold device is used to feed the updating values obtained from the optimizer in every holding time. Practically, the duration of the sampling time and holding time should be chosen to be short enough to catch up the dynamics of the indoor-air condition."

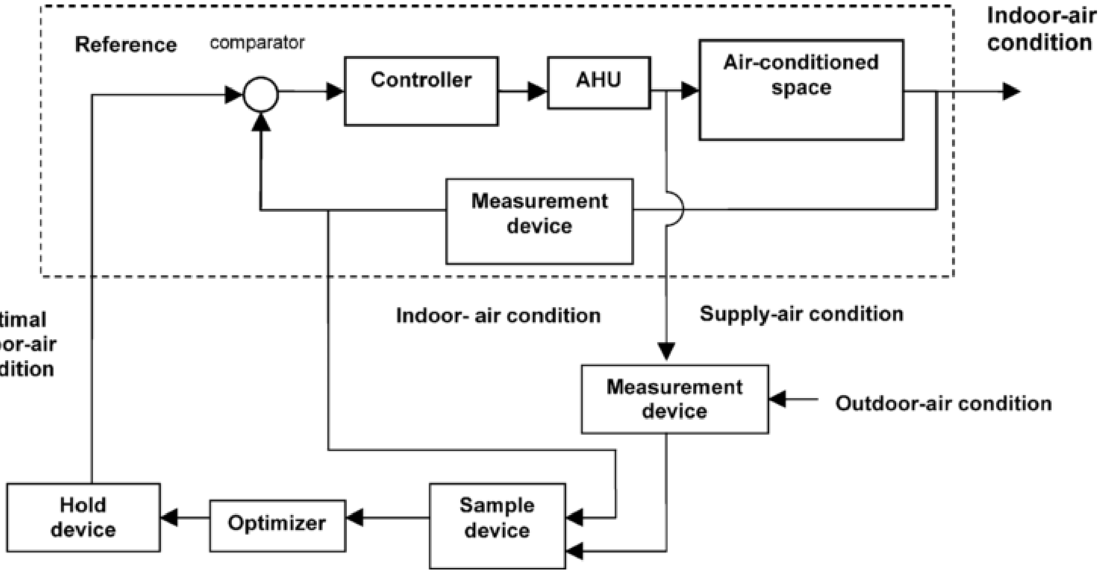


Figure 2.7: Proposed real-time implementation for HVAC control system

Source: Atthajariyakul and Leephakpreeda, (2004)

2.8.3 Hybrid Ventilation Systems

This ventilation system is an optimal combination of both natural and mechanical ventilation systems to achieve the best indoor air quality possible. Heiselberg, (1998) defined hybrid ventilation systems as: *"as systems providing a comfortable internal environment using different features of both natural ventilation and mechanical systems at different times of the day or season of the year. It is a ventilation system where mechanical and natural forces are combined in a two-mode system. The main difference between conventional ventilation systems and hybrid systems is the fact that the latter are intelligent systems with control systems that automatically can switch between natural and mechanical mode in order to minimise energy consumption and maintain a satisfactory indoor environment."* The European Commission adopted Wouters (2000) illustration of a Hybrid ventilation system and it is given below in Figure 2.8.

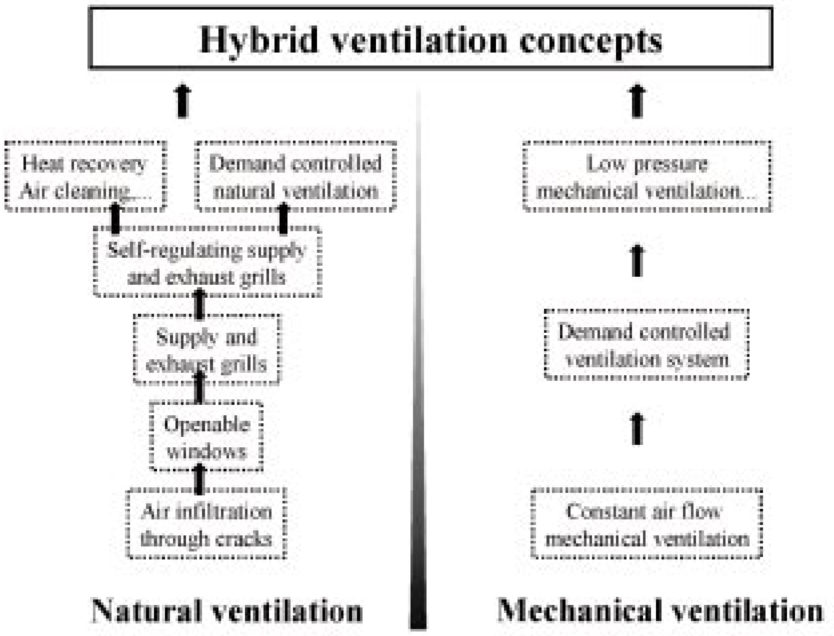


Figure 2.8: Merging the best of natural and mechanical ventilation. Source (EC, 2003)

As earlier mentioned, the decision on which ventilation system to choose depends on a number of factors and characteristics of air quality, flow rate, source control, air cleanliness, etc. However, Seppanen (1998) gave a number of strategies and ventilation technologies along side some parameters to aid in the selection of the right ventilation system for given buildings based on their estimated energy savings or use. Table 2.3 gives these strategies and technologies.

Table 2.3: Ventilation strategies for better indoor air quality and energy efficiency (Source: Seppanen, 1998)

Strategy or Technology	Phase of the technology	Indoor air quality	Estimated energy savings in ventilation
Target values for indoor climate	Available	Improved	Up to 60% depending on climate
Particulate filtration of intake air	Available	Improved	Minor effect on fan power
Chemical air cleaning	Developing	Improved	Up to 100% in ventilation, increase in fan power
Balancing of air flows	Available	Improved	10-20%
Better ventilation efficiency	Available/developing	Improved	Up to 50%
Location of air intakes	Available	Improved	No effect
Heat recovery for large buildings Houses	Available Available	No effect No effect	Upto 70% in heating Up to 50% in heating
Demand controlled ventilation	Available/developing	No effect	Up to 30-40%, up to 50% in large spaces

Control of specific pollution sources	Available	Improved	Depends on application
Control of material emissons	Developing	Improved	Up to 50%
Task ventilation	Available/developing	Improved	10-30%
Local exhausts	Available	Improved	Depends on application
Natural ventilation and free cooling	Available/developing	Improved	Up to 60%
Operation and maintenance	Available/developing	Improved	High (depends on initial level)

2.9 Sources of Indoor Air Pollutants

Different pollutant sources have different characteristics, toxicity, hazardousness, as such, the level of alert will differ. Some of these characteristics to consider are; the pollutant emitting capability i.e. how much pollutant does the source give off, hazardous nature of the emissions, proximity of occupants to the pollutant source, and the purifying capability of the ventilation system. Some common indoor air pollutant sources are:

Building Site or Location: The proximity of buildings to indoor pollutant sources can have a great influence on the air quality of the indoor spaces. For example, residential of commercial buildings located near highways and thoroughfares, construction sites, industrial and chemical plants may experience higher particulates and other pollutants levels.

Building Design: It is no surprise that poorly designed buildings, with respect to IAQ, will experience higher indoor air pollution because of the deficiency in ventilation as pollutants are trapped inside the buildings. Poor designs could be in unstable or weak foundations, leaking roofs, poorly designed facades, window and door openings, which may allow pollutant or water intrusion. Outside air intakes placed near sources where pollutants are drawn back into the building (e.g., idling vehicles, products of combustion, waste containers, etc.) or where building exhaust reenters into the building can be a constant source of pollutants (EC, 2003).

Building Systems Design and Maintenance: Broken down HVAC systems leave buildings vulnerable to outdoor pollutants which can find their way into the building from outside pollutant sources such as; particulates, exhaust from vehicles, smoke etc. In addition, changes to the building design or use should also incorporate changes or adjustments to the air-conditioning and mechanical ventilation system to accommodate the new changes either in temperature, humidity, or airflow.

Renovation Activities: Renovations are commonplace for dust and paint smells. Therefore, it is important that ducts and ventilation channels as well as the ACMV system be isolated and barriers put up to protect the ventilation ducts from collecting dust and other harmful particulates coming from construction materials. Also by so doing, other parts of the building are protected.

Local Exhaust Ventilation and Occupant activities: Areas where certain activities with high pollutant attributes take place, such as kitchen, motor garages, maintenance shops, barbershops and beauty salons, toilets, laundry, and trash rooms etc. should be highly ventilated.

Building materials and furnishings: Building materials and home furniture come away with pollutants from the factories and manufacturing plant. This furniture may be made of pressed wood, which releases particles into the air thereby compromising the indoor air quality. Building materials on the other hand can overtime, breakdown and begin to release pollutants or through some disturbance, like wetness, allow for molds to grow on walls and ceilings thereby compromising the indoor air quality.

2.10 Sustainable Architecture and Urban Development

Sustainability has become a wide-ranging concept that can be applied to almost every aspect of life on earth, from local to a global scale and over various time periods (ASHRAE, 2009). Sustainable buildings has been defined by the European Commission as buildings “that provide a liveable and healthy environment for their inhabitants and meet their needs without impairing the capacity of the local, regional and global environmental systems to satisfy the needs of future generations.”

The word sustainability is derived from the Latin sustinere (tenere, to hold). Dictionaries provide more than ten meanings for sustainability. The main ones being to “maintain", "support", or "endure (Dictionary.com, 2010). However, since the 1980s, sustainability has been used more in the sense of human sustainability on planet earth and this has resulted in the most widely quoted definition of sustainability and sustainable development, that of the Brundtland Commission of the United Nations on March 20, 1987: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987, Bossel, 1999).

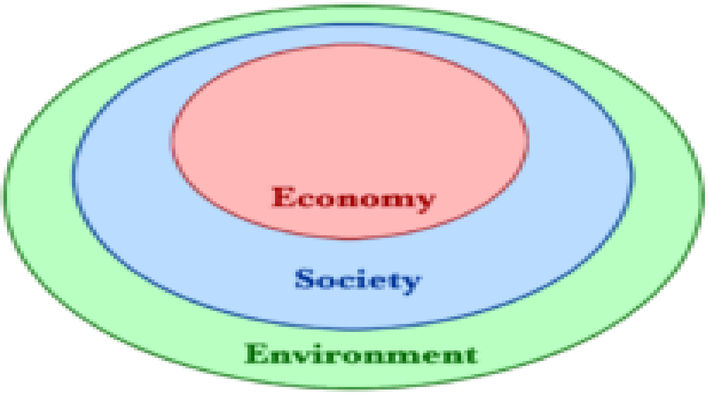


Figure 2.9: The three pillars of sustainability suggest that both economy and society are constrained by environmental limits (Cato, 2009)

Emhemed (2005) used the same definition and Sherlock (Sherlock, 1991) shares Brundtland's definition: "*Sustainability means living now in such a way that we do not threaten future life*". On the other hand, McDonough et al., (2003) think that "*Sustainable development is a tentative concept that has not been defined very well*". He argues that there is still much debate as to what the word sustainability actually means and suggests that in its original context, Brundtland's definition was only the human point of view. In order to embrace the idea of a global ecology with common values, the meaning must be expanded to allow all parts of nature to meet their own needs now and in the future.

The field of sustainable development can be theoretically broken into three parts: economic development, social development, and environmental protection (Adams, 2006).

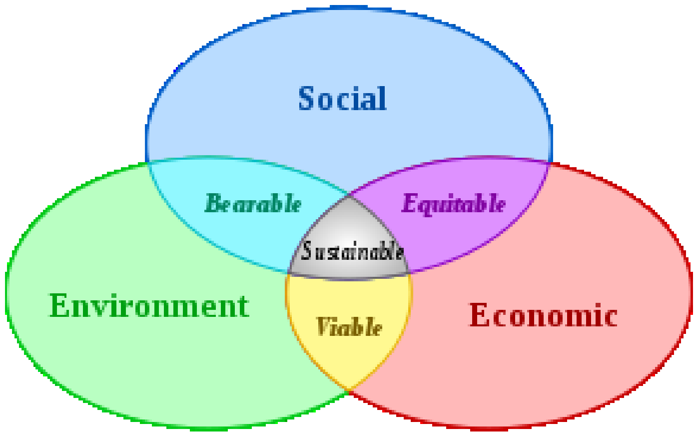


Figure 2.10: Scheme of Sustainable Development (Adams, 2006).

Evans (2007) clarified that the three domains of SD are the three basic aspects of sustainable development cited by Robinson:

- Energy in the built environment, on national and international scales;
- Environmental impact of the built environment, caused by energy use at local, regional
- Sustainability of the built environment

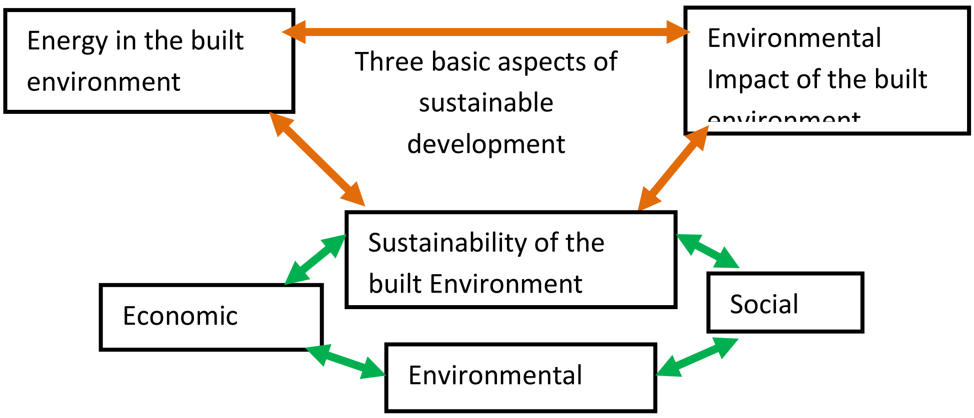


Figure 2.11: Aspects of Sustainable Development (Evans, 2007)

Cole and Lorch (2007) discussed a four sided model of sustainable development (SD), which includes; environment, equity, public participation and futurity. The different scales of response to SD in the urban environment are; sustainable construction industry, sustainable built environment, sustainable communities and global sustainability. Furthermore, they mentioned that there are a wide range of SD conceptual models, and none of which provides an adequate representation of sustainable urban development. A process model of SD has five aspects:

- SD is a relative, rather than an absolute concept;
- SD is a process, not a product or fixed destination;
- SD is concerned with a very long timeframe;
- SD is an ethical construct;
- SD must be culturally grounded

In general, sustainability deals with the relationships between human and natural systems (Curwell, 2003). Curwell defines sustainable “green” architecture as a planned effort at designing a built environment that is energy and ecologically considerate, both internally and externally. Accordingly, the main goal of SD in the built environment is to protect and improve the quality of life as well as looking to the needs of future generations; consequently, sustainable architecture and building play an important role for the future development of the built environment. The principles and the importance of sustainable architecture will be explained in the next section.

This section is important because it shows the importance of environmental aspects such IAQ and OAQ to sustainable developments.

2.11 Sustainable Architecture and Building Construction

Sustainable architecture and construction as a concept appeared more or less at the same time as the concept of sustainable development evolved. Sustainable design is the conception and understanding of environmentally sensitive and responsible expression as a part of the evolving matrix of nature (McDonough and Braungart, 2003). Sustainable buildings were described as those buildings that have minimal adverse effects on the natural environment, in its immediate surroundings and on the wider regional and global setting (Cofaigh et al., 1996). On the other hand, reductions in the consumption of energy was emphasised by Sherlock (1991) as a step towards sustainability, and argues that the best way for this is “…*to reduce our need to travel … to live in compact cities where everything is close at hand”* (Sherlock, 1991).

(Park, 1998) in his review, summarised four major principles of sustainable building design as follows;

1) Provide a healthy environment for the workplace by providing good ventilation;
2) Select building technologies and materials that are “green”, such as using local materials;
3) Consume less energy in the new systems in the building than market standards;
4) Have a recycling plan for waste and water.

On the other hand, (John et al., 2005) had added another parameter in his paper about sustainable building solutions, he listed the five objectives of sustainable buildings as; resource efficiency, energy efficiency (including greenhouse gas emissions reduction), pollution prevention (including indoor air quality occupant wellbeing and noise abatement), harmonisation with environment, and integrated and systemic approaches.

2.12 Healthy Buildings

Indoor environmental quality refers to all aspects of the indoor environment that affect the health and well-being of occupants. This must include not only air quality but also light, thermal, acoustic, vibration, and other aspects of the indoor environment(Levin et al., 1995). Seven indoor environmental factors that can impact the health of humans have been called the "Seven Sisters." (Flatheim, 1991 cited by; Dumont, 2008b). The factors that comprise indoor air quality are as follows: lighting, temperature, sound and vibration, electromagnetic fields, flora and fauna, and the psychological and social environment (Dumont, 2008a)

With respect to the indoor environment, a healthy building is one that does not adversely affect the occupants. Some authors suggest that it should even enhance the occupants’ productivity and sense of well-being to be considered healthy (Lavin et al., 2006). Thus, it is not only the absence of harmful environmental characteristics but also the presence of beneficial ones that defines a healthy building. Issues of functionality, practicality, building science, occupant comfort, safety and health, should be considered in order to achieve a successful and beautiful building, as depicted in Figure 2.12.

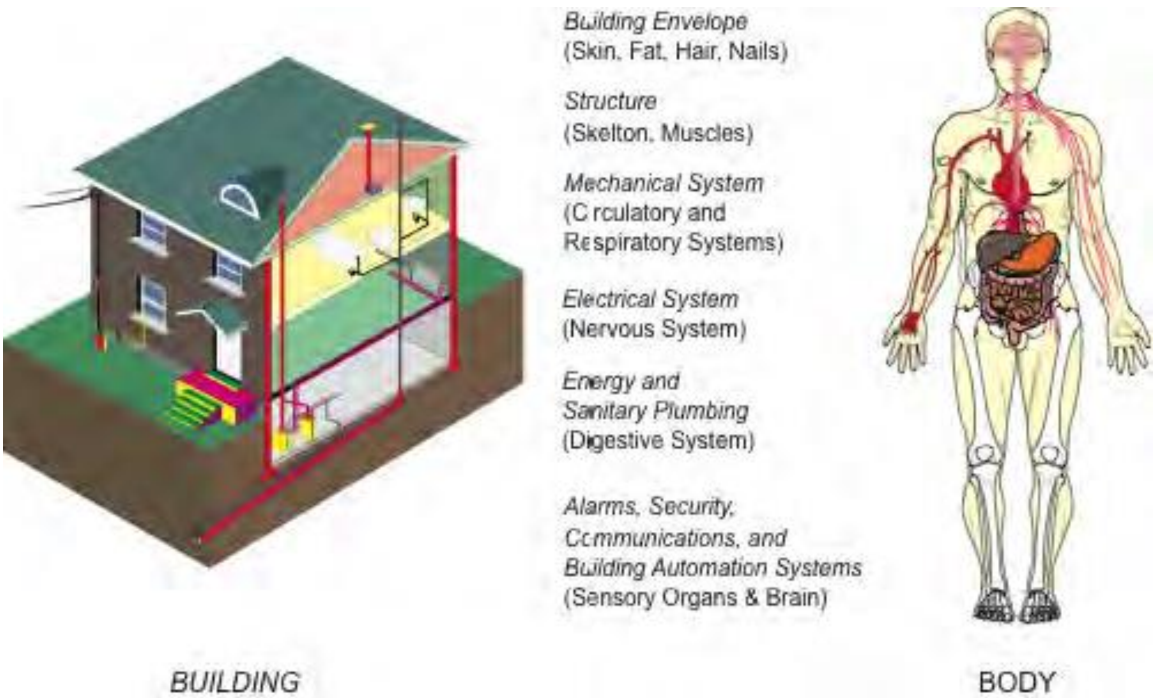


Figure 2.12: The building as an analogue of the human body now forms the contemporary basis of the building as a system concept (Kesik, 2008)

This approach to architecture can be compared to the functioning of the human body where all the organs, tissues and muscles are inter-related and co-dependent (Lavin et al, 2006). According to Kesik (2008) *"achieving healthy indoor air quality involves balancing factors, such as building finishes, furnishings, indoor vegetation, mechanical systems, building maintenance, energy efficiency and sustainability. This list illustrates how providing clean indoor air involves an interdisciplinary approach to building design and construction."* In the past, design professionals - architects, engineers and interior designers, have often overlooked indoor air quality. Teamwork, mutual respect and discipline will all contribute towards healthy and clean indoor environments. As a leader of the design process, architects are well positioned to advance the need for maintaining occupant health and well-being.

2.12.1 Thermal Comfort and Health

Three factors are responsible for thermal comfort in homes: temperature, air movement, and humidity. Temperature has an impact on air quality and could lead to great discomfort. Thermal sensation is a strong motivator and may cause the occupant to behave in a way, that can overwhelm the original design needs of the ventilation system. High indoor temperature increases the likelihood of Sick Building Syndrome (SBS) symptoms (EC, 2003). Ventilation can be used to control indoor temperature and humidity. Both indoor air quality and temperature are considered when ventilating a building. Air movement is also a massive consideration when designing ventilation systems. The air movement or the speed in which the HVAC should blow in air is at the discretion of the occupants. Indoor air movement that's high in velocity and even turbulent sometimes may cause discomfort from draughts if the occupants are already comfortable or cool. However, if temperatures are higher and occupants feel hot, too little air movement cannot solve discomfort, and higher air movement may be welcome (EC, 2003). Lastly, indoor humidity also affects comfort and may need to be increased or reduced depending on the weather condition and the occupants themselves. For example, where outdoor air is used for ventilation, in cold weather, very low indoor humidity can occur, which then causes dryness, nasal and optical discomfort. Furthermore, in hot weather, high relative humidity can occur, which reduces the ability to lose heat by evaporative means (sweating) can increase discomfort from overheating. It also increases the presence of dust mites allergens and molds, which cause asthma and other allergic diseases.

There are many research studies that have focussed on the control of comfort associated with HVAC systems. One of which is the work of Atthajariyakul and Leephakpreeda (2004), who focused on presenting an alternative means of determining the real-time of optimal indoor air condition for thermal comfort, air quality and efficient energy usage. Predicted mean vote (PMV), CO2 concentration and cooling/heating load are used as parameter indices for thermal comfort, indoor-air quality and energy consumption respectively. PMV indirectly indicates the satisfaction of the thermal comfort i.e. it shows the optimal thermal comfort. According to Atthajariyakul and Leephakpreeda (2004), PMV *"is defined by the most important six thermal variables: human activity level, clothing insulation, mean radiant temperature, humidity, temperature and velocity of indoor air… where temperature and velocity of indoor air have been commonly used as controlled vari- ables for the HVAC system in order to keep PMV index at the comfort range."*

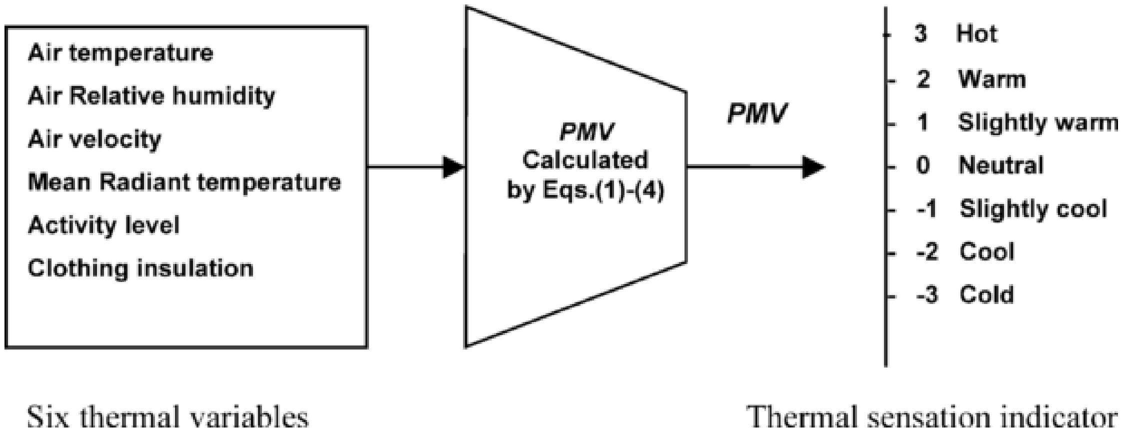


Figure 2.13: PMV and Thermal Sensation (Source, Atthajariyakul and Leephakpreeda, (2004)

To calculate the comfort level and indoor air quality for human and energy usage in HVAC systems, parameter indices are used; i.e. thermal comfort index (PMV, indoor-air quality index (CO2 and other pollutants), and energy consumption index. For thermal comfort, the PMV value is recommended to be maintained at 0 with a tolerance of ±0.5 to ensure a comfortable indoor climate, because this value depicts the range in which 90% of the people occupying a building are satisfied (Atthajariyakul and Leephakpreeda, 2004). According to Atthajariyakul and Leephakpreeda (2004), the value of PMV can be determined by:

$$\begin{aligned} \mathrm{PMV} = {} & (0.325\,\mathrm{e}^{-0.042M} + 0.032) \\ & \times[M - 0.35(43 - 0.061M - P_\mathrm{v}) \\ & -0.42(M - 50) - 0.0023M(44 - P_\mathrm{v}) \\ & -0.0014M(34 - T_\mathrm{i}) - 3.4 \times 10^{-8} f_\mathrm{cl}((T_\mathrm{cl} + 273)^4 \\ & -(T_\mathrm{mrt} + 273)^4) - f_\mathrm{cl} h_\mathrm{c}(T_\mathrm{cl} - T_\mathrm{i})] \qquad (1) \end{aligned}$$

with

$$\begin{aligned} T_\mathrm{cl} = {} & 35.7 - 0.032M - 0.18 I_\mathrm{cl}[3.4 \times 10^{-8} f_\mathrm{cl}((T_\mathrm{cl} + 273)^4 \\ & -(T_\mathrm{mrt} + 273)^4) - f_\mathrm{cl} h_\mathrm{c}(T_\mathrm{cl} + T_\mathrm{i})]] \qquad (2) \end{aligned}$$

$$h_\mathrm{c} = \begin{cases} 2.05(T_\mathrm{cl} - T_\mathrm{i})^{0.25} & \text{for } 2.38(T_\mathrm{cl} - T_\mathrm{i})^{0.25} > 10.4\sqrt{v} \\ 10.4\sqrt{v} & \text{for } 2.38(T_\mathrm{cl} - T_\mathrm{i})^{0.25} < 10.4\sqrt{v} \end{cases} \qquad (3)$$

$$P_\mathrm{v} = \frac{P_\mathrm{s}\,\mathrm{RH}}{100} \qquad (4)$$

where "Ti is the indoor-air temperature (◦C), $Tmrt$ is the mean radiant temperature (◦C), M is the human activity (kcal/hm^2), v is the relative air velocity (m/s), Pv is the vapour pressure in the air (mmHg), I_{cl} is the thermal resistance of the clothing (clo: 1 clo = 0.18◦Cm^{2}h/cal), hc is the convective heat transfer coefficient (kcal/m^{2}h ◦C), f_{cl} is the ratio of the surface area of the clothed body to the surface area of the nude body, T_{cl} is the outer surface temperature of clothing (◦C), RH is the relative humidity in percent, Ps is the saturated vapour pressure at a specific temperature."

2.12.2 Acoustic Performance

All ventilations systems are more often than not, noisy and also serve as mediums that carry sound from the external environment. Therefore, within the framework of a sustainable living environment, noise is an important aspect for the comfort of inhabitants. Ventilation systems easily transmit noise from the outside to the inside environment. A proper choice on design and operation of the ventilation systems will deal with this problem (EC, 2003). IAQ is also concerned with eliminating noise as it causes discomfort, irritation, damage to hearing, sleep disturbance, cardiovascular and psychophysiological effects, effects on performance, annoyance and effects on social behavior (EC, 2003). Table 2.4 shows the maximum limits allowed for indoor noise in residential environments in Kuwait.

Table 2.4: Maximum limits allowed for indoor noise in residential environments in Kuwait.

Type of Indoor Location/ or Activity Inside this Location	**Recommended noise level in dB(A)**
Residential Buildings	
A- Residential houses (villas) and residential units (flats) located at rural areas and outer suburbs)	
* Sitting and living areas	30-40
Sleeping area	25-30
Entertainment and working areas inside the house	40-45
B-Residential houses (villas) and residential units (flats) in inner suburbs	
Sitting and living areas	35-40
Sleeping areas	30-35
Entertainment and working areas inside the house	40-45

Source: KEPA (2012)

2.12.3 IAQ and Energy Use

Buildings consume a lot of energy and are said to be the most important energy consuming economic sectors. Now because buildings are affected by their environment and vice versa, therefore, attention to the environmental quality of indoor spaces is very important. Three factors must be considered when trying to achieve environmental quality of indoor spaces: the building physics, energy consumption, and the outdoor conditions. The European Commission (2003) emphasize that since buildings have a long life, spanning several decades and even centuries, "all decisions made at the design stage have long term effects on the energy balance and the environment."

In the past, there was the belief that good indoor air quality and energy efficiency were at conflict with each other. That is, because buildings use a lot of energy via their HVAC systems, therefore, desiring good indoor air quality means spending a lot of money on energy. But it's been shown by Roulet et al. (1995) that it doesn't have to be so – one can have good indoor air quality without spending a lot of money on energy if the building and the HVAC system are designed in a manner that maximizes the ventilation of the spaces. The challenge today is to find the right compromise that allows at the same time for good IAQ and highly efficient energy (EC, 2003).

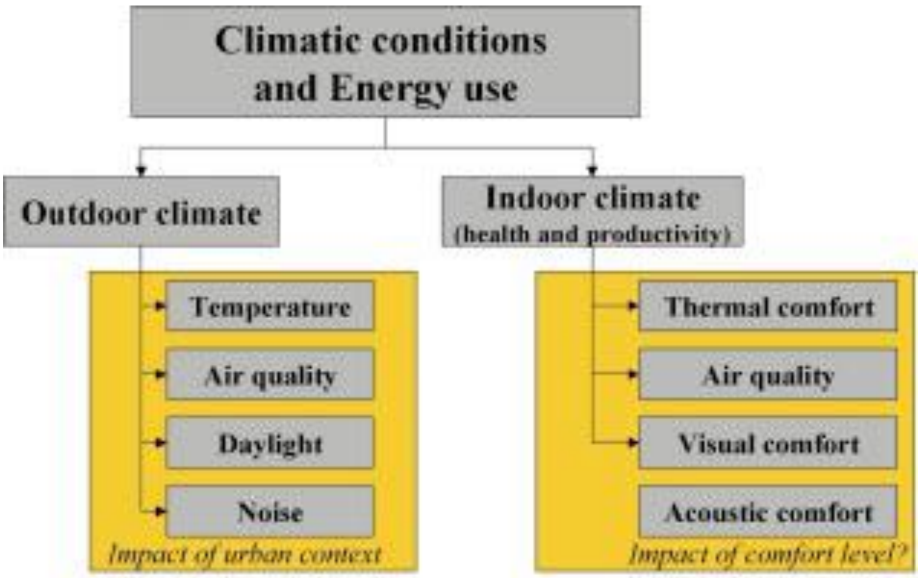


Figure 2.14: Outdoor climate and indoor climate characteristics strongly influence the energy use of buildings (EC, 2003).

Specific characteristics of urban climate have in different ways an impact on the energy use of buildings (EC, 2003). Figure 2.14 shows that four environmental factors contribute to the energy use in buildings – temperature, air quality, daylight, and even noise, which in turn can affect the IAQ of the indoor spaces. In seasons of high temperature, buildings' demand for electricity to power air conditions. This increases smog production and pollutants emission, not only from the power plant but also from the AC system themselves. For buildings that ventilate their indoor spaces by opening windows and doors, the outdoor pollutants can greatly compromise the indoor air quality (IAQ). However, for buildings that do not ventilate its indoor spaces with outdoor air, achieving a good level of indoor air quality requires an increase in energy use by the HVAC systems. In general, outdoor air is considered to be of lower quality (except on the country side) as such, regulations do not factor in outdoor air when designing for IAQ.

In most countries, the largest users of energy in cities are buildings. The research by the European Commission on energy consumption levels in the major European cities has shown that the energy consumption of the residential sector varied between 28-48% and that of commercial building, between 20-30% in cities. This is shown in Table 2.5 below.

Table 2.5: End Use energy consumption in selected European cities

City	Residential (%)	Commercial (%)	Industrial (%)	Transport (%)	Total (GJ/capita)
Berlin	33	29	15	23	78
Bologna	36	21	11	32	67
Brussels	43	29	5	23	94
Copenhagen	48	26	6	20	78
Hanover	28	25	26	21	112
Helsinki	34	23	9	34	89
London	36	24	11	29	89.10

Source (EC, 2003)

Noise levels also increase the energy use in buildings. According to European Commission (2003) cooling and thermal comfort can be impacted by high temperatures in summer time, therefore "night ventilation can be a very effective strategy for improving thermal comfort in summer and/or eliminating or strongly reducing the energy use for cooling. However, if too high noise levels occur (as is common in many urban environments), intensive night ventilation may not be an appropriate strategy. As such, the typical noise levels in urban environments may influence also the energy use of buildings." It is also clear that there often are lower daylight levels in dense urban environments. This may result in more intensive use of artificial lighting and therefore an increased energy use (EC, 2003).

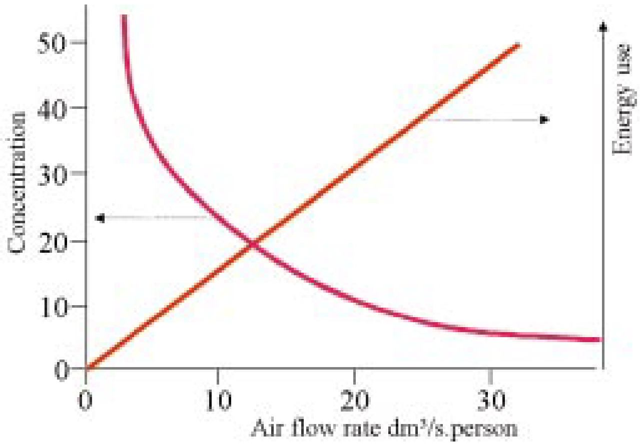


Figure 2.15: Typical relation between ventilation rate, concentration and the energy use for ventilation (Source: EC, 2003)

In the European Commission's explanation of the relationship between ventilation rate, concentration and the energy use, it states: *"Ventilation is an important parameter for the indoor air quality in buildings. In general, the more ventilation, the lower the exposure to pollutants from inside. Hence ventilation also has its energy consequences. In case heating or cooling is required, the energy penalty is the most important reason to minimize the amount of ventilation air"* (EC, 2003).

2.13 IAQ Standards and Regulations

Construction and ventilation of buildings are capital-intensive projects, therefore, it is imperative that the major players (owner(s), consultants, building contractor, ventilation firms, etc.) come together and agree on the objectives and functionality of the building and system, in order to create a building environment that meets the client's objectives as well as societal standards and regulations. It is important that these objectives are clearly written so that nothing is misinterpreted.

The European Commission (2003) distinguishes between standards and regulations. Regulations, EC (2003) states, are mandatory and therefore applicable to all projects covered be the regulation. Whereas, standards are based on client's objectives, building use and performance. Ventilation standards should be based on a clear philosophy, which is, "to remove or dilute the indoor generated pollutants and supply fresh air for human beings (IEE, 1996). Of course there are many more reasons why buildings are ventilated but removing pollutants is the primary reason.

In most developed countries some form of ventilation standards and regulations exists, not so much in third world countries. There are countries, even in Europe that do not have appropriate standards and regulations. The general uncertainties that surround indoor air quality and ventilation of buildings should not be used as excuse not to have standards and regulations. There is also the problem of application of the necessary standards and regulations, so much so that, there are new and retrofitted buildings that are not in line with application standards and regulations, even the developed countries, the so called first world nations like the UK, USA, and some European countries. Therefore, it shows that having a mechanical ventilation system is not a guarantee that an appropriate airflow rate is achieved. The European Commission state that for this reason *"therefore, it is not sufficient to have good standards and regulations, it is also important to develop a coherent framework for the implementation of these standards and regulations."*

One of the major reasons for this misalignment between standards and regulations, and applicability is the nature in which the standards and regulations are written. Most standards and regulation are written in a descriptive form rather than expressed in terms of real figures of maximum allowable exposure levels such as maximum flow rates levels. This type of non-descriptive standard and regulations, is called a performance oriented regulations and standards (EC, 2003). The exposure of people to pollutants in a building is nowadays the most appropriate model for performance based approach. Therefore, EC states that it is imperative that during design and use, owners should consider the following:

- all possible indoor pollutant sources;
- the time different people spent in different buildings indoors and within the building in the different rooms and outdoor on several locations with different concentrations;
- from that data evaluate the total exposure.

Another basic problem with IAQ regulations and standards is that there is not one universal standard. Every country has its own and the regulations vary from country to country. For example the European Commission adopted Wouters' (2000) table, which compares the air supply requirements in various countries. This is given in Table 2.6 below.

Table 2.6: Comparison of air supply requirements in various European countries

	Belgium	France	Netherlands	UK
Air supply closable?	Obligatory	Not allowed	Obligatory	Required according guidance in Approved Document I
Dimensioning principles	Air flow proportional with floor area 1 $dm^3/s.m^2$ floor area for $\Delta P = 2$ Pa	Fixed value	Air flow proportional with floor area 0.9 $dm^3/s.m^2$ floor area for $\Delta P = 1$ Pa	Fixed value
Mechanical exhaust				
≤7 m^2 bedroom	7 dm^3/s at 2 Pa	30 m^3/h at 20 Pa	7 dm^3/s at 1 Pa	8000 mm^2
14 m^2 bedroom	14 dm^3/s at 2 Pa	30 m^3/h at 20 Pa	12.6 dm^3/s at 1 Pa	8000 mm^2
Natural exhaust				
≤7 m^2 bedroom	7 dm^3/s at 2 Pa	45 m^3/h at 20 Pa	7 dm^3/s at 1 Pa	8000 mm^2
14 m^2 bedroom	14 dm^3/s at 2 Pa	45 m^3/h at 20 Pa	14 dm^3/s at 1 Pa	8000 mm^2

Source: Wouters' (2000)

Furthermore, there are standard and regulations that govern 'energy efficient ventilation systems' as well as 'energy efficient buildings'. The two are not the same. Regulations and standards that focus on energy efficient ventilation systems and/or their components, relates to, for example, type of filter, fan power, efficiency of heat changers, airtightness performance of ductwork, etc. (EC. 2016). On the other hand, standards and regulations that focus on the total energy performance of the overall building. However, this overall energy performance influences, greatly, the use of efficient ventilation systems. A proper example of standards and regulations of that define energy performance of buildings is the European Energy Performance Directive (EPD). The following are examples of some of the regulations that was abstracted from EC (2003):

"The methodology of calculation of energy performances of buildings shall include at least the following aspects:

- *thermal characteristics of the building (shell and internal partitions, etc.).*
- *These characteristics may also include air-tightness;*

- *heating installation and hot water supply, including their insulation characteristics;*
- *air-conditioning installation;*
- *ventilation;*
- *built-in lighting installation (mainly the non-residential sector);*
- *position and orientation of buildings, including outdoor climate;*
- *passive solar systems and solar protection;*
- *natural ventilation;*
- *indoor climatic conditions, including the designed indoor climate."*

The EPD requires that all member states adhere to these rules and the minimum requirements have to be met by mew buildings and also for major renovations or large buildings (EC, 2003). The European Commission state that:

"The performances of ventilation systems are not only determined by the design, but also by the performances of the components used in the installation, the quality of the installation and the operation and maintenance of the system."

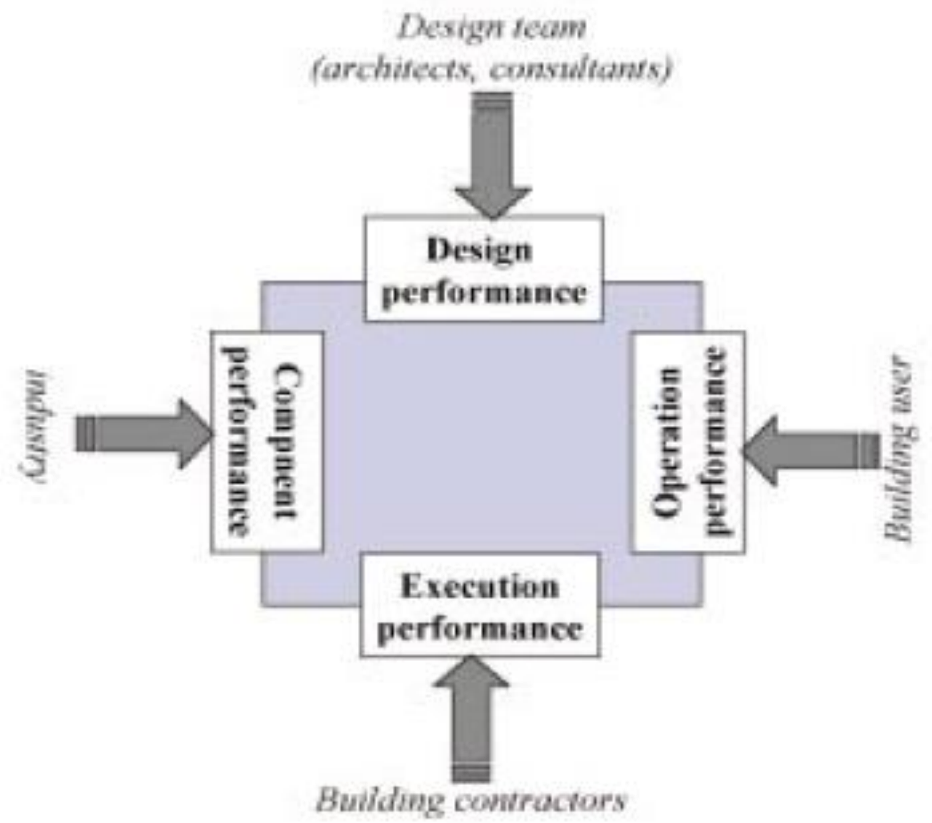


Figure 2.16: Various performance related aspects of ventilation systems (Source: EC, 2003).

2.14 Improving IAQ at design, construction and occupancy

2.14.1 Design

Any good IAQ starts at the structure's design stage. When designing new builds or when retrofitting buildings, the pollution that the building's activities is expected to generate must be considered. Other consideration is the pollution neighbouring buildings generate. For buildings designed to take advantage of natural ventilation, adequate openable windows should be provided for the spaces. For buildings that are not designed to be ventilated using natural ventilation, adequate mechanical ventilation system (e.g. ACMV) powerful enough to suck out contaminated air from the building spaces should be added in the design, whilst the HVAC pumps in clean fresh air into the building. The HVAC system must be placed (in the design) on the side of the building that is expected to have the best outside air quality. According to the IEE (1996) the design must take into consideration; the position of the building, the exhaust opening position, traffic routes, car parks, unloading bays, refuse chutes and other nearby ground level or close to evaporation cooling towers.

During design, deciding on what ventilation systems to use – whether natural ventilation or mechanical ventilation depends on the use of the building and pollution load envisaged. Natural ventilated buildings have opening or envelopes in which air, driven by natural forces, enters the building and exits through other openings. Here, the building and its openings are part of the ventilation system and the ventilation system's design has to be integrated in the building design from the early stages of design (EC, 2003). On the other hand, in mechanically ventilated buildings, the building itself is not part of the ventilation system but its design would nevertheless incorporate aspects where the HVAC system will be installed. According to the EC, *"in mechanically ventilated buildings the ventilation air is conditioned before it is supplied to the rooms via the duct system. Because of supply and exhaust air fans the system is more flexible in respect of building design, and more energy efficient if heat recovery is used."*

The design of the air conditioning and mechanical ventilation (ACMV) system should be adequate enough with regards to the building size, spaces, and activities that will take place within the building, so that the spread of contaminants in the building are kept to the lowest possible level (IEE, 1996). The ACMV system itself must not be made of materials that emit toxic chemicals into the supply air, harbour bacteria, or generate fungi that are harmful to occupants. Adequate frequent cleaning of the system should also be done. In addition, at the design stage, the proposed building materials and finishing must not be chemical emitting, fungi or bacteria generating. The building materials must be fit for purpose and must not compromise good IAQ objectives. Furthermore, value-engineering process must not be an exercise where good IAQ is sacrificed for low cost materials. Good IAQ must be top in the priority list. The building design must make doors and windows and spaces accessible and cleaning possible.

Electrical works e.g. fittings, wirings, conduits, etc. should be made with non-chemical emitting coats and materials that can be harmful to occupants. Also mechanical designs: water supply, drainage, boilers, sewerage and other installations should be well planned for construction and installation in such a way that the risk of leaks and consequential damage caused by leaks is prevented (IEE, 1996).

Furthermore, during design and construction, there should be an IAQ manager, someone responsible for making sure that design, construction and commissioning goes well to provide the best IAQ possible for the building. Achieving good IAQ should be done in an integrated team, where all partners to the project from the design to the construction process, are included in decision-making. The European Commission emphasize that "*IAQ in buildings is affected by several partners in the construction process. The final result depends particularly on the architectural and mechanical designs*... Main contractor, mechanical contractor and several subcontractors also affect the final result... *In this complex process it would be beneficial to appoint a person who is responsible for the IAQ in the process."*

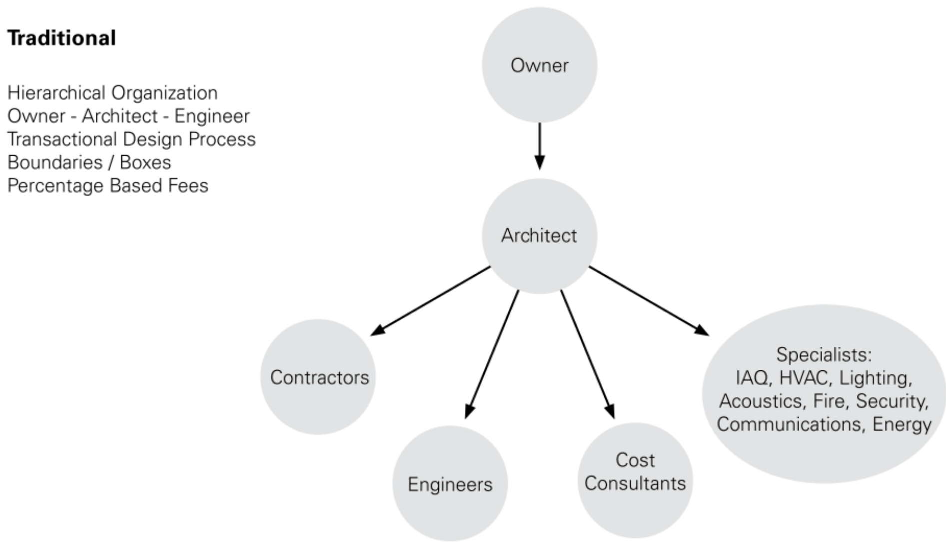


Figure 2.17: Traditional Approach of Achieving IAQ (ASHRAE, 2009)

The rise in indoor air quality (IAQ) problems has been attributed to the prevalent use of the traditional approach to achieving IAQ, which is illustrated in Figure 2.17. When IAQ is bad, building owners and managers can find themselves devoting considerable resources to resolving occupant complaints or dealing with extended periods of building closure, major repair costs, and expensive legal actions. Despite these significant impacts, IAQ is still not a high-priority in design or building management as compared to function, cost, space, aesthetics, and other attributes such as location and parking (ASHRAE, 2009). It is important to make IAQ part of the design at the very beginning of the project. The primary reasons are: to avoid problems that occur when IAQ is treated as an afterthought; and to allow for alternative design concepts that involve decisions made early in the design process (ASHRAE, 2009). Providing technical and evaluated solutions and their effective usage are the keys to efficiently improve IAQ. Incorporating IAQ at the very beginning of conceptual design gets a number of key issues before the design team, enabling them to make informed decisions that will affect the project through the construction and occupancy phases (ASHRAE, 2009).

"Many IAQ problems are the result of IAQ not being considered as a key issue at the very beginning of the design process. Basic design decisions related to site selection, building orientation, and location of outdoor air intakes and decisions on how the building will be heated, cooled, and ventilated are of critical importance to providing good IAQ. Efforts to achieve high levels of building performance without diligent considerations of IAQ at the beginning of the design process often lead to IAQ problems and represent missed opportunities to ensure good IAQ. Lack"

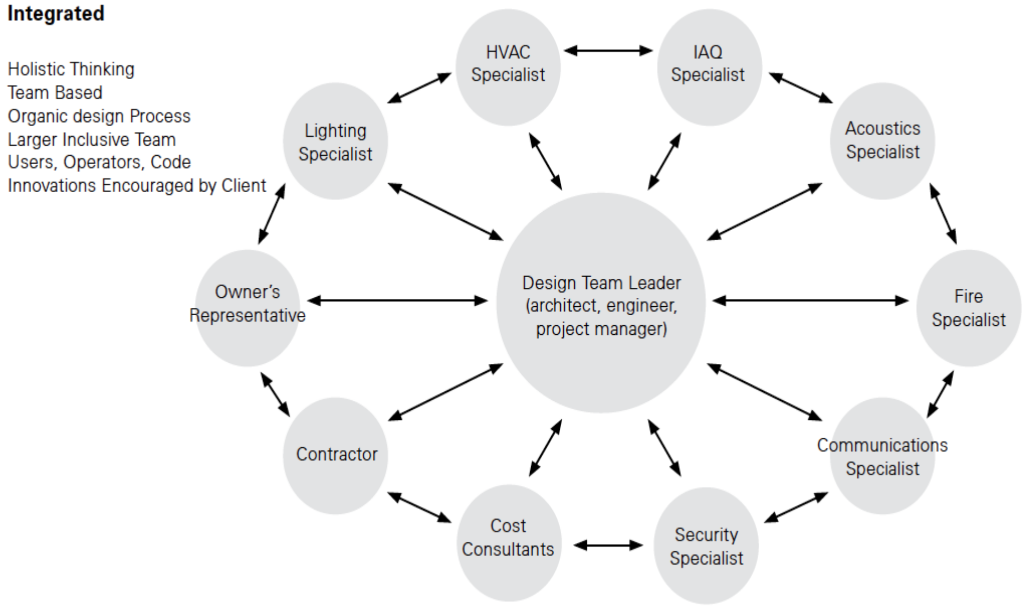


Figure 2.18: Integrated Approach of achieving IAQ (ASHRAE, 2009)

The beginning of the design must adopt an integrated approach to achieving good IAQ. The easiest and most effective way to accomplish integrated design is to assemble the entire design team at the beginning of the project and to brainstorm siting, overall building configuration, ventilation, thermal control, and illumination concepts as a group. The give-and-take of the initial design charette with the key members present will help each team member to appreciate the specialized concerns of the others and enable the group to develop a solution that best integrates everyone's best ideas (ASHRAE, 2009). Figure 2.19 shows the construction activities that facilitate achievement of good IAQ.

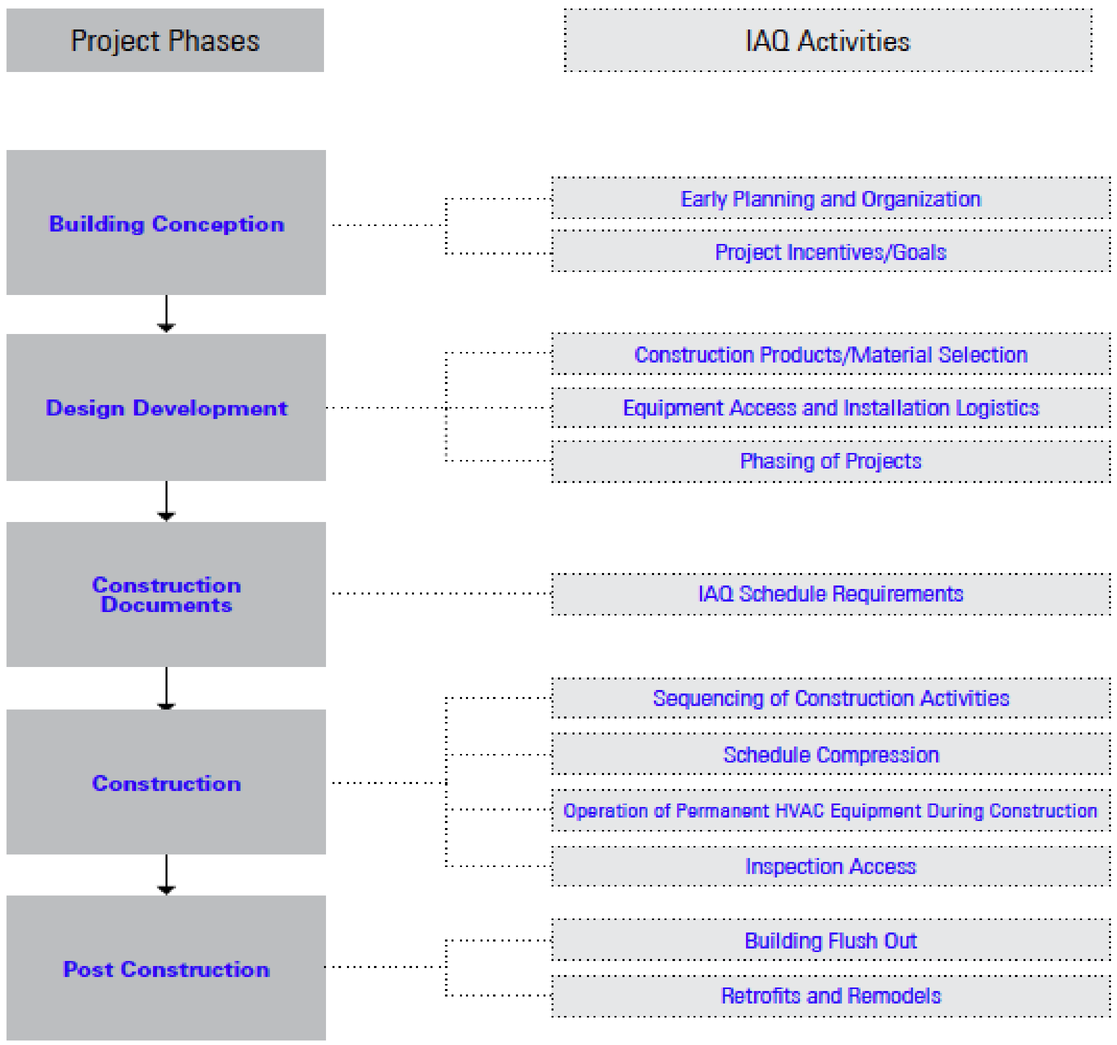


Figure 2.19: Construction Activities to facilitate good IAQ (Source, ASHRAE, 2009)

2.14.2 Construction

The purpose of frequent and thorough inspection at every stage in the construction phase cannot be over emphasized. Professional IAQ consultants must carry out this inspection so that acceptable indoor air quality can be secured when the system is put into operation (IEE, 1996). The walls, ground, roofs and other parts of the building must be constructed in such a way that harmful contaminants cannot find their way easily into the building. Well-constructed floors for example, stop pollutants, like radon from getting into the building from the ground. The air-conditioning and mechanical ventilation systems should be constructed in such a way that it is easily accessible to the inspection and maintenance professionals for inspection, repair, cleaning and/or replacement. In addition, the construction of the ACMV systems must be structurally sound i.e. mounted in such a way that the work can be carried out easily and safely. Furthermore, the supply and return air ducts should be designed with dust resistant surfaces so as to curb the easy accumulation of dust in the air-ways. The ducts also need to be constructed so that inspectors and cleaners can easily get in there. Furthermore, other installations must not be constructed or placed near the ACMV system control room.

Filters are very important to the air quality in buildings. Therefore, a filter should be constructed with the ACMV system so that particulates are filtered out before they reach the air supply unit. The filters must be protected from wetness and sealed properly between the walls and the ducts.

2.14.3 Commissioning and operation

According to the Institute of Environmental Epidemiology (IEE), new or retrofitted buildings that are about to be commissioned should demonstrate that the air-conditioning and mechanical systems (ACMV) in the buildings are constructed well to design, specification, standard and regulations, and that they are fit for purpose, that is, the ACMV systems can perform the desired functions for which they were installed. The inspection officer must make sure that the entire ACMV system; supply and return ducts, are cleared of any construction debris and dirt, and cleaned before operation starts. Before commissioning, the inspector must make sure that the ventilation rate produced by the ACMV system is adequate enough to clear out any pollutants in the indoor air and bring the air quality to the required level according to the standards and regulations. Additionally, the inspector must make sure that the pressure levels and pollutants are at acceptable levels, and filters installed properly. ASHRAE (2009) states:

"While a good design is critical to providing good IAQ, if the building systems are not properly installed or commissioned so that they operate as designed, IAQ conditions may be seriously compromised. Therefore, a key factor in achieving good IAQ is a serious commitment to a comprehensive Commissioning effort that starts in the design phase and continues well into occupancy. This effort should include a focus on Commissioning of systems and assemblies critical to good IAQ. Moisture"

IEE (1996) propose that the instructions manual for the operation of each ACMV system should be drawn up, including all necessary information for satisfactory ventilation of the rooms served, and should be done with the help and cooperation of the operations and maintenance staff. The IEE state that the following should be part of the instructions manual:

- a schematic plan of the system;
- its operation; and
- the precautions to be taken specifying checks and their frequency, and steps to be taken to remedy defects and deficiencies.

The inspector must ensure that the ACMV systems control or handling room is not placed on passageway with a lot of traffic or used as a storage room. The handling units must be protected from contaminants and must be provided with enough space to easy accessibility and cleaning. Before commissioning, the inspector must make sure the dead spaces are efficiently ventilation to avoid stagnant air from being locked up in small pockets around the building.

2.14.4 Maintenance

Good indoor air quality (IAQ) depends greatly on proper and frequent maintenance of the ventilation system. the ASHRAE standards provides guidelines and emphasis on the need for proper maintenance of HVAC systems. Regular maintenance and cleaning of the ACMV system must be carried out by a competent person. Maintenance staff should be familiar with the prevention of any hazard arising from the building (IEE, 1996). The IEE state that the schedule of maintenance for the ACMV system should be in accordance with the manufacturer's recommendations to ensure that the equipment operate efficiently. In the case where the manufacturer's instructions or recommendation manuals is not found, IEE recommends that the building and its ACMV system be inspected **at least every six months**, for functionality and efficiency so that the system is meeting the IAQ objectives of the building. The IEE (1996) gives the following recommendations:

Table 2.7: IEE (1996) recommendations for the maintenance of building and ACMV systems

- "The building and its ACMV system should be inspected **at least every six months** with regard to functions, which are significant for the indoor air quality. Normal operation of the system should be monitored so that it continues to operate at maximum efficiency and breakdowns are avoided.

- The ACMV system and the air handling unit room should be cleaned and maintained in such a way that the indoor air quality is not adversely affected by the cleaning and maintenance. The components of air-handling units such as fans and dampers should be cleaned **at least every six months**, depending on the condition of the incoming air and use of the system. Filters should be cleaned or replaced so that they are performing properly **at all times** and do not become clogged.

- Cooling coils, condensate pipes and water trays should be checked regularly for signs of sludge, algae or rust build-up, chokage and leaks where water could enter the airstream. Coils and condensate pipes should be cleaned **at least every six months**. The trays should be cleaned **at least every one month** to ensure that contaminants do not build up. Any ferrous metal surface should be treated with an anticorrosion coating. Re-circulating water should also be treated to prevent rust but that treated water must not be allowed to enter the airstream.

- Cooling towers should be cleaned and treated in accordance with guidelines specified in the Code of Practice for the control of legionella bacteria in air-conditioning cooling towers.

- The ACMV system should be checked and adjusted to ensure correct airflow, temperature and humidity **after the first year of operation** and **at least every two years** thereafter. It should also be checked and adjusted after any renovations or changes in floor layout that might affect air distribution.

- Records should be kept of all maintenance work - when and what was done."

One of the major problems associated with poor indoor air quality is the fact that ventilation systems are not changed as buildings' use and buildings' indoor climate requirement changes. Ones building use and requirements changes, the ventilation systems that ensure the indoor climate must be adjusted accordingly. Not adhering to this may result into IAQ problems in the future e.g. sick building syndrome.

Training of building operators is also a problem. As the technological world takes over, buildings are becoming more and more complicated and technologically advanced. The building operators need to keep up with the advancement through education and training. Building operators need to be trained properly to perform the tasks necessary to the ventilation system to function properly and be sufficient to handle the pollutant load. Lack of of technical knowhow and/or training may lead to poor operation of buildings and deteriorated indoor climate (EC, 2003). EC (2003) gives an example of poor technical knowhow of operators and how that may affect indoor air quality.

"A typical mistake in operation, for example, is saving in heating costs by reducing ventilation rates or operation hours of ventilation. This may result in serious indoor climate and moisture problems in the long term. Poor maintenance may result in serious failures in the operation of a ventilation system which again may lead to the problem of deteriorated indoor air quality."

Another major problem is the lack of 'label schemes' and/or clear operational instructions on ventilation systems. In Sweden, thousands of ventilation systems were tested in 1998, and they found that systems that were without satisfactory operational and maintenance instructions had 50% more faults in performance compared to those with satisfactory instructions. This emphasizes the importance of label schemes to ensure proper operation of the ventilation system, which in turn affects the IAQ of the building. Appendix 3 documents international labelling schemes for low VOC emitting products.

2.14.5 Renovations

Renovation is one of those activities that can seriously compromise the Indoor Air Quality (IAQ) of a building if proper precaution and planning is done. Renovation activities can kick off dust into air in indoor spaces and can probably setoff contaminants or pollutants that have built up over the years and have laid dormant within the building, which then contaminates the air in the building. IEE (1996) recommends that refurbishment works should be undertaken in such a way that a satisfactory indoor environment is secured, and can be achieved by doing the following:

- "Processes and activities should be selected so that they have the lowest possible emission. Where processes and activities which pollute the air cannot be avoided, they should as far as possible be encapsulated, provided with local extraction, carried out in areas with direct exhaust to the exterior, or limited to times when few people are exposed.
- The building materials should not contain any toxic substances, which could pose a hazard to health when used in the occupied building. Fittings, fixtures, furnishings and furniture should be manufactured, selected, handled, stored and used so that emission to the room air is the least possible.
- For occupied buildings undergoing partial renovation, spaces to be renovated should be effectively isolated from the occupied zones. If necessary, supply air should be separated so that acceptable indoor air quality for the occupants is maintained. Concentrations of formaldehyde, volatile organic compounds, suspended particulate matter and other contaminants in room air should be within the limits specified in the IAQ standards.
- After any major renovation to the building where the air-conditioning system has been affected (eg. by partitioning of office space), rebalancing of the air distribution should be required."

2.14.6 Quality Control

Quality control is an essential activity that will ensure consistent level of good IAQ in a building and will benefit the dwellers greatly. After occupancy and the ACMV system has been in operation for six months, an auditor or inspector should be sent into building to investigate any occurrence of building-associated illnesses, and then every two years thereafter. This ensures that the indoor air quality is acceptable and conforms to specifications (IEE, 1996). In addition, lab testing of indoor air quality should be done in government-accredited laboratories. Lastly, all plans, drawings, specifications, and maintenance logs on the building and its ACMV systems should be kept by the owner or whichever authority has the caretaker responsibility and should be provided upon request, especially at times of inspection.

Finally, the European Commission made a grand statement on the ultimate activities to achieving good indoor air quality. It states:

"Good performance of ventilation depends on the whole chain of the building process: targets levels, design, manufacturing, installation, commissioning, operation and maintenance. The final result is as good as the weakest link in the chain. Thus it is important to develop the entire chain."

In light of this, the commission emphasized that there is a need for acceptable standards. Every country should have acceptable standards based on their climate and activities. The commission states; "*the standards should be based on the accepted indoor air quality, possibly offering various categories of indoor air quality for the use of individual building owners. In addition to the performance standards, prescriptive guidelines are needed for designers and manufactures. These guidelines have to be derived from the performance standards. Essential for these guidelines is the focus on indoor air quality. Hygiene of mechanical system has to be an essential contents of these guidelines."*

2.15 Solutions to poor IAQ at Occupancy Stage

There are three key strategies that occupants can adopt to improve the indoor air quality of their homes. They are: Eliminating the source, Ventilation and Filtration. There is possibly a fourth strategy, which is Moisture control. It is important to note that all four strategies must be employed to achieve the best indoor air quality possible (Waterfurnace, 2016). Using only one or two methods is generally insufficient. Bluepoint Environment (BE) (2016) also outline similar solutions to reduce indoor air pollution. However, there are no clear established standards and regulation stating to what proportion should these strategies be used on different types of buildings. That is, to know the appropriate balance in the use of each one of the strategies. “Therefore, there is the need for the establishment of criteria to select on which strategy shall the priority be put on” (EC, 2003).

Eliminate the Sources – The general consensus is that the most effective strategy for reducing indoor air pollution is to eliminate or reduce the sources of contaminants such as radon, smoke, CO2 and other volatile organic compounds and particulate matter (EC, 2003). Reducing, and/or removing the source of the indoor air pollution in households cannot be overemphasized. With the exception of off-gassing of new building materials, sources of indoor air contaminants can usually be controlled or managed by the homeowner. These include proper use of bathroom and kitchen exhaust fans, discontinuing indoor tobacco smoking, proper ventilation of gas stoves and furnaces, proper storage of cleaning supplies, fuels and chemicals, adequate cleaning procedures including the indoor air conditioning coil and duct system, and removal of contaminated carpet, wall, or even ventilation (HVAC) system (Waterfurnace, 2016). The need to smoke outside cannot be overemphasized. There are an endless list of contaminants and resulting adverse health effects caused by smoking. IAQ can also be improved by not spraying combustible products indoors or near ventilation units. This can cause rapid spread of contaminants and fire through the ventilation systems. Another strategy is to maintain clean roof, gutters, and storm drainage (BE, 2016). To prevent water leaks, and moisture build-ups in the home, basement, etc. thereby eliminating the sources where pollutants and allergens can develop.

However, the European Commission states that source control at all levels means much more than what was outlined above. It implies essentially, a basic attitude in tune with the concept of sustainability, which shall influence the whole urban design process. Therefore, they have proposed three criteria in which designers and mechanical engineers can refer to in order to achieve sustainability when designing for indoor air quality. It states:

“Source control shall be an objective:

- *in the urban design of the city itself, be it a new quarter or a retrofitting project, in order to reduce the needs for energy and, for instance, to facilitate the aeration of the building and surroundings;*

- *in the design of the building itself at every single decision regarding the space distribution and orientation, the use of materials and its needs for energy; and*
- *in the selection of all building products in tune with the specific requirements of the Construction Products Directive 89/106."*

Ventilate the Space — Ensuring proper ventilation is one of the most effective ways of keeping the indoor air clean. Effective ventilation increases the amount of clean outdoor air, removes pollutants through filtration and helps reduce the build-up of excessive moisture. Once the sources to pollution have been removed, the air must be cleaned and circulated with natural outdoor air. The concentrations of indoor air pollutants are dramatically reduced when they are mixed with fresh outdoor air. Increase the amount of outdoor, natural air coming indoors. Open windows, doors, turn on fans in windows, attics, crawl spaces, turn on kitchen and bathroom exhaust fans, and air conditioning units with vent open (BE, 2016). Make sure that fuel burning furnaces, fireplaces, heaters, range tops, exhaust fans and other appliances are vented to the outside well away from windows and heating ventilation and air conditioning (HVAC) intakes. Although ventilation can be achieved by simply opening a window, the air coming inside is unfiltered, and enters the home at a generally higher or lower temperature than the indoor air, causing additional heating or cooling requirements (Waterfurnace, 2016).

Ventilation rate is one of the key performance issues that have to be factored in when designing a HVAC system. The performance is based on the ability of the system to be able to handle or the pollution load of the spaces and also the capability of the ventilation air to dilute the pollution in the rooms. Mechanical ventilation in not the only way to ventilate spaces or rooms in a building. Natural ventilation is another to effectively ventilate buildings provided that the outdoor air is certified to be clean enough to be used fro the purpose of indoor ventilation. Better, yet, a combination of the two that is a hybrid form of ventilation is rather the best way to ventilate buildings now. Good ventilating of building spaces using natural means lies on well-defined and controlled dimension of the building openings, location and conditions of operation, which are incorporated in the building design.

Ventilation in and of itself does not affect residents' health. What does though is the amount of pollutants that is subject to the rate of ventilation. A ventilation rate below 10L/s per person means the rate of ventilation is insufficient to dilute the amount of pollutants in the room, which in turn causes increase in health issues of residents. On the other hand, a ventilation rate of up to 20L/s per person removes or greatly reduces the health effects associated with poor indoor air quality (EC, 2003). The European commission has a given formula in which to calculate indoor concentration, in which ventilation/flow rate, air concentration, pollutant generation rate, and pollutant removal rate are all considered. The formula is given as:

$$C_{in} = C_s + [(S/V) / (\lambda_v + \Sigma\lambda_{other})]$$

Where:

C_{in} = the indoor concentration,

C_s = the concentration in the air entering the space,

S/V = the indoor pollutant generation rate per unit air volume,

λ_v = the ventilation rate equal to outside air flow rate divided by indoor volume,

$\Sigma\lambda_{other}$ = the sum of all other indoor pollutant removal rates.

In practice, all four variables are not constant and may be had to measure. Therefore, a further explanation on the formula is given below.

"In practice, the situation is not as simple as suggested by the equation. The indoor pollutant emission rate (source strength) is usually not well known and not even constant. Indoor pollutant source strengths are highly variable among buildings, and considered the biggest cause of the variation in pollutant concentrations among buildings. Pollutants may be adsorbed by room surfaces during high concentration periods and desorbed again into the air during low concentration periods.

In many buildings, ventilation rates are not constant. For example, ventilation systems may not operate at night, and during operation rates of ventilation may change with internal heat loads or with outdoor air temperature. Pollutant concentrations may not reach equilibrium until several hours after ventilation rates stabilize. Thus, the indoor air quality is also dependent on operation schedule of the ventilation system. Additionally, the concentration of pollutants in the air entering the space is affected by five major factors: (1) the level of pollutants outdoors; (2) possible recirculation of return air; (3) the location of outdoor intake relative to outdoor air pollution sources; (4) pollution sources in the air handling *system; and (5) pollutant removal from supply air by filters, sorbents, or deposition on duct surfaces.*

The quality of the outdoor air has a significant effect on the cleaning capacity of ventilation air and should be taken in consideration while designing the ventilation. The air quality may vary depending on the time of the day in urban areas, for example the pollution from traffic is usually higher in the daytime as pollution from industrial sources and energy production is more constant over the time. The ventilation rates should reflect this variation."

Filter the Air — Another way of improving indoor air quality is through cleaning the air. That is, removing particles and/or gasses in the air. The most common method of cleaning is through filtration or through using filters. Proper filtration/cleaning using high efficiency filters (unlike the common, inexpensive filters found in hardware stores) is a key strategy to improve air quality. Forced air heating and cooling systems move air within the home constantly during operation. Homeowners who neglect to change or clean the system's filter subject themselves to higher levels of indoor airborne particles, along with higher heating and cooling costs (Waterfurnace, 2016). There is the controversy on the effective and efficiency of air filters to actually remove particles and gasses from the indoor air because filters vary in quality so much. some filters are even feared to be made of pollutant emitting materials. There is also some controversy about the efficiency of filters in particular in what regards the potential for incubating microorganisms and emitting smelling odours.

The United States Environmental Protection Agency (USEPA) provides a comprehensive list of air cleaners ranging from small table-top versions to sophisticated whole-house models. Occupants can further enhance the IAQ of their homes by replacing old filters. Old filters in heating, air conditioning, and ventilation units (HVAC), can be a major cause of indoor air pollution, and must be monitored, and replaced if necessary (BE, 2016). However, the European Commission states that the availability of different options regarding filters emphasize the need to establish a set of criteria and rules on how to select and size the appropriate filter for each specific service.

Today, many houses are designed to keep fresh air out. Therefore, the law requires many buildings, to have mechanical devices that have a positive impact on the air in the home.

Such devices, technologies or systems used to improve air in homes concentrate on two key strategies – ventilation and filtration. These include heat recovery ventilators, super-efficient HEPA filters and a variety of other high efficiency air cleaners and filters (Waterfurnace, 2016). Examples of such technologies are: Heat Recovery Ventilators (HRV), MERV 11 Disposable Filters, HEPA Filters, Electrostatic Air Filters, and Electronic Air Cleaners.

Heat Recovery Ventilators (HRVs): are designed with an air circulatory function that moves stale contaminated air from inside the home, baths and kitchens, to the outdoors, whilst, drawing fresh, oxygen-rich air form the outside, filters it and delivers it throughout the home. This action constantly replenishes the polluted air with an equal amount of clean and fresh air, thereby, providing a balanced system. In order for the new, fresh, and clean air to have the same temperature as the air inside the home, HRVs are built with an aluminium heat exchange core that transfers the heat from the air exiting the home to the fresh air coming in. This is possible because the two air streams i.e. the stale polluted air and the clean fresh air pass each other through the HRV, and are separated by the aluminium core which enables the heat transfer. It is important to note that the two streams pass each other but they do not mix. The effect happens during cooling, and its efficiency is certified 83% (Waterfurnace, 2016). HRVs can be connected to bathroom and kitchen fans.

HEPA Filters: On the other hand, HEPA filters are designed to provide the best filtration possible. It currently is the best choice with regards to filtration. It uses a technology that targets very small particles that particularly find it easy to pass through other filters. HEPA's filters are 99.9% efficient for particle sizes 0.30 microns and larger (Waterfurnace, 2016).

Minimum Efficiency Reporting Value (MERV) 11 Disposable Filters: This is another filter that's sold on its ability to trap particles ranging in size from 0.3 to 10.0 microns from the indoor air. These include pollens, mold spores, dust, fungal spores, and pet dander. MERV 11 is currently the best MERV filter among the range. Other filters such as MERV 4 and so on are less efficient - the higher the MERV rating, the more efficient the filter (Waterfurnace, 2016).

Electrostatic Air and Electronic Air Filters: these filters on the other hand use electrical magnetic charges/field generated from polypropylene filtration media and/or non-ionizing polarized media to arrest dusts, pollens, and molds particles. Electrostatic Air filters are 90%

efficient while Electronic Air Filters has a 97% efficiency rating to capture particles of 0.30 microns and above.

Table 2.8: Common Indoor Pollutant

Common Indoor Pollutant	Typical Particle Size (microns)	
Pollen, mold, plant spores	7-70	Larger
Dust mites	3-10	
Hairspray	3-10	
Large bacteria	1-20	↕
Auto emissions	1-3	
Lead dust	1-3	
Fungal spores	0.50-7	
Cooking smoke/odors	0.30-1	
Paint pigments	0.30-1	
Dust	0.20-8	
Pet dander	0.15-8	
Small bacteria	0.08-1	
Tobacco	0.008-0.6	Smaller
Viruses	0.005-0.01	
Volatile organic compounds	Less than 0.001	

Source: Waterfurnace (2016)

Control Moisture – The simple fact is that mould needs moisture to live. Control moisture and control mould. Greenguard is an organisation responsible for certifying products and materials, and helps buyers identify and trust--interior products and materials that have low chemical emissions, improving the quality of the air in which the products are used. They state that the following can help occupants keep moisture out of their living spaces: keep homes dry using dehumidifiers, take immediate action during floods to clean and dry walls, have exhaust fans in bathrooms, and install filters.

2.16 Discrepancy in International Standards & Guidelines

A wide range of IAQ standards and guidelines exist. The guidelines and standards vary with respect to their source. Some standards are derived from practice, whereas others are based on the results of scientific studies, or consensus based on available knowledge. Some of the standards focus on acceptable levels for occupant comfort and the avoidance of odour irritation, whereas others are based on health concerns. Some of the guidelines and standards were developed for industrial settings, where contaminant concentrations are likely to be relatively high, whereas others were created for non-industrial settings, such as offices and residences. Some of the standards and guidelines are legally enforced, as opposed to other recommended criteria which are voluntarily adhered to (Charles, 2005). If regulations are based on IAQ threshold levels for single pollutants solely, then this is not effective, and so source control or source management is the best way to proceed (EC, 2003).

There are three control strategies used to improve the IAQ in a building (ASHRAE, 1999)

- Source elimination
- Local source control
- Dilution of the indoor contaminants by ventilation.

Reduction of all emissions, of all products encountered in the indoor environment, will at least reduce the number and concentrations of pollutants even though the mechanisms behind it are not known. Quantification of the emitted substances will only permit to identify major sources for some compounds.

2.17 Summary

The literature review to date has shown that whilst there are clear links between IAQ and health, the measurement, regulation and control of pollutants remains a difficult issue. Some standards do exist, but these are patchy in nature and are not user friendly for the stakeholders influencing building design and construction in Kuwait. The main aim behind this research's aim to develop a framework for good IAQ in design, construction and occupancy stage in Kuwaiti housing developments, is so that building environments can provide healthy and comfortable IAQ conditions that are energy efficient.

Ultimately, the literature review revealed that there are four pillars to achieving good IAQ at design, construction, and occupancy stages. They are: integrated project delivery approach, commissioning, scheduling and sequencing, and documentation and reporting. Good IAQ process ensures the protection of occupants' health (EC, 2003). A good IAQ process that incorporates the four pillars combine in most efficient way possible to provide the best healthy environment for residents as well curb building related illnesses and loss of productivity. To reiterate the need for regulations and standards for good indoor air quality

(IAQ), this study refers to a statement by the World Health Organisation (WHO). It states that the *"key strategy for the management of IAQ consists of developing a comprehensive, scientifically sound and thoroughly considered action plan which targets both new constructions and existing buildings."* According to Fisk and Rosenfeld (1997), the potential cost to society of poor indoor air quality is high. They state that poor 'energy saving' strategies, bad HVAC design, malfunctioning installations, poor maintenance or lack of commissioning may cost more to society and business life than what is gained from energy or other savings. On the flip side, experimental studies have demonstrated that improving IAQ in institutions, domestic and commercial buildings, improves productivity with performance in office tasks going up to 6% (EC, 2003). Therefore, improving the indoor air quality of buildings is definitely a worthwhile investment. This is why the findings and recommendations of this study will be especially important for the Kuwaiti people.

3 CHAPTER 3| KUWAIT, IAQ, AND REGULATIONS AND STANDARDS

3.1 Introduction

The GIS locates the State of Kuwait at longitudes 46°33’ and 48°30’ East and latitudes 28°30’and 30°5’ North. It situated in the northwestern end of the Arabian Peninsula with a total land area of approximately 17,818 km2. The State of Kuwait is consisting of a mainland, that is, Kuwait City, and nine other islands that are uninhabited on the Arabian Gulf (KEPA, 2012).

Figure 3.1: Map of the State of Kuwait (Source: KEPA, 2012)

KEPA (2012) categorize the entire coastline perimeter into two distinct zones; with Kuwait bay, Failaka, Maskan, Bubiyan, Ouha, and Warba on the North zone, and Ras Al-Ardh on the South zone.

3.2 Kuwait Demographic

Kuwait has an estimated current population of 56,200 and has steadily been increasing in population over the past two decades, with a 3.3 average growth yearly. an overwhelmingly urban population that has grown steadily over the past two decades. 1994 to 2011 saw the most growth in a period, with a 4.1% per year on average growth. The number of foreign workers has also increased exponentially to about 4.6% per year on average in the same period (KEPA, 2012). Kuwait city has a busy economy as it is the commercial capital. It is the banking, government, cultural, political, and economic center of the country.

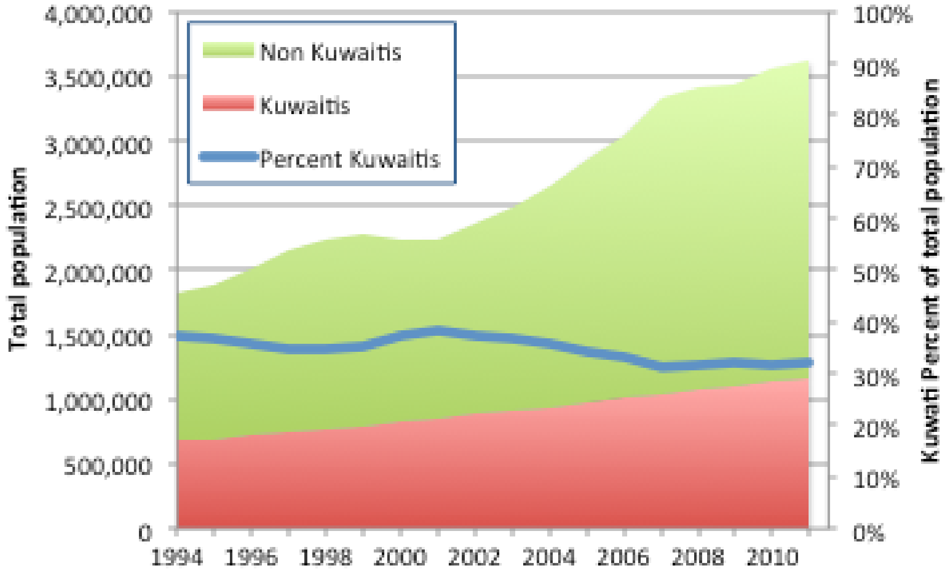


Figure 3.2: Population Composition (KEPA, 2012)

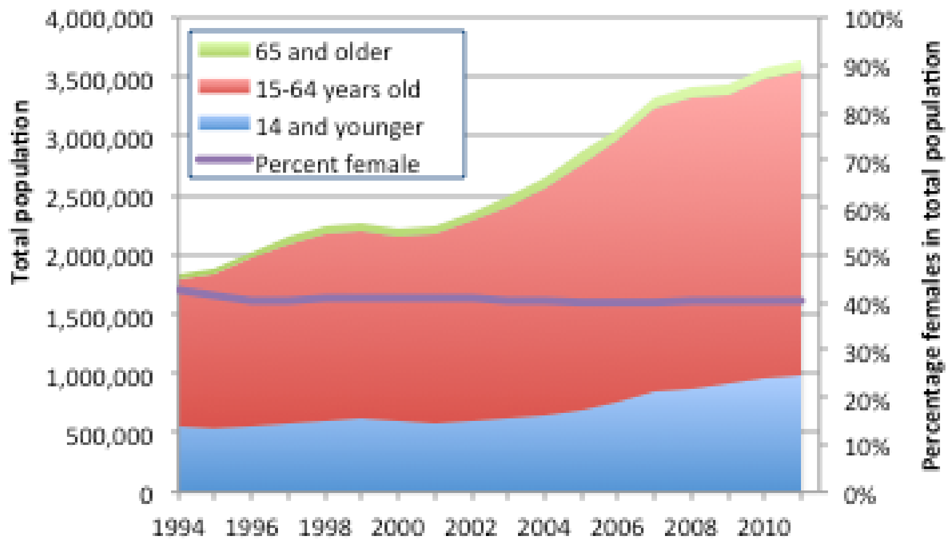


Figure 3.3: Population age and gender characteristics (source: KEPA, 2012)

In Figure 3.3, the years 1994 to 2011 saw the male population rise to about 60% of the population, mainly before of the presence of a huge number of foreign workers which is mainly male. However, the age of the population is mainly between 16 and 64 years of age and roughly 51% of these in 2005 are young Kuwaitis. It was also reported by KEPA (2012) that the gender split between male and female is roughly 50%-50%.

3.3 Climate condition of Kuwait

Kuwait climate can be described as a hyper-arid desert climate - hot and dry. Temperatures can range from 42°C to 46°C in summer, and can get up to 53.5°C. An average rainfall that varies from 75 to 150 millimeters a year is still insufficient to cool the place. A particular air-quality compromiser is Dust storms. They are particularly prevalent in the summer and can reach speeds up to 50 km per hour. Kuwait City has experienced or recorded subzero temperatures in the past with the lowest recorded temperature at −4°C in January 1964. Figure 3.4 The average climatic conditions between 1962-2008 at Kuwait airport is shown in Figure 3.4 below, (KEPA, 2012).

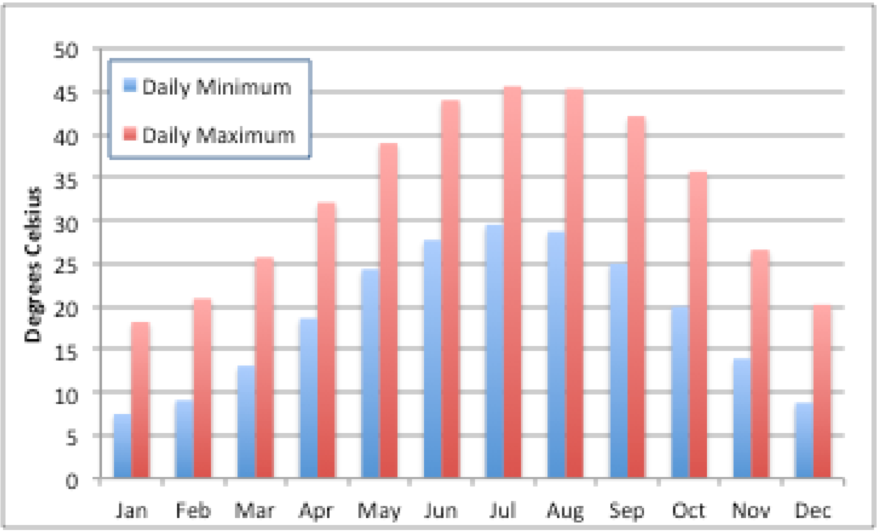


Figure 3.4: Kuwait average monthly temperature, 1962-2008 (source, KEPA, 2012)

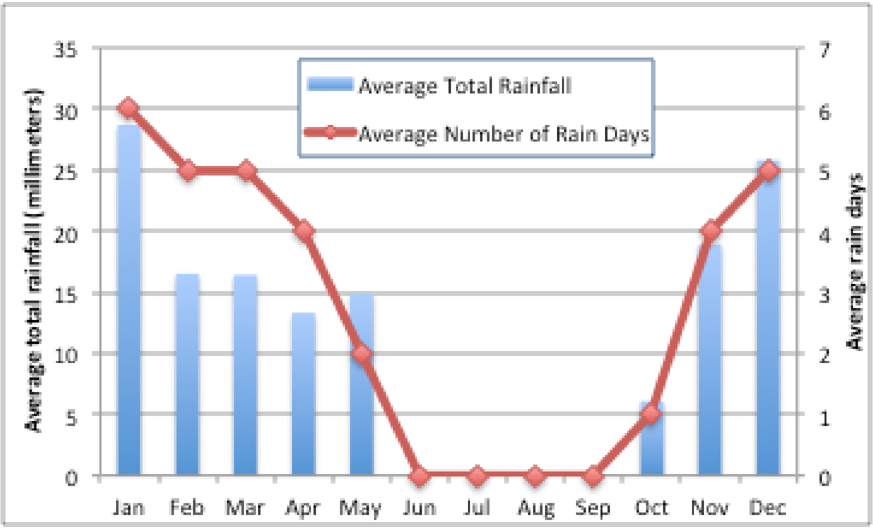


Figure 3.5: Kuwait average monthly rainfall, 1962-2008 (source, KEPA, 2012)

Three prominent features that characterize Kuwait's climate

- *Humidity:* From mid-August through September, humidity can exceed 95%. This is due to high seawater temperatures coinciding with tropospheric temperature inversions. Relative humidity over the last 48 years (1962–2010) has average about 48%, with mean yearly maximums varying from 84% to 95%.

- *Evaporation:* Over the period 1994-2011, average evaporation rates vary from 3 to 13mm per day, with maximum levels ranging from 20 to 48 mm per day.

- *Dust storms:* While they can occur in any season, dust storms are particularly frequent in the summer and can reach speeds up to 100 km per hour (See Figure 3.6). Dust storms are aggravated by practices of overgrazing and citizen (uncontrolled) camping and are known to contribute to serious health impacts in Kuwait such as asthma incidence rates of 175 per day and road traffic accident rates that are over three times normal rates (Safar, 1985, KISR, 2012).

Figure 3.6: Dust storm approaching Kuwait City on 25 March 2011 (Source: KEPA, 2012)

Kuwait's climate exhibits all four seasons. Between 6 December and 15 February (two months) the winter period is expected to start. Low temperatures, clouds, rain and a cold northwesterly wind characterize this season (KEPA, 2012).

3.4 Kuwait Environment

According to KEPA, environmental education and awareness is a national commitment and an essential and integral part of the education program at all levels in Kuwait (KEPA, 2012). The organization (KEPA) aims to develop a concern and create awareness amongst Kuwiatis about environmental challenges and the value of environmental services. The programs aim to enhance commitment on an individual basis and on a collective basis towards protection of the environment. Moneys of about $30m have been allocated and spent for these programs since 1991, where policies have been enacted to give priority to environmental research projects. Many institutions within Kuwait City have substantial capacity to conduct environmental activities with real results. Only that not much has been done.

3.4.1 Greenhouse Gas Emission in Kuwait

Greenhouse gas emission research in Kuwait started in the late 90s. Using the revised IPCC 1996 Guidelines, and Good Practice Guidance, Kuwait developed its first greenhouse gas inventory. Using 1994 as the base year of inventories, Table 3.1 summarizes Kuwait's overall GHG emissions profile. Total National Emission was 32,373 Gg CO2e, energy with the highest emission rate at 30,855 Gg; followed by Waste at 784 Gg, industrial processes at 668 Gg, agriculture at 66 Gg, Solvent and other product use at 0, and land-use change, and last, forestry at -22. According to KEPA (2012), fossil fuel burning and emissions caused by oil and gas operations are responsible for about 95.3% of all GHG emissions in Kuwait City. With Waste at 2.4% of all GHG emissions and so on.

Table 3.1: Total Green House Gas Emission in Kuwait, 1994 (Gg) (source: KEPA,2012)

GHG Sources & Sinks	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
1 Energy	30,855	28,856	92.69	0.17	113	544	522	320
2 Industrial Processes	668	668	0.00	0.00	0	0	0	0
3 Solvent & Other Product Use	0	0	0.00	0.00	0	0	0	0
4 Agriculture	66	0	2.70	0.03	0	0	0	0
5 Land-Use Change & Forestry	-22	-22	0.00	0.00	0	0	0	0
6 Waste	784	0	33.80	0.24	0	0	0	0
Total National Emissions	32,373	29,524	129.19	0.44	113	544	522	320
Net National Emissions	**32,351**	**29,502**	**129.19**	**0.44**	**113**	**544**	**522**	**320**

3.4.2 Vulnerability and Adaptation

The climate vulnerability of Kuwait was done with respect to coastal zones and water resources, to which temperature and rainfall were looked at first. The results showed that the average annual temperatures will increase in the future with a 1.6°C increase over the average annual temperature moving forward. On the other hand, rainfall is forecasted to decline in the future reversing past trends in Kuwait, with an annual decrease of about 2 mm/year per decade through 2035. This will have an adverse effect on farmers, plantations, and grazing areas of livestock. Increased dust storms have also been forecasted for Kuwait City (KEPA, 2012).

According to KEPA, the coastal lines of about 350 km upon which Kuwait depends on are under threat of climate change. This will have an adverse effect on Kuwait's geo-economic, socioeconomic activities and development, because the coastline is the region which inhabits most of the population and critical infrastructure. Other threat of climate change are; the rising seas causing the risk of flooding, coastal lagoons and salt marshes may be lost, and the quality of groundwater may continually deteriorate. GIS, using its latest analysis techniques, and a sea level rise scenario approach, projected about 542 km2 of land area, and about 174,000 people at risk. Table 3.2 provides a summary of results.

Table 3.2: Extent of inundated area and population at risk under the SLR scenerios (source: KEPA,2012)

	Sea level rise scenario							
	Low (MHTL + 0.5 m)		Central-Low (MHTL + 1.0 m)		Central-high (MHTL + 1.5 m)		High (MHTL + 2.0 m)	
Coastal zone	Km^2	% of total	Km^2	% of total	Km^2	% of total	Km^2	% of total
Northern	199	1.1	408	2.3	416	2.3	419	2.4
Central	34	0.2	34	0.2	34	0.2	76	0.4
Southern	7	<0.1	7	<0.1	46	0.3	46	0.3
Total inundation	**241**	**1.4**	**450**	**2.5**	**496**	**2.8**	**542**	**3.0**
People at risk (thousand)	**65.1**	**1.8**	**65.1**	**1.8**	**125.8**	**3.5**	**173.7**	**4.8**

3.5 Kuwait Pollution risk from Transportation

Kuwait has enjoyed a very rapid growth in it socioeconomic and infrastructure development in the forty years. The construction of freeways and other accesses has contributed immensely to the development of the socio-economic sectors in Kuwait (Al-Salem and Khan, 2010). The overwhelming and increasing population of over three million relative to its land mass, and the number of vehicle fleet on the roads, Kuwait City is experiencing increasing volumes of traffic. Hence, the outdoor air is becoming increasingly polluted. The air quality is becoming a major air pollution issue and concern for the people living in Kuwait City. Given that Kuwait City is by far dependent on automobiles for travel. The smoke/sooth caused by traffic congestion during rush hours (within city limits and along major highways) contribute mainly to the CO, NOx and VOCs levels in the air. According to Al-Salem and Khan (2010) there is an average of 611 to 2792 vehicles/hr. on the roads in Kuwait City. Also, Al-Salem and Khan (2010) showed that; activities on the city harbor, oil fields, power stations, refineries, also contribute to the traffic-related airborne pollutants and pollution load in Kuwait City. Although, the latter contribute the least to the overall air pollution. Kuwait has three major refineries located on the south and called the ‘refineries belt’. Along that belt are other industrial activities such as petrochemical processing facilities, conversion industries, and fossil fuel power plants on the north. These activities are the main sources of SO2 and NOx pollutants in the city of Kuwait. In addition, H2S and NH3 pollutants are generally emitted by old landfills, oil fields, and other agricultural activities that take place within the vicinity of the city (Al-Salem and Khan, 2010).

Al-Salem and Khan (2010) documents the work of Al-Mutairi and Koushki (2009). Al-Mutairi and Koushki (2009) analyzed 7 years of data from 1998 to 2004 of three outdoor air monitoring stations of KEPA. Results showed that the concentration levels of gases such as CH4, CO, NOx, O3, SO2, and TS, had increased over the same period, with NOx and SO2 exceeding the permitted standards. Pollution from Traffic, hitherto, was the main source of ambient air pollution in Kuwait City. However, in recent years, oil refineries, power plants, industrial activities, etc. contributes the most to the ambient air pollution in both the urban and rural areas. Furthermore, there is no literature available that has reviewed air pollution trends or sources in the city of Kuwait.

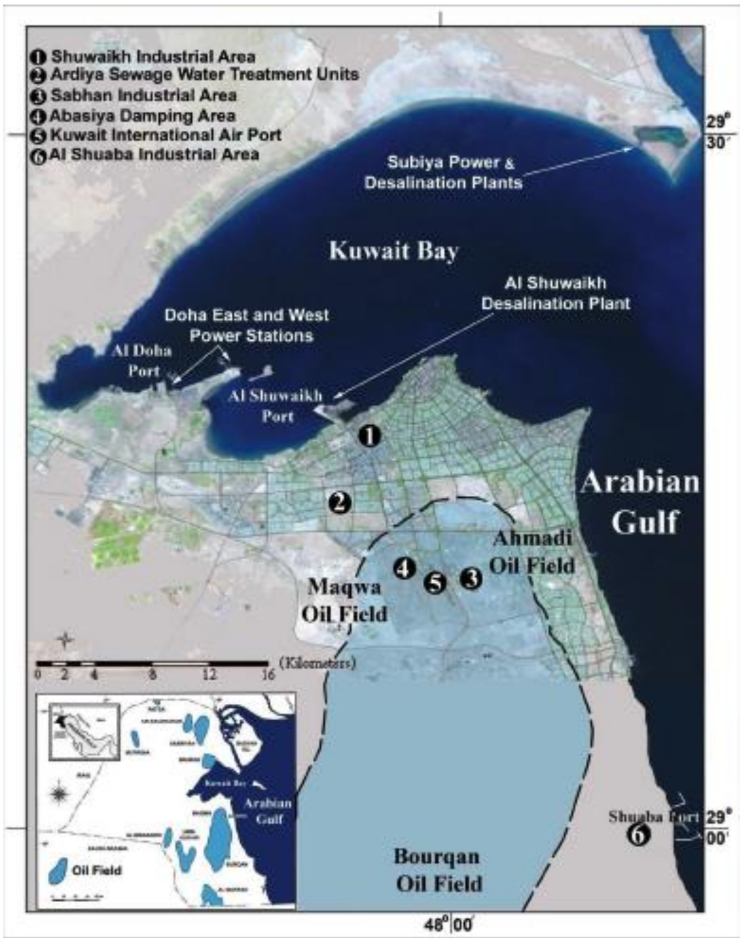


Figure 3.7: Possible local sources of pollutants to Kuwait City (Source: Al-Awadhi, 2014).

3.5.1 Major Pollution Sources and Activities within the State of Kuwait.

The geographic characteristics of Kuwait and the human activities in Kuwait make it susceptible to air pollution. Furthermore, the major contributors to the ambient air pollution load are; the petrochemical and conversion factories, the harbor activities from the north, and traffic-related emissions from the south (Al-Salem and Khan, 2010). Majority of the CO, NOx and VOCs levels in the ambient air of the city are mainly contributed by traffic congestion which reach peak levels during rush hours. Major roads such as King Abdulaziz (Fahaheel), 5th and 6th ring road, are where high levels emissions are seen because of the heavy traffic in the area. Al-Salem and Khan (2010) report that there are 100 registered cars to 33 residents in Kuwait. In other words, every resident has three cars. This astounding number contribute to the level of pollutant that Kuwait City contends with in its ambient air. Kuwait Environment Public Authority (KEPA) must take up the mantle of studies of how the level of pollution in the ambient air affect Indoor Air Quality in residential and well commercial areas in Kuwait City.

3.5.2 Primary Pollutants Monitoring.

compared to its neighbors, Kuwait suffers more from pollutant effects (Al-Salem and Khan, 2010). KEPA's strategically located ambient air monitoring stations take these readings. However, it has been argued that the locations of the monitoring stations are not strategic after all and need to be redistributed within the city, in residential areas to measure actual impact of a number of primary pollutants such as CO2. Abdul-Wahab (2009) compared the concentration of primary pollutants in residential areas of Kuwait and that of Oman, in terms of air pollutants and their loads. His result showed higher levels of primary pollutants in Kuwait urban residential areas than Oman's suburban industrial area. This levels are pretty high for residential areas. The results also showed that both non-methane hydrocarbons NMHC, NO2, and CO, peaked three times daily which was also linked to the traffic loads on the roads, and that these numbers have exceeded the Kuwait standards for residential areas (Al-Salem and Khan, 2010).

3.5.3 Secondary Pollutants.

According to Al-Salem and Khan (2010), the secondary pollutant in the ambient air that is of major concern is ground level ozone (O3). The high ambient temperatures and high emissions some primary pollutants contribute to ozone formation, with power plants, cars, and diesel operated machinery or vehicles, as major contributors of secondary pollutants. Therefore, the priority is to control ozone formation by controlling the emission of precursor gases i.e. NOx and VOCs (Al-Salem and Khan, 2010). Hence reducing the number of cars on the roads, and adopting alternative, green power generation strategies is crucial to reducing the ozone levels and formations (Al-Salem and Khan, 2010).

3.5.4 Health Impact.

Brunekreef and Holgate (2002) state that both primary and secondary pollutants have: a health impact on human health, negatively affect; plant life, crop yield, and the eco-system (Al-Salem and Khan, 2010). Pollutants such as tropospheric O3 found in urban regions have detrimental impacts on human health (Karandinos and Saitanis, 2005; sited in (Al-Salem and Khan, 2010).

Research is clear on the link between air pollution and the number of health effects on the Kuwaiti population of different ages and groups in the unban area of Kuwait (Beinstein et al. 2004). Studies have shown that between August-October 1991, 40% of the patients in Kuwait hospitals suffered a respiratory related problem, even after discounting the first Gulf War and oil fields fires effects. Al-Ghawaby et al (1994) drew a strong correlation between specific pollutant and symptoms to respiratory diseases.

3.6 Kuwait studies in IAQ

There has been very few studies done in the indoor air quality in the state of Kuwait, however, some studies were done on a specific pollutant and consequential effects.

1. A study in Kuwait university was conducted about student knowledge and attitudes indicating a low level knowledge about indoor air pollution and subsequent consequences (Khamees and Alamari, 2009) although teachers showed a greater knowledge than students. The overall study shows lack of knowledge and awareness in Kuwaiti high school students.

2. Results of a research carried out by Al-Azmi et al, (2008) on 300 residents in Kuwait showed that radon concentration in the living room, basement and bedrooms ranged between 4.0-241.8 Bq m-3 and a mean value of 32.8 Bq m-3, with most values are confined within the range of 10-50 Bq m-3 for all locations and only a few cases were above the value of 100 Bq m-3. However, the author didn’t specify the regulation he was comparing the findings to. Yet in September 2009, the World Health Organisation released a comprehensive global initiative on radon, that recommended a reference level of 100 Bq/m3 for radon, urging establishments to strengthen policies of radon measurement and mitigation programs as well as development building codes requiring radon prevention measures in homes under construction (Field, 2009), hence there is big

span between 4 - 241 Bq m-3, also there is no current regulation which exists that professionals could relate to in Kuwait. Another consideration is that radon levels could accumulate over time, one day the readings may be lower than acceptable limits, but with time the radon level could rise, due to the fact that buildings are sealed and the radon gases are trapped, therefore, radon levels could exceed the international standards. Further, there is no mitigation procedure, which exists in Kuwait to expel radon out of the dwellings.

3. A study was conducted called 'Factors Responsible for Asthma and Rhinitis among Kuwaiti School children' which concluded that there is a high prevalence of asthma and rhinitis among school children in Kuwait (Abal et al., 2010). Another study was conducted which showed that 26% of the sample of children had asthma, which is far from optimal. (Khadadah et al., 2009)

4. Another study was conducted with the objective of investigating the relationship between indoor air quality and asthma symptoms. Data mining techniques were employed to discover the correlation between indoor air quality measures and asthma symptoms and triggers. The main trigger considered was the concentration of nitrogen dioxide, but other triggers investigated were dust mites, smoking and others. The study validated the author's hypothesis that there was a high correlation between the indoor concentration of nitrogen dioxide and asthma symptoms in Kuwaiti indoor environments (Al-Anzi and Salman, 2011).

5. The international study of asthma and allergies in childhood (ISAAC) was set up to use standardised written and video questionnaires to study the prevalence of asthma, allergic rhinitis (AR) and eczema in different countries of the world. Kuwait ranked 13th among 56 countries in the prevalence of symptoms of asthma in children with a prevalence of current wheeze of 16% among Kuwaiti children (Behbehani et al., 2000). The prevalence is higher than other countries in the Arab world where similar surveys were done, namely Oman, Morocco and Lebanon.

3.7 Greenhouse Gas Mitigation

According to the State of Kuwait Environment Public Authority (KEPA) (2012) *"an evaluation of key technology options to reduce GHG emissions was carried out to develop a* *better understanding within Kuwait of the potential synergies such options may enjoy with national development goals and priorities. These benefits include, but are not limited to, reduced air pollution levels, enhanced institutional environment for new technologies, diversified power supply, reduced road congestion, and job creation."*

Figure 3.8 shows the impact of GHG mitigation options, which are; centralized solar and wind, green buildings, fuel switching, and district cooling. According to KEPA (2012) the implementation of these GHG mitigation options in Kuwait would lead to significant reductions in CO2e emissions by 2020. A total of 10,284 Gg of CO2e would be avoided in 2020, roughly equivalent to 10% of the Baseline GHG levels in that year. Figure 3.8 provides a summary of results.

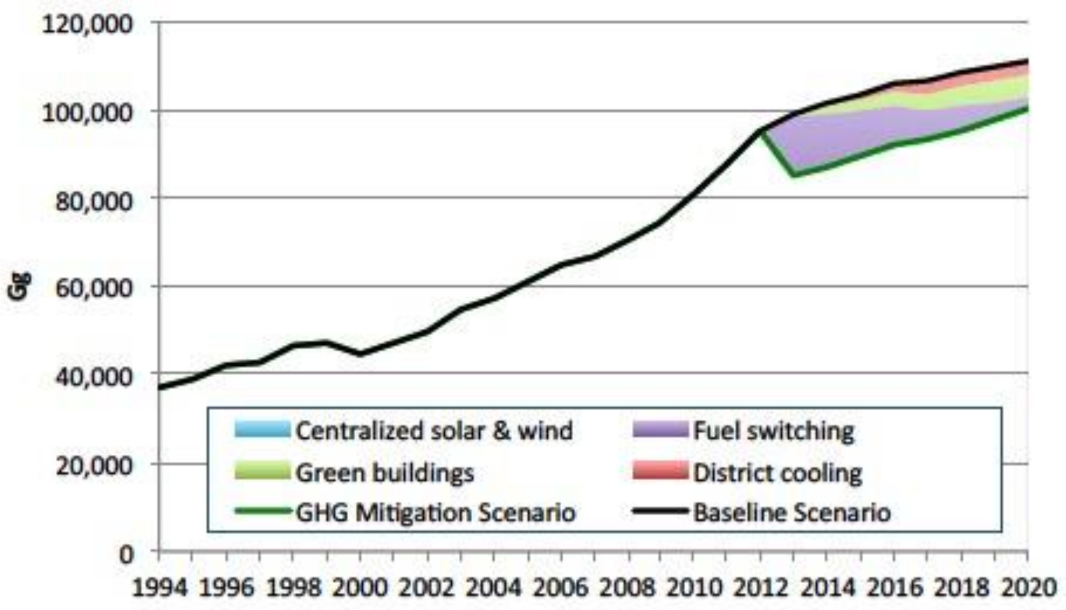


Figure 3.8: Impact of GHG mitigation option, 1994-2020 (source: KEPA,2012)

3.8 Technology Needs Assessment

The assessment of Technology Needs in Kuwait was aimed at identifying technology options to mitigate against the effects of climate change in Kuwait.

"Due to the prominence of energy production and consumption in Kuwait's GHG emission profile, the focus for mitigation technologies was on the energy sector. Specifically, technologies for electricity generation, as well as technologies that can reduce residential building energy consumption were targeted. A total of 16 priority mitigation technologies are

recommended. For adaptation technologies, the focus was on coastal zones, water resources, and public health (KEPA, 2012)*."*

The priority technologies are not without barriers if they are intended to be adopted all over the country. To overcome these barriers the government and private sector key stakeholders, as well as the technology companies themselves would need to draft policies and measures that will reform, educate, support, and strengthen the emergence of these technologies.

3.9 Rules and Regulations.

State of Kuwait rules and regulation governing emission rates of ambient air pollutants are implemented by KEPA formerly a division of the Kuwait Ministry of Health. This government body was officially recognized and given legal powers in the year 2001. Currently, there is a set threshold limit of emissions of the different ambient air pollutants. Both residential and industrial areas have their set threshold.

3.10 Summary

It is evident that though rules and regulations governing emission rates of ambient air pollutants in the state of Kuwait exist, but there are no rules and regulations or guidance that govern good Indoor Air Quality (IAQ) and household pollutant level in Kuwait housing developments. However, in the last decade, many countries have set out to investigate indoor air quality and the pollutant concentration levels (Al-Rashidi, 2011). As a result, many countries have drafted IAQ guidance or IAQ rules and regulations to indicate the level of acceptable concentrations of indoor pollutants. For example, in Table 3.3 Al-Rashidi (2011) summarizes a IAQ standards and guidance (by country) for common indoor air pollutants. However, the Kuwait Environment Public Authority (2001) standard is very scanty and only discusses industrial, commercial and workplace pollution standards and not housing, and that is what make it different from this research. Furthermore, it does not discuss how to improve the achievement of good IAQ in the design, construction, operation and management stages of a housing project. Appendix 2 and 4 also documents international standards and regulations of different organizations, and Ambient air quality standards for residential areas in Kuwait respectively. These appendices might be useful to the reader.

Table 3.3: International and Kuwait Standards and Guidelines for Common Indoor Air Pollutants (in ppm)

	NIOSH (1992)	Canadian (1995)	OSHA	MAK (2000)	NAAOS/EPA (2000)	WHO/Europe (2000)	ACGIH (2001)	Hong Kong (2003)	KW-EPA (2001)
Sulphur Dioxide (SO_2)	2 [8 hr] 5 [15 min]	0.019 [8 hr] 0.38 [5 min]	5 [8hr]	0.5 [8 hr] 1.0 [5 min]	0.14 [24 hr] 0.03 [1 yr]	0.047 [24 hr] 0.012 [1 yr]	2 [8 hr] 5 [15 min]	0.03 / 0.04 [8 hr]	2 [8 hr] 5 [15 min]
Nitrogen Dioxide (NO_2)	1.0 [15 min]	0.05 [1 yr] 0.25 [1 hr]	5 [Ceiling]	5 [8 hr] 10 [5 min]	0.05 [1 yr]	0.1 [1 hr] 0.02 [1 yr]	3 [8 hr] 5 [15 min]	0.021/ 0.08 [8 hr]	0.026 / 0.08 [8 hr]
Carbon Dioxide (CO_2)	5000 [8 hr] 30000 [15 min]	3500 [8 hr]	5000 [8 hr]	5000 [8 hr] 10000 [15 min]			5000 [8 hr] 30000 [15 min]	800 / 1000 [8 hr]	600 / 1000 [8 hr]
Carbon Monoxide (CO)	35 200 [Ceiling]	11 [8 hr] 25 [1 hr]	50	30 60 [30 min]	9 [8 hr] 35 [1 hr]	86 [15 min] 51 [30 min] 25 [1 hr] 8.6 [8 hr]	25	1.7 / 8.7 [8 hr]	86 [15 min] 51 [30 min] 25 [1 hr] 8.6 [8 hr]
Particular Matter (< 2.5 μm)		0.1 mg/m^3 [1 hr] 0.04 mg/m^3 [8 hr]	5 mg/m^3	1.5 mg/m^3 For < 4 μm	35$\mu g/m^3$ [24hr] 15$\mu g/m^3$ [1 yr]	25$\mu g/m^3$ [24hr] 10$\mu g/m^3$ [1 yr]	3 mg/m^3		0.23 mg/m^3 [24 hr] 0.07 mg/m^3 [1 yr]
Formaldehyde (HCHO)	0.016 [8 hr] 0.1 [15 min]	0.1 [5 min] 0.04 [1 yr]	0.75 [8 hr] 2 [15 min]	0.3 [8 hr] 1.0 [5 min]	0.4 [8 hr]	0.081 [30 min]	0.3 [ceiling]	0.024 / 0.081 [8 hr]	0.08 [30 min]
Radon (Rn)	4 pCi/L [1 yr]	5 pCi/L [1 yr]	4 pCi/L [1 yr]		4 pCi/L [1 yr]	2.7 pCi/L [1 yr]		4 / 5 pCi/L [8 hr]	4 pCi/L [1 yr]
Ozone (O_3)	0.1 [8 hr]	0.02 [8 hr]	0.1 [8 hr]	0.06 [8 hr]	0.12 [1 hr] 0.07 [8 hr]	0.06 [8 hr]	0.05 – heavy work 0.2 – any work [2 hr]	0.025 / 0.061 [8 hr]	0.03 / 0.1 [8 hr]

Source: Al-Rashidi (2011)

4 CHAPTER 4| RESEARCH METHODOLOGY

4.1 Introduction

According to Collis and Hussey (2003), methodology refers to the overall approach to the research process, from the theoretical underpinning to the collection and analysis of the data. There are several types of research methodology, which can help the researcher to conduct the research, and the nature of the research usually identifies the most appropriate methodology. The methodology employed must allow for the effective pursuit of the research objective(s) and answer the research question(s). For example, the research onion given by Saunders et al, (2009), show all the possible research positions or directions that can be taken by any research study.

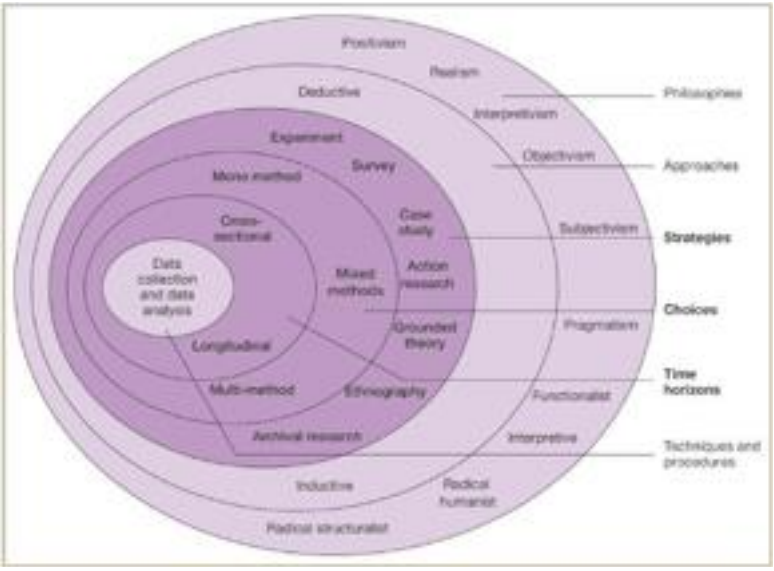


Figure 4.1: Research Onion (Saunders et al., 2009)

This study will adopt the nested research methodology approach, as identified by (Kagioglou et al., 2000). The thesis will first discuss the research philosophy, and will be followed by a discussion on the research approach; quantitative and qualitative research methods, followed by the research strategy; research choices, research design, research technique, and methods of data collection and analysis. But first, lets look at the philosophical position of this research.

Figure 4.2: Nested Approach of research methodological design (Kagioglou et al., 2000)

4.2 Research Philosophy

The concept of research philosophy refers to the process of scientific practice based on people's views and assumptions regarding the nature of knowledge. Research philosophy can help to classify the type of evidence required, how to gather it and how to understand it in order to find an answer to the basic problem under investigation. Reference to research philosophies enable the researcher to resolve the research questions by identifying, adapting or even creating research designs that project beyond existing experience and knowledge (Easterby et al., 2002 cited in Kulatunga, 2007).

The research philosophy is dependent on the researcher's thinking and assumptions about the process of knowledge (Saunders et al., 2003). Failure to think through philosophical issues, can seriously affect the quality of management research (Easterby-Smith et al., 2002). An understanding of philosophical issues is very useful, since it can help to clarify research designs and the methods by which data is collected and analysed.

4.2.1 Ontology

According to Saunders et al (2009), ontology is concerned with the nature of reality - how the world operates and the laws that govern social entities. Ontology, he said, seeks to answer the question whether social entities exist independent of social actors (Objectivism) or is social phenomena caused by the actions of social actors (Subjectivism). Therefore, lets look at the two separately. *Objectivism* is an aspect of ontology that is concerned with view that social entities exist independent of social actors. For example, objectivism approach asserts that the law of gravity exist outside of human influence. While *Subjectivism* is concerned with the social phenomena that is created from the perceptions and consequent actions of social actors – an understanding of the meanings individuals attaches to social phenomena (Saunders et al, 2009). This has to do with how social actors interact and how that creates social phenomena as that interaction continues to change. According to Saunders et al (2009), as the social actors interact, they also try to 'interpret' the situation. So not only do social actors try to interpret their situation, they also try to make sense of it.

4.2.2 Epistemology

Epistemology is concerned with what constitutes acceptable knowledge within a particular field of research. That is, should a quantitative researcher put more authority on his research than a qualitative researcher? This question is what epistemology seeks to answer. There are two types of epistemology – positivist philosophy that advocates for more quantitative approach to research; and, interpretivist philosophy, which is more concerned with measuring intangibles like emotions (Saunders et al, 2009).

Positivism

This aspect of epistemology and therefore, philosophy, is an advocate for quantitative crude data, more like the natural scientific approach, and affirm that "only observable phenomena can lead to credible data" (Saunders et al, 2009). In other words, the researcher is assumed to work only in an observable social reality which will end in generalizable laws similar to the laws produced in natural and/or physical science research. As against results based on the researcher's interpretation of the phenomena, which can not be entirely value free.

Realism

This is another aspect of epistemology which is similar to positivism but differs in its assumption that an unobservable phenomenon exists regardless of its perceived absence. According to Saunders et al (2009), there are two types of realisms; direct realism and indirect realism. Direct realism states that our senses tell us the right thing and we can trust them. For example, that what we see or feel is the actual representation of reality. On the other hand, however, indirect realism asserts that we can not trust our senses. That sometimes what we perceive may not be the actual representation of reality. For instance, the example of the "bent oar". The observer can swear that the oar is bent in the water when in reality, the oar is straight. Therefore, indirect realism states that we can not always trust our senses, and therefore, the unobservable phenomenon exists regardless of its perceived absence.

Interpretivism

This is yet another aspect of epistemology which states that the interpretations of the interactions between social phenomenon e.g. people, can be trusted as accurate representations. The researcher however, must observe or interpret the interactions from the lens of the subjects under the study and not impose meanings to actions which are contrary to the subject's meaning of the same action. The researcher has to allow himself to be guided by the subjects and be open minded to allow the research to be organic and accept whatever new findings or direction that comes up (Saunders et al, 2009).

4.2.3 Axiology

Axiology is a philosophical approach that is concerned with; how much influence has a researcher's values influenced the choice of, interpretation, and outcome of their research. There are two parts to axiology *value-free* or *value-laden* (Saunders et al, 2009). Axiology asks the question; to what extent has our values influenced our judgement or changed our research method, research design choices, and even analysis? Both quantitative and qualitative research works, can be influenced by the researcher's values. However, results from qualitative research are more at risk of being value-laden. Research results from natural sciences claim to be value free, because the results do not depend on the researcher's interpretation of the results. It just is. But Saunders et al, (2009) argues that not all natural science research is free from value interference. The research is value laden by virtue of the researcher's discretion to choose that topic.

4.2.4 Pragmatism

According to Saunders et al (2009) pragmatism is another aspect of research philosophy that argues that the single most important thing in any research, is the 'research question'. Basically, the research question is king. This is because Saunders and his colleagues believed that the philosophical stance of any research; ontological, epistemological, and axiological, all depend on the research question. And there is no one best position in research philosophy and frankly, can be combined within one study if in doing so, the research question is answered perfectly.

4.3 The philosophical stance of this research

This research, which aims to improve In-door Air Quality (IAQ) in Kuwaiti Housing Developments at Pre-Construction, Construction, And Occupancy Stages, through the development of a framework that will do just that, adopts the subjectivist view that social actors create social phenomena. This is because the researcher here, will be dealing with how people cause and influence social phenomena. The Epistemological stance of this research is the interpretivist view because the perception of feelings and opinions of construction stakeholders with regards to improvement of indoor air quality (IAQ) is to be studied. Although, It may be argued that the research also flirts with the 'positivist' position since the research also make use of questionnaires in gathering quantitative information to support the qualitative data collected from interviews. Therefore, we can say that the research's epistemological position is 'positivist/interpretivist'. The axiological stance of this research is value-laden because every research has an element of bias even in quantitative research – the choice of a topic is value laden.

4.4 Research approach

There are two types of research approaches: deductive and inductive. With deductive approach, a hypothesis (or hypotheses) is developed from existing theory and a research strategy is designed to test the hypothesis. On the other hand, inductive approach collects data and then from the analysis, a theory is developed.

4.4.1 Deductive approach

Deductive approach is similar to the research done in the natural sciences. At the start of deductive research, a hypothesis is created which has some form of a 'causal relationship' element to it. Then as the study proceeds, the hypothesis is tested or modified (if necessary) to see is its true or not; then finally, conclusions are drawn. Usually deductive research is closely related with positivism. Deductive research also seeks to reach a generalizable conclusion (Saunders et al, 2009).

4.4.2 *Inductive approach*

Inductive approach starts with a large amount of data that is analysed to arrive at a conclusion that can be theorised. Inductive approach can be described as "a research in which theory follows data unlike in deductive approach" (Saunders et al, 2009). In inductive research, no hypothesis is involved. The researcher is has an idea but is generally oblivious of what he or she will find in the field, and the research may keep changing as the study goes deeper and deeper.

The research approach is inductive approach as data collection from the field, and observations aims to build up a substantial theoretical framework.

4.5 Research strategy

Naoum (2007) states that there are two types of research strategies: qualitative and quantitative research strategies. The choice of research strategy depends on the research question and the availability of data, after that is ascertained, then the research strategy can be chosen; qualitative or quantitative. It is important to know that both research strategies can be used in the same study. In the case where the two are used in the same research, it is call multiple method research. It is called a mono method research where only one research strategy used. Furthermore, a multiple research strategy involves using both quantitative and qualitative data collection strategy. So for example, questionnaires and interviews. The multiple method research is can divided into two categories; multi-method and mixed methods research (Saunders et al, 2009). The multi-method research is where both qualitative and quantitative data collection techniques are used but the qualitative data is analysed qualitatively and the quantitative data is analysed quantitatively. While in mixed method research, the qualitative data is analysed quantitatively and vice versa. So for example, interview data which is qualitative is converted into numbers, that is, analysed quantitatively.

Table 4.1: Quantitative and Qualitative research according to their respective natures

Topic	Quantitative research	Qualitative research
Research enquiry	**Exploratory, descriptive and explanatory**	**Exploratory, descriptive and explanatory**
Nature of questions and responses	Who, what, when, where, why, how many Relatively superficial and rational responses Measurement, testing and validation	What, when, where, why Below the surface and emotional responses Exploration, understanding, and idea generation
Sampling approach	Probability and non-probability methods	Non-probability methods
Sample size	Relatively large	Relatively small
Data collection	Not very flexible Interviews and observation Standardized Structured More closed questions	Flexible Interviews and observation Less standardized Less structured More open-ended and non-directive questions
Data	Numbers, percentages, means Less detail or depth Context poor High reliability, low validity Statistical inference possible	Words, pictures, diagrams Detailed and in-depth Context rich High validity, low reliability Statistical inference not possible
Cost	Relatively low cost per respondent Relatively high project cost	Relatively high cost per respondent Relatively low project cost

Source: Naoum (2007)

There are strategies that enable researchers to meet their objectives. These strategies are as follows; experiment, survey, case study, action research, grounded theory, ethnographic, and archival research. It is important to note that all these strategies have pro and cons, therefore, the researcher would need to select the strategy that best answers the research questions and meets the research's aim and objectives.

4.5.1Experiment

Experiments are the most widely adopted research strategy in the natural sciences because, they claim that experiments by definition is a set up that allows, observation, testing verification and retesting. And that is the scientific way. Saunders et al (2009) states that experiments are often the 'gold standard' against which rigour of other strategies are accessed.

4.5.1 ***Survey***

Survey strategy operates on the basis of statistical sampling, which must be the right representation of the population size to allow for generalisation (Fellows and Liu, 1997). It is usually associated with deductive approach also to collect large amounts of data quickly usually, through a questionnaire administered to a sample, although interviews can also be used (Saunders et al, 2009).

4.5.2 *Case study*

Case studies strategy is defined as “an empirical investigation of the particular contemporary phenomena within its real-life contexts using multiple sources of evidence" (Saunders et al, 2009). The case study is different from; experiment and surveys because it is not done in a controlled environment and does not merely work within context respectively. According to Yin, (2009) case study strategies are in four classifications; single case studies, multiple case studies, holistic studies, and embedded case studies. Single case studies are adopted for in-depth understanding of a single context; while multiple case studies identifies multiple occurrence of an event so as to generalise from the findings. Holistic and embedded case studies refer to the unit of analysis. Saunders et al (2009) confirm that if the research is concerned only with the researcher’s organisation as a whole then the organisation is a holistic case study. While the in-depth study of subunits within the organisation will be considered as an embedded case to the research. Yin (1994) lists several examples of different case studies along with the appropriate research design of each, for exploratory, explanatory, and descriptive case studies. He points out that case studies are the ideal strategy when the focus is on a contemporary phenomenon within some real-life context and when the investigator has little control over events.

4.5.3 *Action research*

Fellow and Liu (1997) state that action research involves active participation by the researcher in the process on the study, in order to identify, promote and even identify problems and potential solutions.

4.5.4 *Grounded theory*

Grounded theory is an inductive approach focused on "theory building" (Saunders et al 2009). Grounded theory starts with data collection from which theory is developed. Based on this theory hypothesis can be drawn and tested if the researcher chooses to do so.

4.5.5 *Ethnography*

In ethnography, the research is part of the study. He or she becomes part of the group understood and observes subjects’ behaviour as they interact with their social world (Fellow and Liu, 1997). This research process requires a great deal of flexibility (Saunders et al (2009) since the researcher will constantly be developing new patterns of thoughts about what is being observed. The problem with ethnography is that is it impossible to determine the extent to which the researcher's values have influenced the results of the study (Fellow and Liu, 1997).

4.5.6 ***Archival research***

Archival research uses with records and documents as principal sources of data (Saunders et al, 2009). Archival research strategy is the analysis of data collected from the day-to-day activities of the organisation.

4.5.7 Triangulation

There are numerous data collection techniques; interviews, observations, documentary analysis, focus groups, and questionnaires; to mention a few. When the data collection technique adopted in a research is a combination of any two or more techniques, it is most likely for triangulation purposes. Having said that, it is important to note that the concept of triangulation refers to the use of different data collection techniques within one study to validate the results received from a different data collection technique. Saunders et al, (2009) defines triangulation as *"The use of two or more independent sources of data or data-collection methods within one study in order to help ensure that the data are telling you what you think they are telling you ... For example, qualitative data collected using semi-structured group interviews may be a valuable way of triangulating quantitative data collected by other means such as a questionnaire."*

4.6 Selected research strategy in this thesis

The selected research strategy for this research is not experiment, as we are not dealing with subjects in a controlled environment. We are dealing with humans who can be rational and irrational at the same time and in situations that cannot be duplicated. This means a retesting will be impossible. The research strategy is also not case study approach, as we are not dealing with cases in isolation. It is neither action research, ethnography, nor archival research, as the researcher is not part of, or directly involved with the subjects under study; or using records and documents as principal sources of data; respectively. The selected research strategy for this research is therefore, a combination of 'grounded theory' and 'survey' approach, since the research is attempting to develop a framework for improving in-door air quality (IAQ) in Kuwaiti housing developments at all stages of a construction project (design, construction, and post-construction). And this will be achieved through the use of interviews and questionnaires. The literature review has informed the research with regards to the themes of analysis. These themes are in line with the research objectives and form the basis of the investigation during data collection.

4.7 Research choices

There are two research choices; quantitative and qualitative (Saunders et al, 2009). These two extreme data collection techniques and data analysis procedures – quantitative and qualitative methods; use statistical techniques of data collection e.g. questionnaires (numeric based); and non-statistical method of data collection, for example, interviews, and coding, respectively. It is important to note that the two are not mutually exclusive but can be combined is a single research if required to answer the research question. We have the mono method, the multiple methods, and the mixed method. Mono means one, therefore uses a single data collection techniques and corresponding analysis procedures; multiple methods use more than one data collection technique and analysis procedures. Third among the methods is mixed-method research, which is a mix of Mono methods either sequentially or in paragraphs. That is, both quantitative and qualitative worldviews are used but quantitative data are analysed quantitatively and qualitative data is analysed qualitative (Saunders et al, 2009). The fourth and last is, *mixed-model research* which combines quantitative and qualitative data collection techniques and analysis procedures. That is, quantitative data may be analysed qualitatively (expanding numbers into words) and qualitative data may be analysed quantitatively (reducing words into numbers).

Therefore, the selected research choice for this research is the mixed-method research as it involves both qualitative and quantitative data collection techniques and the data is analysed according to the process it was collected. That is, quantitative data are analysed quantitatively and qualitative data is analysed qualitative.

4.8 Research design

Research design is a statement of clear objectives, sources of data to be collected, research constraints, and ethical issues. Research designs, as described by Creswell, are “plans and procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis” (Creswell, 2009). This definition has been emphasized further as “a framework for the collection and analyses of data to answer the research question and meet research objectives providing reasoned justification for choice of data source, collection methods and analysis techniques" (Saunders et al., 2009). The research structure is shown below.

Table 4.2: Research Process

Research Process Stages and Themes	**Research Method**
Stage 1: Best practice of IAQ around the world and Kuwait (corresponding Objective 1 and 2)	Literature review
Stage 2: Common Practice in Kuwait; IAQ perspective (Corresponding to objective 3)	Interviews and Questionnaire based Survey
Stage 3: Core Barriers and Challenges prohibiting IAQ in design practice (corresponding to Objective 4)	Interviews and questionnaires
Stage 4: Conceptual framework development (corresponding to objective 5)	Content analysis
Stage 5: Refine and validation of the framework (Objective 5 and 6)	Member checking

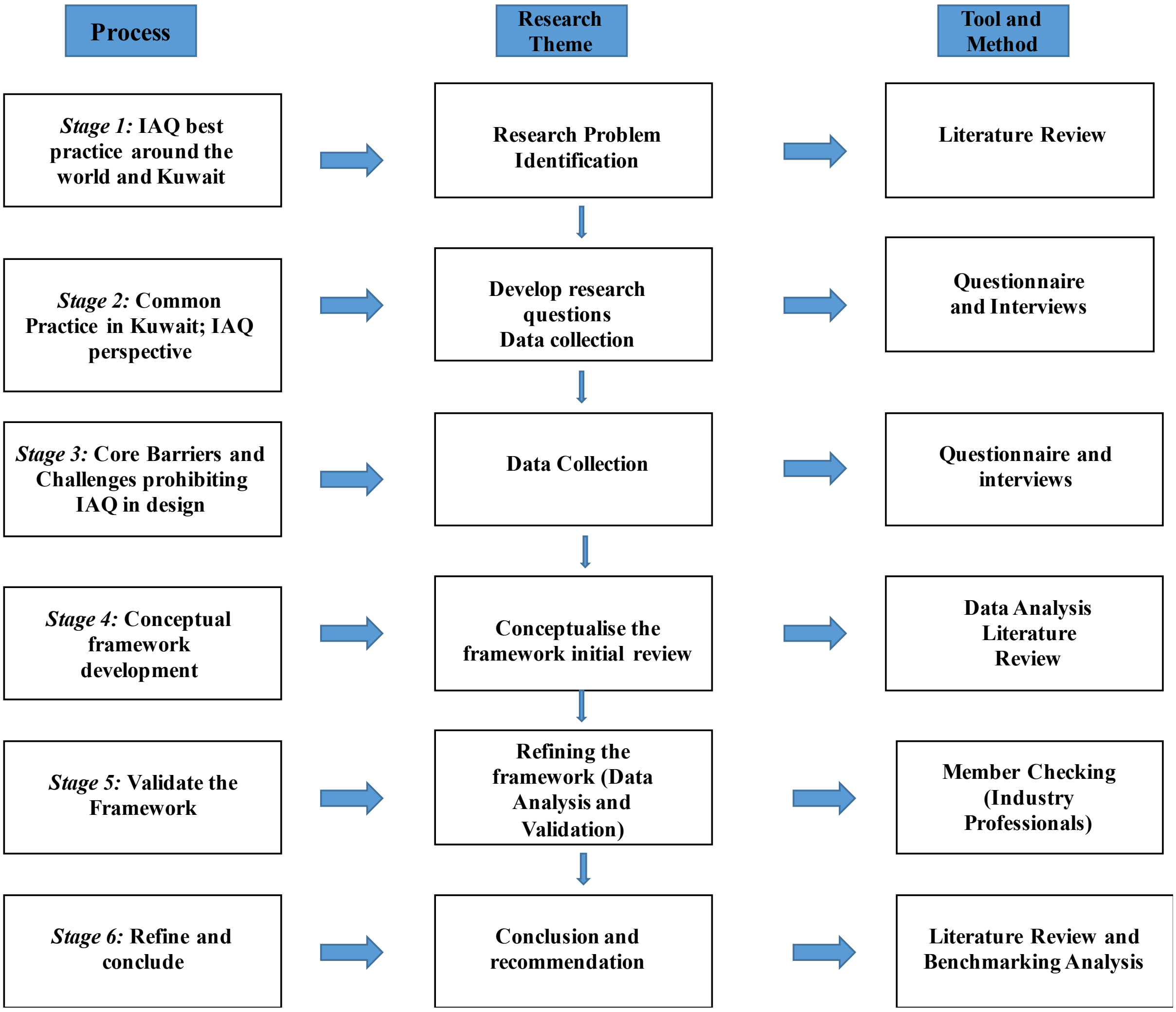


Figure 4.3: Research Structure

Stage 1: Data Collection, IAQ and Best Practices

At this stage, the research will conduct a review of literature on IAQ and Best practice of IAQ around the world. This is to enable the research to gain a proper grounding of the subject area. The research will also review literature on IAQ within the Kuwaiti housing development sector; the current status of IAQ, practices, standards and regulations, barriers etcetera. A proper review of literature will point out all the IAQ areas of important with regards to housing developments and also what the latest research and findings are.

Stage 2: Data Collection, Common Practice in Kuwait from IAQ Perspective

Here, the data collection adopted is a combination of semi-structured interviews and a questionnaire survey. The semi-structured interviews will help the research obtain information on the current practices; like standards, patterns and behaviours of industry professional towards achieving good IAQ; core barriers and challenges prohibiting IAQ in design practice and implementation.

Stage 3: Data Analysis, Initial Conceptual Framework Development

Upon the review of literature, the research inevitably will begin to shape the nature of IAQ in Kuwait housing development. Therefore, the research will attempt the development of an initial conceptual framework which later, will be refined to fit the data findings.

Stage 4: Data Collection, Gaining in-depth Views about IAQ in Kuwait

Based on the information collected, a content analysis will be conducted. The nature of the analysis will involve coding of information into themes that were partly developed from literature and some developed as the research evolved. These themes will be categorised under the following three stages: pre-construction, construction, and post- construction. It is imperative that it is done in this sequence so that the improved framework can be developed as indicated in the research aim.

Stage 5: Data Analysis, Refining and Validation of the Framework as the Final Version

Of course, the framework will not go without a proper validation. The research will make use to Member checking technique to validate the framework. The member checking technique involves approaching the same members of the research sample group to validate the framework. This makes sense because they are the ones directly involved and affected and therefore are in the best place say whether or not the framework is valid; reliable and applicable. Upon validation of the framework, the framework will be improved upon and the 3rd and final version developed. Here, the research will achieve its aim.

4.9 Research technique

Selecting the research methodology appropriate to the research is very important for the research problem and research questions to be explored (Yin, 1994b). A 'mixed method' approach is used in this research. That is, combining quantitative and qualitative methodologies, using interviews and questionnaires to understand the overall picture of the indoor air quality in Kuwait. The interviews aim to capture an in-depth view of issues and factors inhibiting stakeholders from implementing healthy, conscious practices in their design. The questionnaires are to government officials who supervise the architects and other project participants as well as to professionals in the industry who are directly involved with indoor air quality issues on construction projects. The interviews will be conducted with architects, government representatives, and contractors' etcetera, and this data will be analysed qualitatively, thus using a mixed method approach.

Also, Yin (1994) emphasises that there is no single source of evidence that has a complete advantage over all others. Therefore, a mixed approach may be more appropriate. However, interviewing is found to be the most widely used data collection technique in a qualitative approach for its high level of flexibility and its capability of producing data of great depth (Yin, 1994). The research techniques adopted provide a triangulation approach (questionnaire confirms interview data) and established to reduce the biases inherent in the study.

All of these steps and procedures for the research design were explained by the research onion diagram in the next section, which shows how the researcher goes from the broad research philosophy to detailed techniques of data collection and analysis.

4.10 Sampling

The art of selecting respondents or participants for a research study is called "Sampling". Out of a population a sample is chosen. This sample is made up of the sample units, or element. But the object of study is called the unit of analysis. This could be anything, from people, to institutions, to phenomena. The total number of that unit of analysis, make up the population from which the sample group was derived (Bailey, 1978). The sample frame covering this study is the total number of construction professionals in Kuwait whose actions on a housing project directly or indirectly affects IAQ.

There are advantages of sampling. Sampling can be used as a tool when the research population is so large, it would be impossible to study the whole population. Therefore, it is imperative to choose a representative number out of the population for the research exercise. By so doing, money, time and effort is saved. It is also possible that the endeavour to study the entire population as against taking a snapshot (sample) may leads to inaccurate results by the end of the research because some areas of the population may undergo changes in the time the research takes to study the entire population. In addition, it is also advantageous when the sample respondents know that their responses are exclusive and anonymous thereby allowing them to speak freely without fear of prejudice. There are two types of sampling: probability sampling, and non-probability sampling.

4.10.1 Probability sampling

This is the type of sampling that deals with known probabilities, that is, the probability of selecting a sample unit is known. They are classified into: random sampling, systematic sampling, stratified sampling, and cluster sampling. Random sampling is a sampling technique in which all the units of the population have an equal chance of being selected for the study. It is the most common sampling method world wide. Systematic sampling on the other hand, is a form of structure random sampling that involves selecting a unit at a set interval e.g. the *k*th unit, within the population (Bailey, 1978). But this sampling method is said to be less accurate in its representation of the population. Stratified sampling involves separating the members of the population into distinct groups or strata which do not overlap, "and then using random sampling or systematic sampling technique to select the research sample from the stratum" (Bailey, 1978). Lastly, cluster sampling involves grouping the sampling units in clusters from which the research sample is selected but in multiple stages. However, it is said that this cluster sampling method is also less accurate than random sampling because, each stage of selection may have its own embedded probability of errors. And therefore by the end of the selection process, the cumulative errors of each selection stage combine to to make up the supposed inaccuracy of the results.

4.10.2 Non-probability sampling

Non-probability sampling is a technique of selecting a sample from a population in which the probability of selecting each sample unit is not known. There are different types of non-probability sampling: convenience sampling, quota sampling, dimensional sampling, snowballing sampling, and purposeful/purposive sampling. Convenience sampling is choosing a sample out of convenience. According to Bailey (1978), this is when the researcher selects the nearest, closest, easiest, the less stressful sample unit – basically because it is convenient. Those more difficult and farther away are not selected. This technique saves time but is less accurate and less representative of the entire population. Quota sampling on the other hand is selecting a sample in a stratified form but must represent the entire population. Dimension sampling is another form of non-probability sampling where variables or criteria define those units that are selected. That is, only those units that meet the criteria make it into the sample group. Snowballing sampling is another form of non-probability sampling that makes use of information gotten from a sample unit to identify another sample unit. In the case where the sample units are humans, the respondents' networks can be used to get more respondents or the respondents are asked to recommend other people who could fit the study (Bailey, 1978).

Lastly, purposeful or purposive sampling is also known a judgement sampling and it involves the researcher's decision to choose only those units which, he/she deems to have the right information, experience, or skill, to answer the research questions. This art is more like choosing an informant. According to Tongco (2007), purposive sampling is a non random sampling the is applicable when studying aspects of life of phenomenon that is exclusive to a group such as; culture, industry (like IAQ in Kuwait housing), language etc. that only the members of the group can give information on the subject. For example, not all players or construction professionals in Kuwait have experience or duties that greatly influence IAQ, like the quantity surveyor's duties does not affect IAQ therefore it may not be very useful to interview quantity surveyors. But the architect, M&E engineers, facilities managers, IAQ and HVAC specialist, contractor etc. all affect good IAQ whether in design, construction, or post-construction. Consequently, purposive sampling fits this research study where only those with knowledge in IAQ, or whose duties on a housing project will affect IAQ directly or indirectly, will be interviewed, and questionnaires distributed to. Purposive sampling technique strategies are explained in Table 4.3 below.

Table 4.3: Purposeful/Purposive Sampling Strategies

S/N	Strategies
1	First, the researcher makes judgements before, during, and after sampling about what to sample and how to use the sample in making claims from their research.
2	Secondly, their judgements are made with reference to what is known about the phenomena under study. This includes recognising that much can be learnt from exploring the ways in which phenomena are described through variables, categories and insight from both quantitative and qualitative research.
3	Thirdly, based o what is learnt before the research starts and as the research proceeds, researchers are strategic in selecting a limited number of cases toward producing the most information that is usable.
4	Fourthly, researchers are aware of who the audience for their research will be and choose sampling strategies that will produce the most credible results for the audiences.
5	Fifth, these decisions are always constrained by resources, an important consideration but one that should be addressed only after the first four themes are considered. Qualitative researchers would always like to sample more, but have to make choices with reference to time to do fieldwork, budget, and their capacity to analyse the data they collect.
6	And finally, there are quite different logics to qualitative and quantitative sampling strategies. These differences are exemplified in the purpose of the purposeful sample.

Source: Emmel (2013)

4.11 Sample selection criteria

Kuwaiti construction professionals are the target sample group especially architects, mechanical, and electrical engineers, designers, facilities managers, IAQ specialists, HVAC specialists, Kuwait municipality planning permission officers, etc. The research selection criteria were based on the professional's IAQ knowledge and experience and most importantly, the extent to which the individual's duties on the project affects IAQ. For example, the architect's duties heavily affect IAQ either positively or negatively because the architect does the designing of the building and in Kuwait contexts, the architect is the one responsible for coordinating all the other project participants; mechanical, structural, and electrical engineers, and other subcontractors and specialist contractors, most of which their duties on the project affect the IAQ of the building as well.

4.12 Methods for data collection

This section explains the commonly used quantitative and qualitative data collection methods as well as their respective data analysis methods. The term methods refer to the tools that are used in collecting and analysing data. Data may be collected from primary or secondary sources (Collis and Hussey, 2003, Saunders et al., 2009). As it can be seen in Figure 4.3 below, the methods from left to right become more quantitative and use more quantitative techniques and vice versa. Qualitative techniques may use, for example conversation and in-depth semi-structured interviews to collect qualitative data (Ghauri et al., 1995).

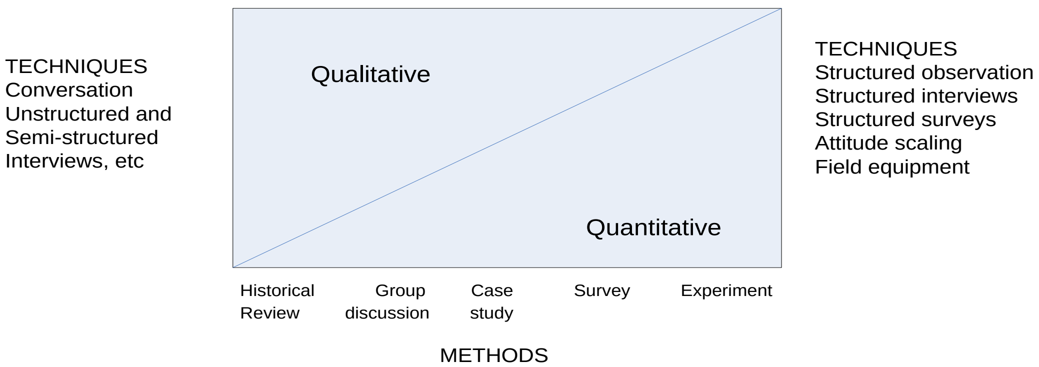


Figure 4.4: Qualitative and quantitative methods and techniques (Source: Ghauri et al., 1995).

Secondary data refers to information, which already exists; for example, archival records, company documentation, publications, and annual reports. Stake (1995) and Yin (1994a) identified at least six sources of evidence in case studies. The following is not an ordered list, but reflects the research of both Stake (1995) and Yin (1994a):

4.12.1 Quantitative data collection

Questionnaires: Quantitative data is usually in the form of numbers. For example: the frequency, rate, and duration, of specific behaviours or conditions (experiments); Numbers of people or percentages of people with certain characteristics in a population etcetera (surveys). Questionnaires use structured questioning styles to obtain data for the purpose of statistical representation of data. This research will use questionnaires to obtain information regarding IAQ and best practice in Kuwait. The questionnaires will be distributed by email to the respondents.

4.12.2 Qualitative data collection

Individual interview: Any structured and purposeful conversation between two people can be said to be an interview. It is one of the most important sources of information in case studies. According to Save the Children (STC) (2015), *"It is designed to elicit the interviewee's knowledge or perspective on a topic. Individual interviews, which can include key informant interviews, are useful for exploring an individual's beliefs, values, understandings, feelings, experiences and perspectives of an issue."* (STC, 2015). In order to collect factual information and to understand the best way of improving IAQ in Kuwait housing developments at design, construction and occupancy stage, the research adopted "interviews" as one of the best methods of data collection. One on one interviews were set up with construction professionals in Kuwait. This method of data collection is one of two data collection methods chosen in this research. The other being questionnaires. In interviews, the nature of questioning can be classified into: structured questions, semi-structured, and open ended questions. In this research, semi-structured questioning style will be used so as to allow the interviewee to give as much information about the subject of IAQ but without digressing too much into unnecessary territories.

Documents and Records

- Documents could be letters, memoranda, agendas, administrative documents, newspaper articles or any document related to the investigation.

- Archival records: these include service records, organisational records, lists of names, staff and payroll records, old correspondence and other such records.

Observations

This is a way of collecting reliable evidence through physical present in the field and documenting what is being seen. There are two types: participant-observation and physical artefacts.

Focus group discussions

This is an organised discussion between 6 – 12 people. The environment created by a focus group allows the participants to discuss a particular topic freely. The participants are allowed to voice their opinion whether is agreement or disagreement with each other. The chair of the focus group does the job of directing the conversation and controlling emotions, and making sure that everyone has a voice and is heard. *"Focus group discussions allow you to explore how a group thinks about an issue, the range of opinions and ideas, and the inconsistencies and variations that exist in a particular community in terms of beliefs and their experiences and practices."* (STC, 2015).

Photovoice

With Photovoice, people are given cameras to take pictures and tell whatever story they wish using their photos. According to STC (2015), *"Photovoice is a participatory method that enables people to identify, represent and enhance their community, life circumstances or engagement with a programme through photography and accompanying written captions."*

4.13 Methods of Data Analysis

Data analysis comprises examining, categorising, tabulating, and interpreting the evidence to support, reject or amend a theory and/or to generate new theory.

4.13.1 Content analysis

Content analysis, according or Bailey (1978) is also known as "Coding". Bailey defines content analysis or coding as *"a structured document-analysis technique in which the researcher first constructs a set of mutually exclusive and exhaustive categories that can be used to analyse documents, and then records the frequency with which each of these* *categories is observed in the documents studied."* Content analysis will be adopted as the suitable method of data analysis for this research because of the nature of the research question and volume of data to be analysed. Content analysis is also understood as a form of structured analysis, where the researcher is looking for a checklist of specific behaviours. Since this research will use semi structured interviews to collect large amount of data, coding is the best method to analyse the information to help the research answer the research question in the best possible way. Coding is the reduction of large amounts of information into a few general categories of answers that are easily understood by the researcher as well as any reader. According to Naoum (2007), coding information under themes and ideas is the best way to analyse qualitative data.

The data collected from interviews will be analysed using the assistance of the NVIVO software. The software will aid the research in "Coding" the information into themes that are easily examined and analysed. One of the major advantages of using NVivo software is its capability to improve the data analysis process 'drowning in data' by allowing data to be allocated into categories (Coding), which provided a more streamline structure for discovering emergent themes (Rowe, 2007).

4.13.2 Statistical analysis

Since the research will make use of questionnaires as well, these data will be analysed quantitatively. The SPSS tool, which is presently the most common statistical analysis tool used by researchers around the world may be used to support the quantitative analysis process. The quantitative findings is hoped to support the qualitative findings.

4.14 Limitations of the study

1. Lack of accesses to the study sample with knowledge in field of Indoor Air Quality (IAQ). To overcome this, the researcher persevered in making phones calls and sending out email reminders in order to get a response back.

2. Decision maker's lack of interest to spare part of there time and answer researcher's questions. A similar strategy was used here – the researcher pressed a bit harder to get questions answered. The researcher also learnt to move through the questions faster but to try and make sure that the answer to the question was given before moving on.

3. Lack of specialized professionals in Indoor Air Quality (IAQ) field involved in the design and construction of housing projects.

4. Lack of data and research in Indoor Air Quality (IAQ) in Kuwait that addresses housing.

5. Targeted sample lack of awareness of Indoor Air Quality (IAQ) issues.

4.15 Summary

In summary, the research philosophical position is subjectivism with regards to ontology, interpretivism with regards to epistemology, and value-laden with regards to axiology. The research is an inductive research with both quantitative and qualitative aspects. It is inductive because the research is exploratory in nature (grounded theory) and emerges from an empirical level to a conceptual one, whereas in deductive research, the research flows from the conceptual level to an empirical one. Furthermore, purposeful or purposive sampling technique has been adopted as the appropriate method of sampling that will answer the research question on how to improve good IAQ in Kuwait housing developments at design, construction and post-construction stages. This is because only a subset of construction professionals in Kuwait have knowledge in IAQ, and whose duties on a housing project influence IAQ whether directly or indirectly.

Questionnaires and interviews (semi-structured) were adopted as the appropriate techniques for data collection because the mixed method techniques allowed for triangulations of information or data gathered so that an accurate, reliable, and concise understanding of the context and information necessary to answer the research questions can be achieved. The questionnaire data was analysed by the aid of Nvivo and the interview data was analysed using manual 'content analysis', where the information collected are coded and then themes were derived from them.

5 CHAPTER 5| DATA COLLECTION AND ANALYSIS

5.1 Introduction

The agenda or topics regarding IAQ that were discussed in the study were directly informed by the literature review. These topics (and analysis) are in line with the research objectives and form the basis of the investigation during data collection. But first, lets discuss the demographic of the respondents.

5.2 Sample description

The data collection involved a survey of architects, building owners, engineers, and government officials (Kuwait municipality officials). The respondents were asked about different issues on indoor air quality (IAQ), from understanding of IAQ and implementation, to government enforcement of IAQ compliance. Below is a description of the survey sample.

Table 5.1: Total number of respondents and gender percentages

Variable	Category	Counts	%
Gender	Male	112	74.7
	Female	38	25.3
	Total	150	100

Table 5.1 shows the number of respondents and gender percentages. Males were the samples majority, about three fourths of the sample (74.7 %) while females who participated in the survey were one fourth approximately (25.3 %). chart (1) illustrates gender percentages in the study sample

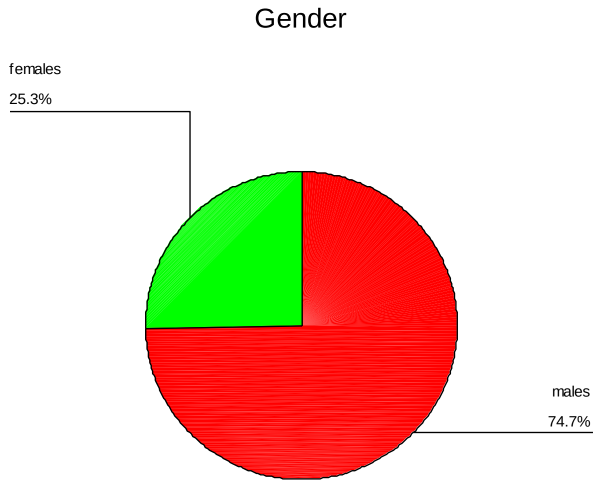


Figure 5.1: Illustrating percentages of the Gender categories

Table 5.2: Frequencies and percentages of Age

Variable	Category	Counts	%
Age	20 - 29	34	22.7
	30 - 39	66	44.0
	40 - 49	35	23.3
	50 and above	15	10.0
	Total	150	100.0

According to the percentage mentioned in Table 5.2, (22.7 %) of the sample were in the smallest age category (20 - 29) years. The largest age category was (30 – 39) years (44.0 %), the age category (40 - 49) years satisfied a percentage of (23.3 %) and that (10.0 %) were in the eldest age category. chart (2) illustrates age percentages in the study sample

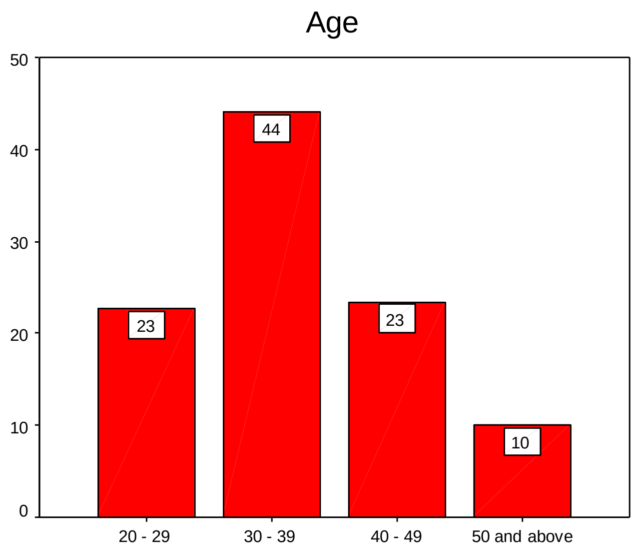


Figure 5.2: Illustrating percentages of the Age categories

Table 5.3: Frequencies and percentages of Education

Variable	Category	Counts	%
Education	B.A	121	80.7
	M.A	27	18.0
	PhD	2	1.3
	Total	150	100.0

Table 5.3 shows the percentages of Education. The B.A education was the largest education category percentage of the study sample (80.7 %) followed by the master education category who participated in the survey (18.0 %) and that the least education category were the PhD which satisfied a percentage of (1.3 %).

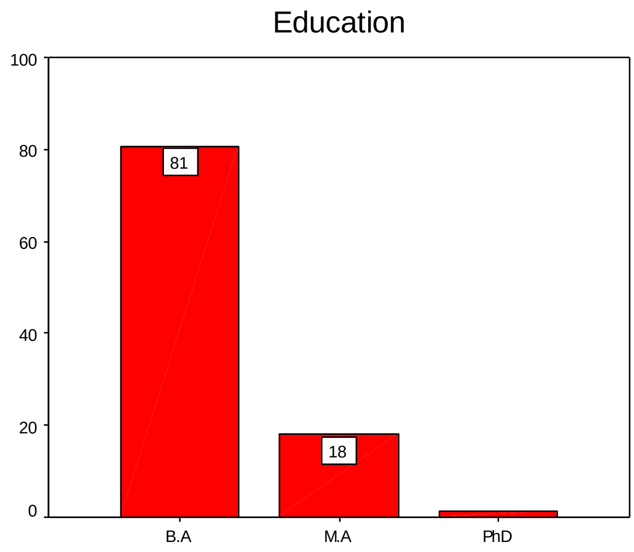


Figure 5.3: Illustrates education percentages in the study sample

Table 5.4: Frequencies and percentages of Designation "Job"

Variable	Category	Counts	%
Designation "Job"	Company managers	5	3.3
	Project managers	5	3.3
	Design engineers	100	66.7
	Supervision, Mechanical and Electrical (M&E) engineers	40	26.7
	Total	150	100.0

Table 5.4 indicates the frequencies and percentages values of the Designation "Job" for the sample individuals. Clearly the design engineers were the largest (66.7 %) of the sample followed by the job designation supervision engineer (26.7 %) then both the company manager and project manager were the same percentages (3.3 %).

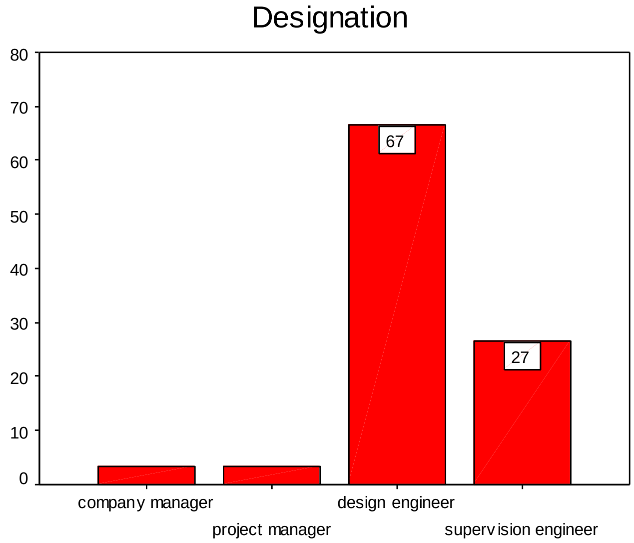


Figure 5.4: Illustrating percentages of the "Job" Designation categories in the study sample

Table 5.5: Frequencies and percentages of years of experience

Variable	Category	Counts	%
years of experience	5 years or less	26	17.3
	6 - 10 years	75	50.0
	11 - 15 years	27	18.0
	16 years and above	22	14.7
	Total	150	100.0

Table 5.5 reflects the results of years of experience percentages for the individuals involved in the sample. Half of the study sample (50.0 %) were in the experience category of (6 – 10) years followed by (18.0 %) of the sample were in the experience category (11 – 15) years then by the experience category (5 or less) years while the least percentage of experience were related to the category (14.7 %). Chart 5 illustrates the percentages

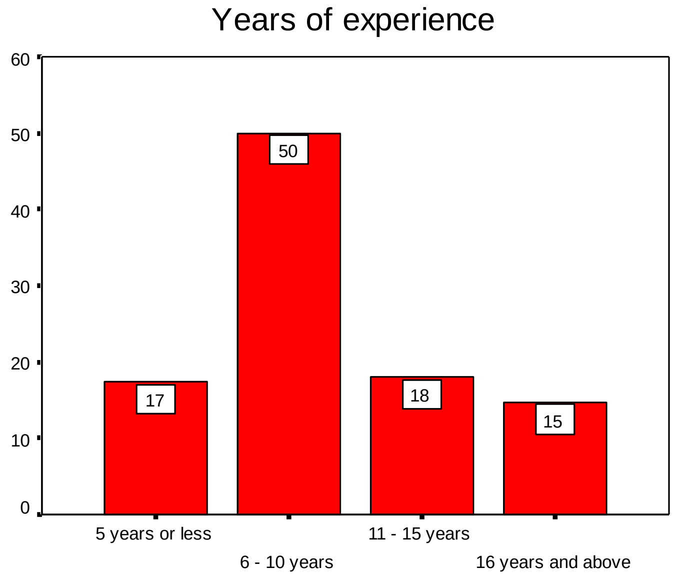


Figure 5.5: Illustrating percentages of the years of experience categories

The results above show that the demographic of the respondents are mostly design engineers, male, aged between 30-39, with first-degree education, and with 6-10 years of industry experience. This is the demographic of decision makers in housing development in Kuwait and they are the ones that the industry and government must target in terms of education and training on the necessity of good IAQ.

To achieve the research aim, it was necessary to address each objective set out from the beginning of the research. The research findings are also presented in the order the objectives were written. Based on the literature review, the following general topics were identified to be the main issues that the study needed to discuss with respondents.

5.3 Understanding of IAQ

Table 5.6 shows that the respondents have a very low knowledge of IAQ

Table 5.6: General understanding of IAQ standards at design and construction

Topic	Respond level	Counts	%
Engineers have a very good and clear Understanding of IAQ standard rules and regulations in both design and construction	Very low	104	69.3
	Low	32	21.3

housing projects "how do you categorize their understanding?"	Moderate	12	8.0
	High	0	0.0
	Very high	2	1.3
	Total	150	100.0

The percentages values provided in Table 5.6 represent responses on the question; "Engineers have a very good and clear understanding of IAQ standard rules and regulations in both design and construction housing projects. How do you categorize their understanding?" About 69.3 % of the sample responded, very low, 21.3 % responded, low, 8.0 % responded, moderate, 0.0 % responded, high, and only 1.3 % responded, very high. The results show that the majority of the sample believed that Kuwaiti engineers have a low, and/or, very low, understanding to IAQ standard rules and regulations in both design and construction of housing projects.

The researcher concludes from looking at the results of this question and the statistical analysis, that the vast majority (90%) of engineers and professional involved in the design and construction of housing lack the knowledge and the know how of indoor air quality strategies, regulation or standards. Most of the respondents stated that natural ventilation was the most common form of IAQ strategy they knew. HVAC systems, because of their technical nature, are very hard to construct or design. They also stated that since there are no ventilation codes and standards in Kuwait, the international ventilation codes for IAQ are based on scientific and medical data from other countries, which will not be the same if the data is obtained in Kuwait. The industry professionals blamed the government for the lack of clearly written down IAQ regulations and standard for housing in Kuwait. On the other hand, respondents from the who were government officials from Kuwait municipality asserted that their office did not have the resources to sponsor the collection of scientific and medical data for the purpose of developing IAQ regulations and standards for residential housing. That order has to come from higher authorities or endorsed by the king. This finding is inline with the findings of Bouhamra and Elkilani (2001). According to Bouhamra and Elkilani (2000), because of the scientific nature of IAQ ventilation standard and codes, the standards offer very little guidance on how to construct or design a system that provide the required indoor air quality. The state that the codes are especially more difficult for less experienced model/system users, as they are not aware of the sensitivity of outdoor pollutant concentrations in relation to the required or expected exposure of the individuals.

According to Bouhamra and Elkilani (2001), there are two very significant parameters that mechanical engineers, HVAC specialists, IAQ designers need to know in order to design a reliable ventilation system:

- *"airflow parameter, such as the number of air changes per hour (i.e., how many times per hour the room air is completely exchanged with outdoor air) and*
- *building parameters that control airflow characteristics, such as the number of doors and windows, the type of HVAC (heating, ventilation and air conditioning) system and the size of the rooms"* (Bouhamra and Elkilani (2001).

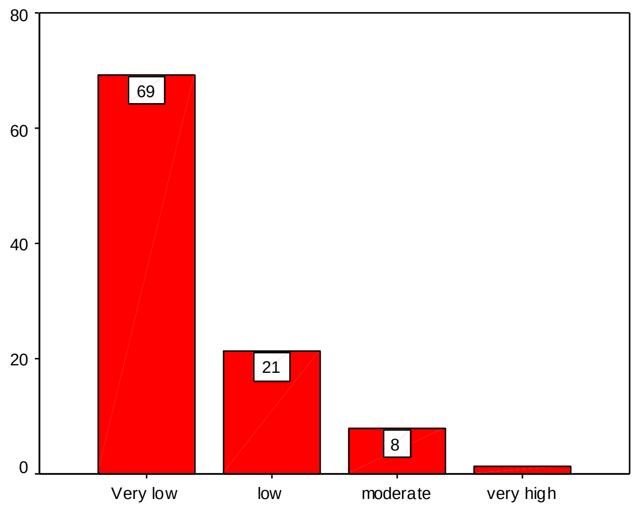


Figure 5.6: Illustrating percentages of understanding of IAQ

Table 5.7:Decision maker's knowledge of IAQ rules in Kuwait

Topic	Respond level	Counts	%
Decision makers in Kuwait have a great understanding in implementing IAQ rules in all of their housing projects (how would you categorize it?)	Very low	66	44.0
	low	67	44.7
	moderate	10	6.7
	high	3	2.0
	very high	4	2.7
	Total	150	100.0

Table 5.7 reflects the percentages of the responds on the question "Decision makers in Kuwait have a great understanding in implementing IAQ rules in all of their housing projects (how would you categorize it?) " about (44.0 %) of the sample responded very low, about (44.7 %) responded by low, (6.7 %) responded moderate, while (2.0 %) responded high and that only (2.7 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

When adding the highest two respondents which adds up to 88.7%, this result indicates that there is a lack of the awareness of decision makers to the concept and the benefits of good indoor air quality standards and how the negative effects on resident's or housing occupant's health is affected by the environments.

The majority of respondents also think there are no specialized professionals in the fields in Kuwait to promote education of IAQ or to provide courses dedicated to IAQ that are taught in universities which address the main issues. Decision makers not familiar with good IAQ measures need training courses especially those involved in or in charge of housing for future planning, design and construction of residential projects.

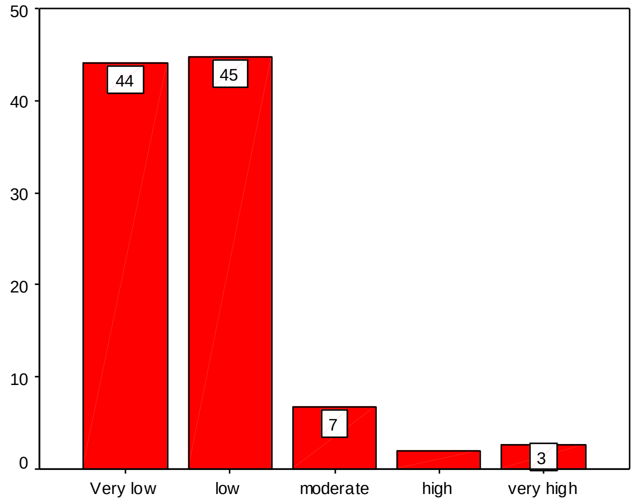


Figure 5.7: Illustrating percentages of decision maker's knowledge of IAQ rules in Kuwait

5.4 IAQ and value engineering process

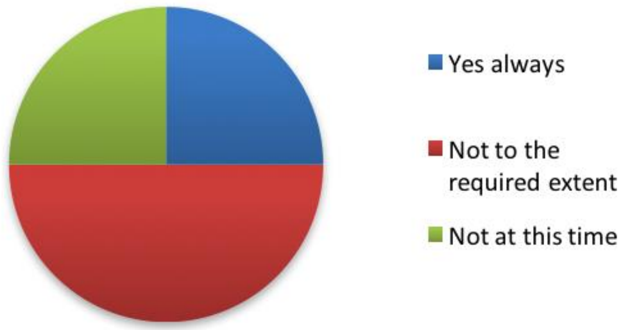


Figure 5.8: IAQ part of value engineering process

75% of respondents affirm that the pursuit of good IAQ through value engineering is not to the extent that it should be. In other words, the issue is often glossed over. The usual compromise is with respect to cost. Only one respondent stated that achieving good IAQ forms a strong part of their value engineering process. This finding corresponds to one of the major factors that contribute to indoor air quality problems given by ASHRAE (2009), which is "budget pressures." According to ASHRAE, *"Budget pressures can lead to less time spent on design, undesirable changes during value engineering, awarding of contracts to contractors who are able to lower their bids by substituting poorer-quality materials and equipment or cutting corners in the execution of the work, and elimination of all or most of the site visits by the design professionals"* (ASHRAE, 2009).

Respondents' confess that though achieving good IAQ forms a strong part of their value engineering process, the 'cost' of achieving good IAQ is a major barrier. In order words, when developers and/or clients see what it would take to achieve a good level of IAQ in their buildings, they opt for an alternative that doesn't give the adequate result but is cheaper for them. However, this research has established that the costs involved in solving IAQ problems far outweigh the cost savings building owners are trying to make. One respondent recalls the difficulties his company faces when dealing with developers and/or clients:

"In Kuwait where we depend on mechanical ventilation, increasing mechanical ventilation comes at a price of increasing the capacity of the system hence the cost. In a very cost

conscious market it is tough to persuade developers to invest in proposer IAQ. It is a lot easier to persuade users as it has a direct impact on their personal wellbeing."

The work of value engineering helps to ensure that costs are reduced without compromising good IAQ. When IAQ is not put on the table during value engineering or when good IAQ is sacrificed for cost savings, the result is that, buildings are completed and handed over to occupants or owners with deficiencies, with poorly designed HVAC systems, and/or with high pollutant emitting materials that were substituted in because they were cheap. The usual areas where IAQ problems develop are usually because of poor design and construction, and/or poorly selected materials and faulty equipment. If IAQ objectives are given additional priority at design and value engineering stages, many IAQ problems will be greatly reduced.

5.5 Standards and regulations of IAQ

All respondents in the study are not aware of any, or do not have any form of Kuwait standards or regulations governing IAQ on their projects. One respondent was definite of some form of standard in his company but could not provide it. The respondents were asked about the sources they rely on to get IAQ requirements, codes and standards, in which they address the IAQ issues on their projects. The respondents mentioned international standards such as IEEE, LEED and ASHRAE. ASHRAE seems to be the general standard adopted by most companies is Kuwait. Other sources known by the respondents are building codes, manufacturers specifications, and experience of designers, which are not sufficient.

Table 5.8: Implementing IAQ rules in both design and construction phases

Topic	Respond level	Counts	%
Implementing IAQ rules in both design and construction phases are a common practice for anyone building a house or a project. (How would you categorize the understanding of IAQ for anyone attempting to build a house or project?) .	Very low	29	19.3
	Low	91	60.7
	Moderate	28	18.7
	High	1	0.7
	Very high	1	0.7
	Total	150	100.0

According to the percentages values mentioned in Table 5.8 representing responds on the question "Implementing IAQ rules in both design and construction phases is a common practice for anyone building a house or a project. (How would you categorize the understanding of IAQ for anyone attempting to build a house or project?) ." about (19.3 %) of the sample responded very low, about (60.7 %) responded by low, (18.7 %) responded moderate, while (0.7 %) responded high and that only (0.7 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

The researcher is convinced that the results to the question of implementation of IAQ standards and regulations by ordinary Kuwaiti individuals, is fair. Implementation is low or very low, because, occupants or residential projects end users lack the understanding, or needed information and awareness about the indoor air quality, pollutant accumulation, health consequences and how detrimental it can be. Both industry professionals (architects, project managers, engineers, etc.) and government officials discouraged the idea of building without competent industry professionals, and urged Kuwaiti individuals to seek professional industry professionals when designing and constructing a building.

Furthermore, buildings may further be compromised by occupants desiring to renovate. Since the initial built house lacks local or international indoor air quality (IAQ) standards, an attempt to make renovations to the building further downgrades its IAQ. Examples of areas that could be affected are: reducing the air inflow to the building by closing openings, positioning windows or doors on the side of the building where there are pollutant generating activities, thereby increasing the potential of pollutants entering the building, etc. Another example of end user mistake, with regards to indoor air quality is, when renovating a building, the final windows and doors sizes may not be wide enough to allow for proper ventilation of the building. Where there is no mechanical ventilation, indoor pollutants could accumulate, until it reaches a threshold that is very detrimental to the health of occupants.

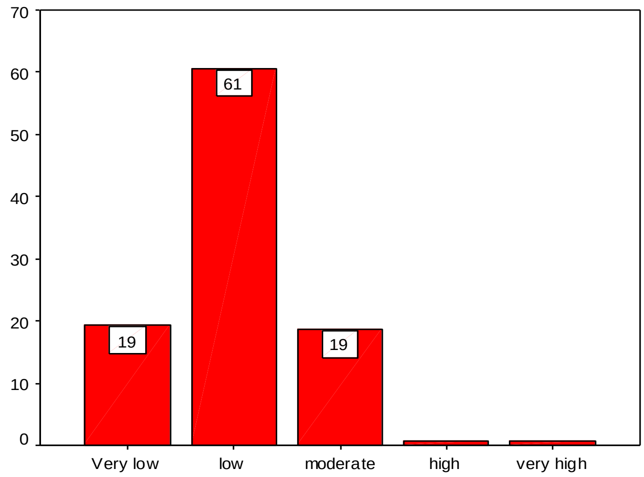


Figure 5.9: Illustrating percentages of implementing IAQ rules in both design and construction phases

Table 5.9: IAQ inspection officer's enforcement of ventilation system and IAQ strategy

Topic	Respond level	Counts	%
Firm laws exist in Kuwait to ban those who do not follow IAQ rules in design and construction phases (how would you categorize government enforcement of ventilation system and IAQ strategy?)	Very low	108	72.0
	Low	21	14.0
	Moderate	12	8.0
	High	2	1.3
	Very high	7	4.7
	Total	150	100.0

Table 5.9 reflects the percentages of the responds on the question "Firm laws exist in Kuwait to ban those who do not follow IAQ rules in design and construction phases (how would you categorize government enforcement of ventilation system and IAQ strategy?) " about (72.0 %) of the sample responded very low, about (14.0 %) responded by low, (8.0 %) responded moderate, while (1.3 %) responded high and that only (4.7 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

The researcher observed that the vast majority of respondents (industry professionals) agree that there is no strict law or mandatory regulation nor standards exist that govern the construction of housing in design stage or construction phase. Furthermore, government officials asserted that they have not been given the mandate to check specific IAQ compliance during planning permissions. They recommend that perhaps they will check compliance if that was made part of their job description.

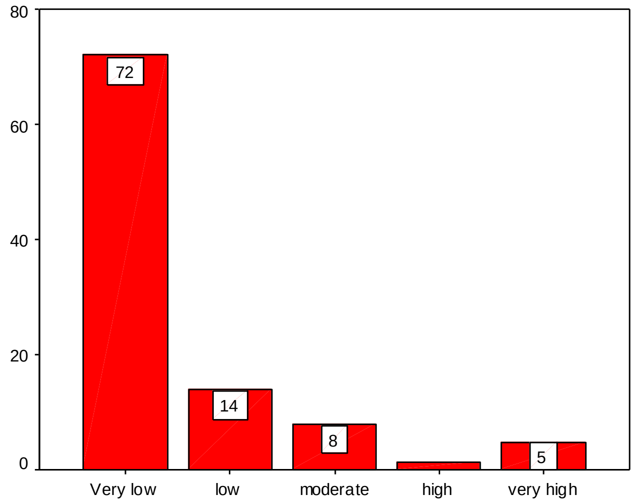


Figure 5.10: Illustrating percentages of government enforcement of ventilation system and IAQ strategy

Table 5.10:Rating of government enforcement of IAQ laws at design

Topic	Respond level	Counts	%
Kuwait government applies Mandatory tough laws concerning the implementation of IAQ in both design and construction housing " How do you rate the government enforcement of laws?	Very low	95	63.3
	Low	25	16.7
	Moderate	15	10.0
	High	11	7.3
	Very high	4	2.7
	Total	150	100.0

According to the percentages values mentioned in Table 5.10 representing responds on the question " Kuwait government applies Mandatory tough laws concerning the implementation of IAQ in both design and construction housing "how do you rate the government enforcement of laws?" about (63.3 %) of the sample responded very low, about (16.7 %)

responded by low, (10.0 %) responded moderate, while (7.3 %) responded high and that only (2.7 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

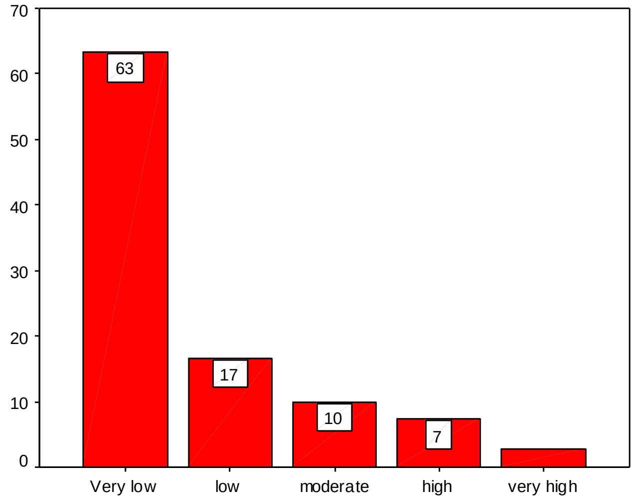


Figure 5.11: Rating of government enforcement of IAQ laws at design

The researcher concludes that the majority of respondents see that the government does not have standards or regulations imposed on residential projects in order to apply the best international standards of indoor air quality (IAQ) in residential projects.

Most government projects lack comforts of living and the ingredients for success to achieve proper healthy environment in terms of residential site projects, or indoor design. Also the researcher concludes that most projects are designed randomly when it comes to site selections, some residential projects are located within close radius to industrial and petrochemical plant down stream, and projects were built on completion bases. Therefore, residential projects designed for the esthetic and structure look rather than the health basis overlook the indoor air quality issues and standards. There is also absence of governmental authority that supervises or monitor IAQ regulations. Therefore, homeowners violate building codes, and one of these codes is indoor air quality IAQ standards.

Another conclusion that could be drawn for this question is that home owners lack the knowledge and awareness of building sick syndrome or the hazardous of poor indoor air.

It is also a general consensus amongst all the respondents that all factors below, contribute to IAQ problems in Kuwait housing developments especially bad design and construction. It is also important to note that these problems occur on different levels depending on the project.

- Bad design and construction
- Faulty installations and commissioning of building systems
- Moisture in building assemblies
- Poor outdoor air quality
- Moisture and dirt in ventilation systems
- Indoor contaminant sources e.g. building materials, furnishings, and foreign materials introduced into the building during operation.
- Contaminant from indoor equipment and activities
- Inadequate ventilation rates
- Ineffective filtration and air cleaning

In Kuwait, experts commonly do the work of detecting pollutants or toxins in the air. However, after that, the responsibility of taking appropriate actions, to reduce or mitigate the emission of these toxins in homes at the design stage, rests with the Architect; at the construction stage, the contractor, and at the handover stage, the Facilities managers or the occupants. The following toxins are common but to varying degree. However, all the respondents did not have any knowledge on how to eliminate, reduce, or mitigate against these toxins.

- Sulphur dioxide (SO_2),
- Nitrogen dioxide (NO_2)
- Carbon monoxide (CO)
- Carbon dioxide (CO_2)
- Formaldehyde (HCHO)
- Radon (Rn)
- Ozone (O_3)
- Hydrocarbons)
- Particulates matters (PM) such as from pets, gas stoves, and tobacco smoke
- Bio aerosols (bacteria, viruses, fungi and pollen, etc)
- Dusts
- Odours

Table 5.11: Use of label schemes to ensure good IAQ

Topic	Respond level	Counts	%
Label scheme rules regulating construction materials manufacturing industry products exist (categorize how accurate is label scheme used to ensure IAQ rules are being applied for a good indoor air quality)	Very low	93	62.0
	Low	25	16.7
	Moderate	15	10.0
	High	7	4.7
	Very high	10	6.7
	Total	150	100.0

Table 5.11 shows the response on the question "Label scheme rules regulating construction materials manufacturing industry products exist (categorize how accurate is label scheme used to ensure IAQ rules are being applied for a good indoor air quality" about (62.0 %) of the sample responded very low, about (16.7 %) responded by low, (10.0 %) responded moderate, while (4.7 %) responded high and that only (6.7 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

The researcher believes by looking at the statistical analysis which addresses label schemes, that most respondents thinks label schemes agency idea does not exist in Kuwait, and if it exists, it is not implemented as it's supposed to, like in other countries - United State of America, or Germany.

There is no monitoring to construction materials imported from outside the country, nor is there labels on these materials stating what the contents are or what they're made of. And if there is, it is so generic in the sense that it is so complicated for customers to understand or comprehend in order to make decision on whether or not to purchase the material.

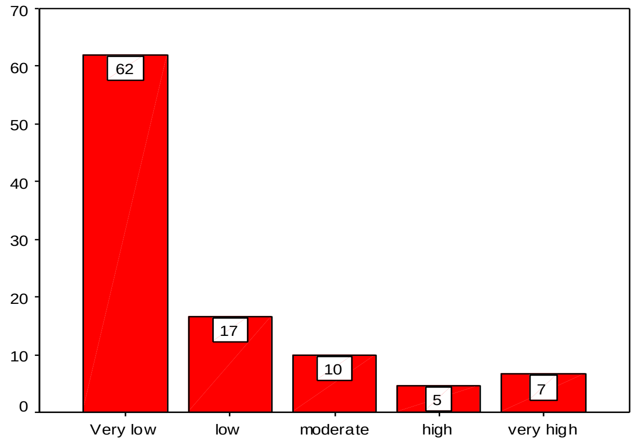


Figure 5.12: Use of label schemes to ensure good IAQ

Table 5.12: Government monitoring and enforcement of ventilation system and IAQ rules at construction and post construction stages

Topic	Respond level	Counts	%
The government plays a very important role in monitoring and enforcing IAQ rules during the construction phase and after delivery of projects to ensure a good quality of indoor air exists (categorize government monitoring and enforcement of ventilation system and IAQ rules during and after construction?)	Very low	97	64.7
	Low	29	19.3
	Moderate	13	8.7
	High	9	6.0
	Very high	2	1.3
	Total	150	100.0

Table 5.12 declares the percentages of the responds on the question "The government plays a very important role in monitoring and enforcing IAQ rules during the construction phase and after delivery of projects to ensure a good quality of indoor air exists (categorize government monitoring and enforcement of ventilation system and IAQ rules during and after construction?)" about (64.7 %) of the sample responded very low, about (19.3 %) responded by low, (8.7 %) responded moderate, while (6.0 %) responded high and that only (1.3 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

By looking at the results, one could draw a conclusion that majority believe the government's role is weak on issues of indoor air pollution and quality. One of respondents states if there is a role one could see it on projects in general and on housing projects in specific. Other respondent said the government role is weak and not strict on old building codes and regulation laws, and how residents are breaking laws on these already established codes.

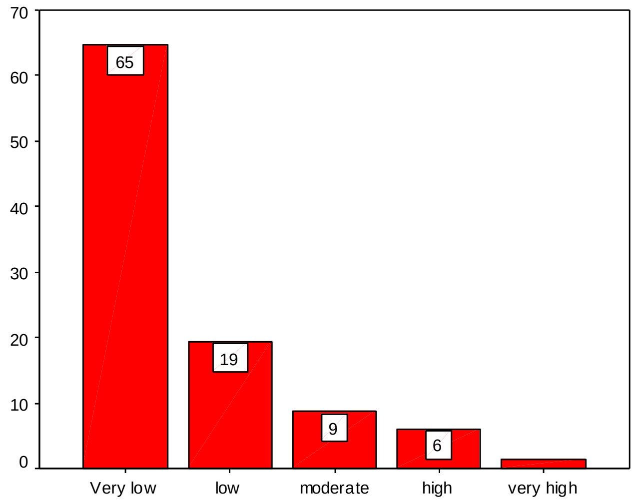


Figure 5.13: Government monitoring and enforcement of ventilation system and IAQ rules during and after construction

Table 5.13: Government monitoring agencies implementation of IAQ standards

Topic	Respond level	Counts	%
Government monitory agencies exist, follows up and monitors the implementation of IAQ in its housing projects " How do you rate their follow up during construction and delivery of projects?	Very low	39	26.0
	Low	57	38.0
	Moderate	37	24.7
	High	14	9.3
	Very high	3	2.0
	Total	150	100.0

The percentages values provided in Table 5.13 represents responds on the question "Government monitory agencies exist, follows up and monitors the implementation of IAQ in its housing projects "how do you rate their follow up during construction and delivery of projects?" about (26.0 %) of the sample responded very low, about (38.0 %) responded by low, (24.7 %) responded moderate, while (9.3 %) responded high and that only (2.0 %)

responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

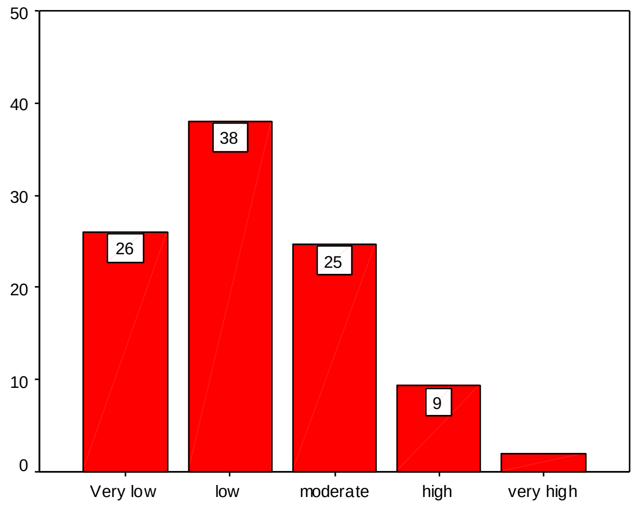


Figure 5.14: Government monitoring agencies implementation of IAQ standards

Looking at the results, the research concludes that results tended to low and very low, which both results adds up to 94%. Therefore, there is obvious government negligence in matters of indoor air quality in design stages and the construction stages to implements international or local standards of indoor air quality.

The majority of respondents also assure the shortening of supervision on issues of indoor air quality, also there is no feedback committee on projects in the construction stage, to trace any errors or shortages of implementation of standards for future projects. The negligence of governments starts at the beginning of the projects by not imposing strict regulation or standards to address indoor air quality issues in design stages or constructions stages. Also not imposing rules on contractors after the finish of residential project and houses.

Table 5.14: Private sector compliance to IAQ rules and standards

Topic	Respond level	Counts	%
Private sector in Kuwait follows and implements IAQ rules in their buildings and housing projects "how do you rate their performance in following	Very low	16	10.7
	Low	98	65.3

and implanting IAQ rules?	Moderate	21	14.0
	High	7	4.7
	Very high	8	5.3
	Total	150	100.0

Table 5.14 represents the percentages of the responds on the question " Private sector in Kuwait follows and implements IAQ rules in their buildings and housing projects “how do you rate their performance in following and implanting IAQ rules? " about (10.7 %) of the sample responded very low, about (65.3 %) responded by low, (14.0 %) responded moderate, while (4.7 %) responded high and that only (5.3 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

The researcher believes that vague building codes and the absences of crystal clear regulation in indoor air quality made the private sector in construction strive towards maximizing space within houses or projects even though it violates indoor air quality to achieve the greatest profitability. For examples the contractor’s windows are sized smaller than international standards, also bathroom vents are cheap quality and not sized properly according the internationals architectural standards, which vents are forcing indoor air out as what are they suppose to be in kitchens or bathrooms.

Majority of respondents agree that private sector in residential construction are not interested in implementing or applying indoor air quality standards due to the cost increase on their budget and local laws are not deterrent, and lack of awareness of public and residential occupant on indoor air quality.

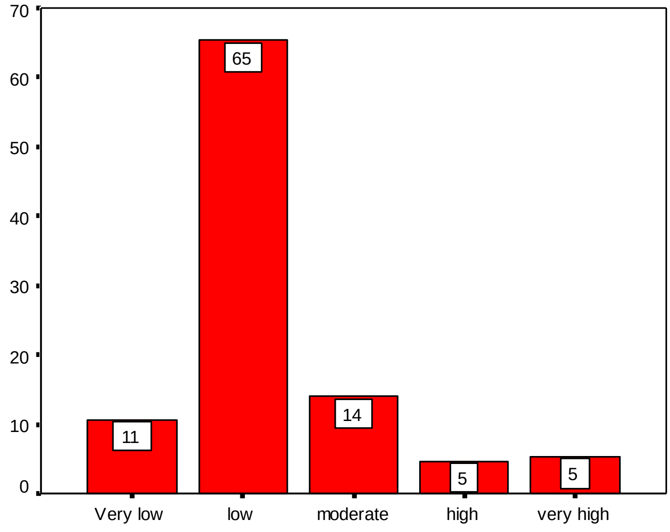
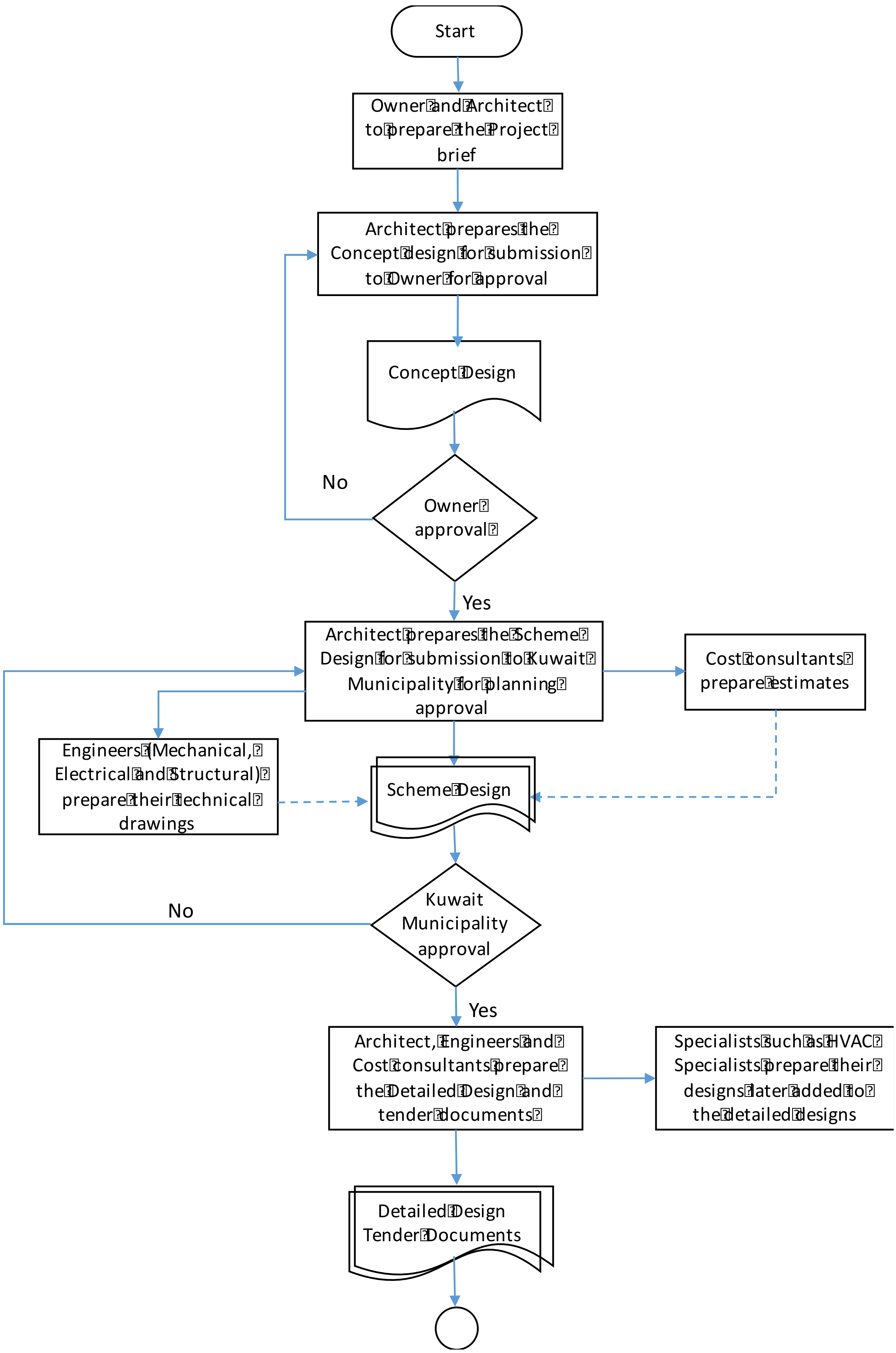


Figure 5.15: Private sector compliance to IAQ rules and standards

5.6 Current Practices to achieving IAQ in Kuwait housing development

In order for this research to be successful in achieving its aim, the current process for achieving IAQ in Kuwait must be understood. This would show the gaps (if any) in the process in which this research intends to fill so that the process is more robust, effective and efficient.

Most of the respondents (architects, M&E and design engineers, construction contractors, facilities managers, etc.) stated that they were aware of the importance of good indoor air quality (IAQ) and admit that achieving good IAQ starts at the design stage, then, construction and commissioning. In that respect, the research asked respondents the following questions: How do you currently achieve IAQ at design stage? How do you currently achieve IAQ at construction stage? How do you currently achieve IAQ at commissioning stage? and How do you currently ensure that good IAQ is maintained at occupancy stage? The predominant and current Kuwait system is similar to the traditional method of achieving IAQ shown in ASHRAE (2009) and follows old RIBA plan of works process. Figure 5.16 below illustrates the current Kuwait process for achieving IAQ.


Start
Owner and Architect to prepare the Project brief
Architect prepares the Concept design for submission to Owner for approval
Concept Design
No
Owner approval
Yes
Architect prepares the Scheme Design for submission to Kuwait Municipality for planning approval
Cost consultants prepare estimates
Engineers (Mechanical, Electrical and Structural) prepare their technical drawings
Scheme Design
No
Kuwait Municipality approval
Yes
Architect, Engineers and Cost consultants prepare the Detailed Design and tender documents
Specialists such as HVAC Specialists prepare their designs later added to the detailed designs
Detailed Design Tender Documents

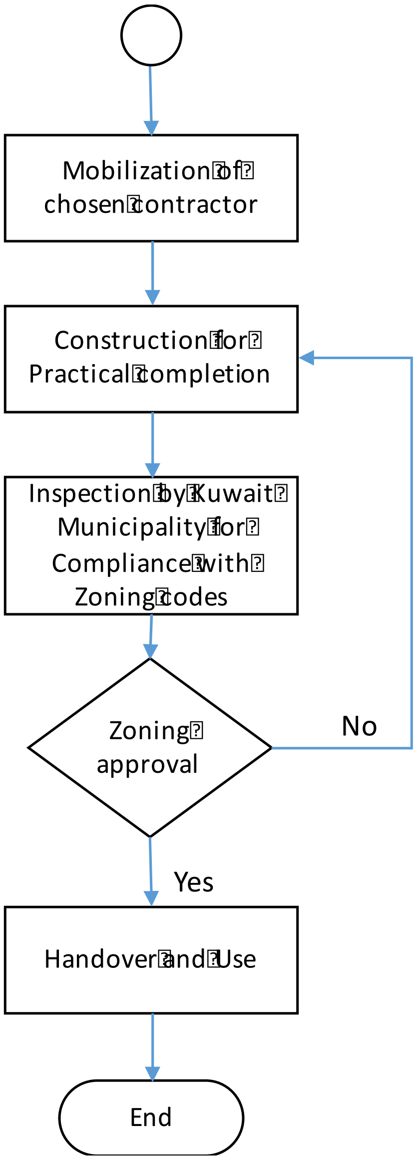


Figure 5.16: Current process of achieving IAQ in Kuwait housing developments

1. *How do you achieve IAQ at design stage?*

Currently in Kuwait most design professionals and architects use natural ventilation in housing by providing openings and also make efforts to adhere to the Kuwait municipality zoning laws. The process is as follows;

The Owner/Client or developer meets and discusses with the architect to prepare the project brief, which includes identification of project objectives (with regards to functionality, cost, budget, etc.), preparation of business case and determination of client's and project risks, site information examination, feasibility studies and recommendations including recommendation for additional surveys (if needed), etcetera. These information is then used by the architect to prepare the concept design, which is sent to the Owner/client for approval. If the design is not approved by the client, the architect collects more information and goes back to the preparation of concept design stage to get it right and return to the client for approval again. Once the design is approved by the Owner/client or developer, the architect prepares the Scheme design or working drawing and sends that document to the cost consultants and engineers like the; structural, mechanical and electrical engineers, who will then prepare their own engineering drawings based on the the architectural drawing they have received. The cost consultant prepares his estimates on how much the project will cost the client. Usually, the cost consultant is appointed by the client.

The HVAC engineer (usually the mechanical engineer) designs the heating and cooling loads of the building. Usually, the ventilation system is a closed circuit AC unit, which means that the system takes the indoor air, cools it, and pumps it back into the building. This is not an effective system as it does not introduce fresh air into the building. However, most developments make use of hybrid system where natural ventilation is used, therefore, the risks of using a closed system is greatly reduced.

Once all the Scheme Designs are finished; the documents are sent to Kuwait municipality for planning approval. The documents may include engineering drawings and/or cost estimates (this is indicated with dotted lines in Figure 5.16). Unfortunately, the Kuwait municipality does not focus on IAQ requirements, rather they focus on zoning code compliance. They check if the plan exceeds the allowable building area permitted by the zoning code, floor plans, elevations, set backs from neighboring houses etc. If the municipality suggest that the designs do not meet zoning codes and refuse permission for the project to go on, the architect has to return to the drawing board and make all the changes necessary to meet Kuwait municipality requirements. On the other hand, if the plans meet the requirement of the municipality, an approval is given and the architect proceeds with the preparation of the detailed designs. After detailed designs, the client receives a full package of full drawings and a contractor is appointed through a tender process to construct the building.

2. *How do you achieve IAQ at construction stage?*

After the tender is finished with the detailed design complete, the contractor moves to site. During the construction, the architect functions also as the project manager who overseas all activities and makes sure that the contractor builds according to design. Unfortunately, IAQ is not a priority for most contractor in Kuwait during construction. Now because IAQ was not put on the table from the beginning, i.e., at the design stage, what happens is that most buildings develop IAQ problems in the future. During construction, contractors do not pay special attention to the ductwork to make sure that they do not collect dust or other particulate substances.

Respondents confessed that at the construction stage, contractors are not monitored for IAQ compliance by the Kuwait municipality. The architect, monitors the contractor but there is no special attention given to IAQ compliance. As a result, many buildings suffer from contractor negligence to protect the ventilation systems; both openings for natural ventilation and designs for mechanical ventilations. Therefore, it is possible that the HVAC systems get contaminated with pollutant emitting substances or dust and particulate substance, which are later fed back into the air when occupants enter the facility.

Another major problem of achieving IAQ at post-construction stage is that most designers and contractors believe that after the building construction has been completed, the operation and maintenance of the building and its facilities is the problem of the owner/client. Which means, in most cases, there was not an input by the facilities managers or IAQ specialists. In addition, architects or designers do not perform any form of evaluation on design performance (commissioning) since they believe the operation phase is the owner's responsibility. "*Moreover",* one of the respondents stated, *"we are not given additional payment for after the defect notification period. So we are not responsible for post occupancy evaluation."*

3. *How do you achieve IAQ at commissioning and occupancy stage?*

The study revealed that evaluation of building performance also known as commissioning was uncommon amongst architects and designers in Kuwait. The commissioning that is supposed to take into account the quality of design and IAQ services and ascertain/check that the systems and equipment's are functioning properly is not done.

After construction, most building owners or developers do not test whether the HVAC system is working as required. The buildings are opened to the population for rent and purchase. Many people move in without testing. There is currently no commissioning requirement. As soon as the construction works are over, occupants take residence. Therefore, many occupants find themselves in un-commissioned HVAC systems that are either faulty or riddled with pollutants (dust and other construction material particulates) that were absorbed during the construction process.

At the end of the construction, building owners have to get inspected by municipality. Usually the inspection is about checking that the building has not exceeded the allowable building area. In other words, making sure the the new build is in accordance with the zoning codes. Thereafter, the building is opened to occupants. There is no checking or inspection on IAQ compliance. In addition, the respondents were asked if there was any evaluation of IAQ satisfaction or IAQ problems that have arisen during occupancy stage. Responses revealed that there were seldom any evaluative mechanisms, for example, user satisfaction surveys, or IAQ design evaluation feedback done after the project has been handed over and occupants have moved in.

With this process in place, Kuwait municipality has the opportunity to checks for IAQ compliance only once – at the planning approval stage. Unfortunately, according to the municipality officials interviewed, the way things are done at the municipality today, IAQ is seldom amongst the list of criteria that inspection officers check for. They mainly check that the plans are in accordance with land use regulation, height of buildings, density zones etcetera. Seldom is IAQ considered during planning permission stage. This shows that there are currently no IAQ compliance checks in place related to housing development in Kuwait. In addition, both industry professionals and Kuwait government officials stated that enforcement of IAQ compliance will be impossible without regulations and standards. This research however, is not for the preparation of regulations and standards but for the development of a framework through which future/existing IAQ regulations and standards could be implemented and enforced.

5.7 Design integration and inclusion of IAQ objectives early in design

An aspect of the literature review in Chapter 2 has suggested that, given the various design stages, the earliest stage in the IAQ or ventilation design process is the most critical period where changes can be made easily with little or cost implication and without variation order production, which will be the case if changes were to be made later during the construction stage. Designers (architects and ventilation designers) form 66.7% of the sample population. Through a discussion with them on the early stages of IAQ design, the research was able to ask relevant questions on their role in collecting and defining owner's/user's or client's IAQ objectives during the early design stages of the project. Designers (architects and design engineers) were asked the following:

(a) what role do designers play in collecting client/owner's IAQ objectives during the project inception, conceptual design, project programing, and scheme design stages?

(b) what measures are taken during the project inception, conceptual design, project programming, and scheme design stages to address client/owner/user's IAQ requirements prior to preparation of detailed design? For example, having an 'integrated design process', which is a gathering of the major players to give their inputs on the IAQ design as early as possible during the project design phase

(c) How is the post-construction stage (occupancy) perceived by designers? Are there efforts made to link aspects of design to the operations and facilities management stage?

These inquiries enabled the research to understand the role of the designers in collecting, defining and dealing with or satisfying these user/client's IAQ requirements as well as the information sources they refer to in Kuwait when making decisions.

The literature review as well as the previous section has highlighted the limited measures taken to implement an integrated design approach during the design of IAQ on housing construction projects in Kuwait. ASHRAE (2009), emphasizes the need for integration of all the major players; architect, engineer, project manager, contractor, facilities manager, HVAC specialist, IAQ specialist, lighting specialist, acoustic specialists, etc., in the design process whose inputs would be valuable in achieving good IAQ in the building. All the inputs of these players as well as the relationships between the inputs, are important in achieving good IAQ on a project. One significant relationship, for example, is the relationship between the design and the input of the facilities managers – that is, what happens at the operations and maintenance stage after design and construction. It is one thing to design the perfect ventilation and IAQ system, it's another altogether to maintain it. Another reason is that, a badly designed ventilation or IAQ system which does not take into consideration the system's operation and maintenance could result into significant IAQ problems and cost for both occupants and owner of the building. That is why the inputs of the facilities manager at the earliest design stage is very important.

The respondents were asked whether the IAQ and HVAC specialists and facilities managers are usually involved during the design stage of the building. Almost all respondents stated that the facilities managers were seldom involved and that communication with facilities managers was uncommon. In fact, some respondents report that the company managing the facility is in many cases unknown to the designer during the design stage. At discussions with respondents, a majority of them felt that the IAQ specialists as well as other project team members should be involved at the concept design stage. Most of the respondents believed that the IAQ and HVAC specialists would be most effective at the concept design stage rather than at the briefing stage. According to Jawdeh (2013), this is due to one or more reasons including; the client's lack of knowledge or awareness of benefits of good IAQ as well as effects of poor IAQ. Also, both the client and the project team are unaware of the significance of the IAQ and HVAC specialists and facilities manager's inputs at the early stages. Furthermore, the facilities manager is not appointed early at the design stage, is because the facilities manager is regarded as a secondary stakeholder in Kuwait. He is only needed after the project is completed. The integrated relationship needs to be replicated in the relationship between the building designers and the contractor, designers and the HVAC specialist, even in the relationship between the designers and the cost consultants, and so on.

However, the 66.7% of the designers that participated in this study asserted that Kuwait has not shown to be adopting the integrated design process, but acknowledge the importance of communicating with the other parties whose inputs are valuable to achieving good IAQ on the project. Therefore, the process needs to be improved. The interaction of the researcher with other respondents of other disciplines also revealed that parties on the project also admit that their relationships with the designers was distant and their services are solicited only after the design has been completed. In the case of facilities managers, they are only called upon after design and construction are complete. This lack of communication and integration is not only affecting the relationship between designers and other managers and engineers, it is also affecting the relationship between the designers themselves.

The current design and construction process does not pay any particular attention to collecting and defining client's IAQ requirement. Therefore, there is a disconnect as designers are not informed about the IAQ requirement due to non-involvement of IAQ or HVAC specialist early enough in the design stage. Although meetings take place between the designer and the client/owner or users, IAQ objectives are seldom brought up or tabled amongst priorities during the concept design stage. As such, architects act at their discretion in designing the building and later involve the mechanical engineer who then adds some HVAC components to the already fixed design to make good IAQ work. This is going about it the wrong way, IAQ objectives must be considered from the time of project brief and the concept design is done with consideration of IAQ and HVAC components; access, size, location etc. These can only be achieved through an integrated design process.

Some good IAQ objectives must form part of the design brief and identified on the concept design documentation. According to ASHRAE (2009), these objectives are:

- Outdoor air intake locations
- Local exhaust and building exhaust locations
- Air cleaning and filtration
- Space air distribution
- Building pressure control
- Internal pressure control
- Microbial control
- Moisture and humidity control

These IAQ objectives should form part of the design process and shared with other major players on the project. With an integrated design approach, IAQ objectives are most likely to be achieved, which means, all major players must be part of the client's organization from the beginning and not come in later on as third party when design is complete.

5.7.1 Inclusion of IAQ Specialist During Design Stage

According to respondents, Kuwaiti clients and/or developers include IAQ specialists at various points in the project depending on their experience and knowledge in the construction industry. Large construction and development companies that are used to building in large scale, as well large government housing initiatives usually have their own in-house IAQ ventilation design specialists who work along with the architect early enough in the design stage. These client/owner/ developer types suggest that previous experience in project development is a factor in achieving good IAQ on projects in Kuwait – at least in the current situation. On the other hand, less experienced clients either do not consult an IAQ specialist at all throughout the project, or involve them very late in the design process, when every addition will be retrospective and costly. Integration reduces the risk of abortive work in the future and the cost savings results from the fact that as design moves further, the level of detail increases; thus, bringing the major players early on the project results in less changes on the detailed design and therefore less money and work required. Respondents also agreed that the following were reasons for integration at pre-design stage:

- It is imperative to accurately pass the IAQ requirements (as shaped by the the different players; designers, IAQ & HVAC specialists, facilities managers etc.) to the designers before they start designing.
- When design progresses to 'developed design' and 'technical design' stages, it is very difficult for changes to made on the design to include IAQ requirements because some IAQ requirements are major design changes. For example, changing facilities managers' access and service corridors, adjusting alignment of shafts and ducts, changing the location of a lift shaft, or a loading bay; all these a major design changes and would cost the client more money to effect.
- The earlier the IAQ requirements are identified, the sooner the designers can include it into the designs. Also designers do not like a project participant coming late at the design stage and making changes because some changes are nearly impossible to effect depending impact it would have on the already set design. Not to mention the high cost of abortive work.

But in Kuwait, integration in seldom found happening on housing projects. This research will help foster not only the importance of achieving IAQ but also how best to achieve it, which is through integration as early as pre-design (brief) stage, up until 'handover and use' stage (RIBA, 2013).

5.8 Barriers to Good IAQ

There are a number of barriers that hinder the proper implementation of IAQ standards in Kuwait housing developments. The respondents were asked to state some of these barriers in the survey. The respondents mentioned 'cost' as the number one challenge for achieving good IAQ in Kuwait.

5.8.1 Cost or Budget

"When IAQ is bad, building owners and managers can find themselves devoting considerable resources to resolving occupant complaints or dealing with extended periods of building closure, major repair costs, and expensive legal actions. When IAQ is good, buildings are more desirable places to work, to learn, to conduct business, and to rent" (ASHRAE, 2009).

This is the main barrier behind most decisions regarding IAQ. Kuwaiti developers as well private individuals get discouraged once they realize that there would be a premium to pay attached to IAQ systems. Though the cost may be an issue to consider, it is however, not recommended to focus on cost at the expense of good IAQ. According to ASHRAE (2009), good IAQ has a direct proportionality to return on investment (ROI) for commercial real estate buildings and learning outcomes for children in schools and homes. In addition, IAQ problems that get out of hand can be quite costly in terms of lost work time, lost use of buildings, expensive building or mechanical system repairs, legal costs, and bad publicity (ASHRAE, 2009).

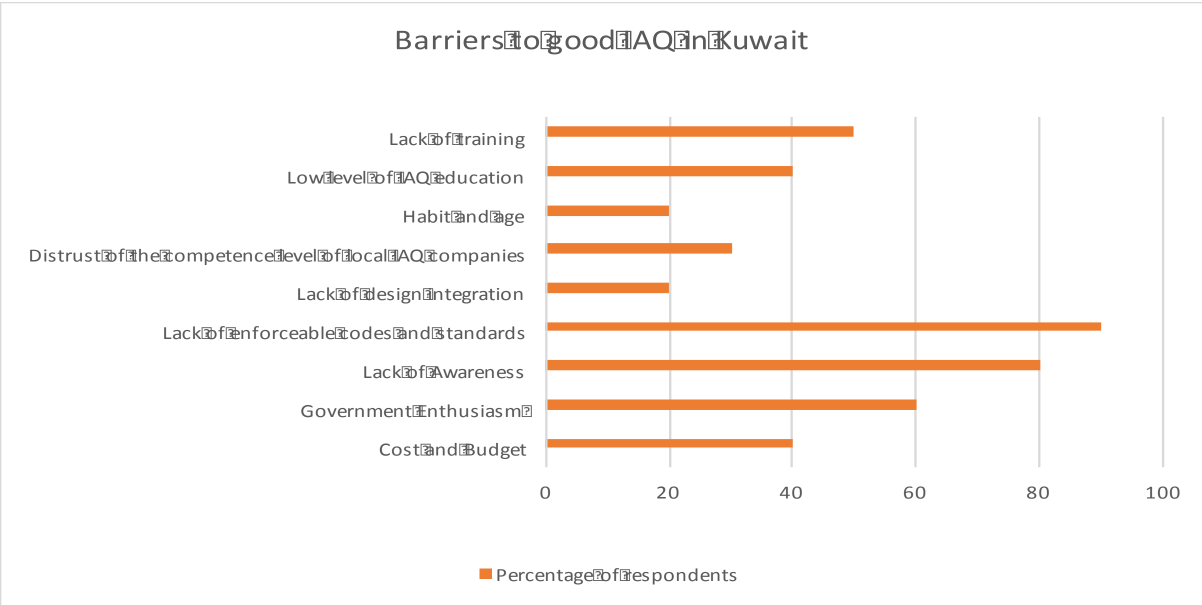


Figure 5.17: Barriers to achieving IAQ according to respondents

40% of the research respondents stated that the high cost of ventilation systems in Kuwait is a barrier to achieving good IAQ. Spending the right money on IAQ in the long-run brings a return on investment that makes money-spent worthwhile (ASHRAE, 2009). The return on investment, though difficult to quantify, can be seen in increased productivity of employees, decline in absenteeism in schools and in businesses, money not being spent on medications to resolve sick building syndrome issues, etc. “The potential reductions in health costs and absenteeism and improvements in work performance from providing better IAQ in nonindustrial workplaces in the U.S. are estimated to be in the high ‘tens of billions of dollars annually’” (ASHRAE, 2009). Many building owners in Kuwait would need a little more education on why they need to spend more on HVAC systems that will provide the best indoor air quality for their tenants.

On the other hand, if building owners resolve to cost savings and design a ventilation system that is below par, one that can not take the pollutant load of the building, then owners of buildings can be sure to encounter a lot of IAQ problems in the future. According to ASHRAE (2009), “the cost of poor IAQ can be striking,” involving many lawsuits, for which settlements have exceeding $10 million dollars and litigation costs paid during the early 2000s to be well over the conservative estimate of $500 million annually. All these issues make the need for a framework for achieving good IAQ in housing imperative. The framework will include IAQ early enough at the design stage and will enhance the ability of all parties to the project (architects and engineers alike) to design, construct, and operate buildings with lower first cost for ventilation equipment as well as lower operating costs, whilst providing good IAQ.

5.8.2 Lack of enforceable IAQ Codes and Standards

The research findings have shown that almost all the respondents (90%) report that there exist little or no codes and standards on IAQ in Kuwait. The same has also established that the government is very weak in enforcing IAQ regulations and standards partly because those standards and regulations do not exist. As we have seen, Kuwait municipality does not check for IAQ compliance at planning permission stage, rather, it checks compliance with zoning and density regulations and standards. In addition, the municipality does not take advantage of the two inspection opportunities it gets to check for IAQ compliance – one at the stage when developers apply for planning permission, and the other at the end of the construction. If IAQ compliance is put on the inspection officer’s checklists, that would go a long way to see that IAQ is taken more seriously by developers, architects and engineers.

Furthermore, respondents state that IAQ codes and standards are not deeply taught to design students only brushed through. Design students well educated in on the importance of good

IAQ in buildings as such they do not readily think about it once they out of university and in the work environment.

5.8.3 Lack of Awareness

The lack of awareness on the part of clients, professionals in the construction industry, and government institutions responsible for environmental protection, is one of the main reasons Kuwait is behind in achieving good IAQ in it housing developments. 80% of the respondents, who are mostly architects, do not have an in-depth knowledge of IAQ requirements. Respondents stressed that there are no competent IAQ specialists operating locally in Kuwait. If a client requires an IAQ specialists, the design team has to consult an international company competent in the field. One respondent stated;

"Local companies competent in IAQ do not exist."

It is important though, to emphasize the word "competent". The respondents acknowledge that many architects and design companies have basic knowledge of IAQ but could not be trusted with complex ventilation design projects. International IAQ specialists are usually consulted on complex IAQ projects.

Additionally, another barrier is due to the fact that the Kuwait scientific and medical data in which IAQ standards and codes are based on are not widely known. For example, there are no journals or books published, or industry workshops taking place regarding good IAQ and ventilation design. Furthermore, in-depth Kuwait IAQ scientific data are not part of students' curriculum at universities, such that, when they graduate, they are already familiar with good IAQ requirements and data to enable them design properly.

Currently in Kuwait, the most unfortunate set of stakeholders to be unaware of IAQ issues and the importance of ensuring it, is the user, or client, or owner and/or building occupant. Since IAQ has not gained popularity in Kuwait, users are unaware of the benefits of IAQ and so do not demand for it. If users are aware of the importance of IAQ in their dwellings, they will demand that IAQ is made a top priority from the very beginning of the project. Some of the respondents, mostly architects, reported that their clients either do not ask for special attention to be given to IAQ or even when it is recommended to them, they opt not to pay for hiring specialist IAQ consultants – siting, budget constraints. 'Cost' as a barrier in achieving IAQ is not only a Kuwaiti problem. It has also been cited in many European countries as well as the United states (EC, 2003) (the subject of cost as a barrier to good IAQ was discussed in more detail above). Most developers design the ventilation systems using natural ventilation. HVAC systems are considered expensive and a luxury. However, with the level of outdoor pollutants currently in Kuwait City, natural ventilation is insufficient. The ventilation system design needs to be hybrid in nature. Jawdeh (2013) gave list of client-related barriers to improving the integration of building design in facilities management. This list similarly represents the barriers to achieving good IAQ in Kuwait that are associated with the lack of awareness of the client/building owner on IAQ issues are requirements. The following are reason affecting the integration of IAQ and HVAC specialists and other consultants during the design stage:

- A lack of understanding on the part of the client on how facilities operate
- Clients ignorant about IAQ
- Clients' lack of experience in relation to HVAC maintenance costs
- Clients believe they are saving money by not getting an IAQ specialist early on in the project as such involving IAQ of HVAC consultants at this stage in seen as a cost incurred and not investment
- Most developers' main priority is the commercial aspect and making profit. They shift the responsibility of maintenance and repair unto the buyers or future users. However, if the developer or client is the end user of the building, IAQ objective are better specified and IAQ managers or competent people in IAQ are usually brought on early enough in the design stage. Also, as end users, they are more ready to pay the additional cost as well as the operational costs.
- Clients have no clear need for having long term planning as IAQ is not introduced in the program.
- There is no tradition for consulting an IAQ specialist early enough in the design stages, since traditionally, IAQ and HVAC specialists are usually involved after the scheme design is complete by which time, most clients refuse any significant modification to the design because they have gotten emotionally attached to their design and do not want to sacrifice the aesthetics. This however, limits the inputs of the IAQ specialist on the design and compromises the possibility of achieving good IAQ on the project.
- Clients' over-reliance on designers to tell them what they need. The problem with this is that most of the designers then have difficulties in collecting and defining what the client requirements are and trying to meet them when designing.

- Clients do not value the integrated design process, and that communication between the major players is important and will most likely translate to cost savings in the future.

According to one respondent, the power to influence the consideration of IAQ related issues during the design stage, rests with the client. He stated that his company usually suggest the implementation of IAQ related measures in the designs but not all clients are willing to pay for the measures suggested to them. He continues;

"at design brief stage, if the client would confirm IAQ objectives in the design brief, the objectives will definitely be accounted for in the design. But that is not the case."

Some architects amongst the respondents stated that some important IAQ objectives such as: location and access to air conditioning units, cleaning of external facades, mould and pollutant control, etc. are not particularly requested by clients. In addition, there is also a sort of negligence fed by ignorance on the part of the clients to not include energy efficient and sustainable materials in the design. If clients do not request for IAQ objectives and requirement to be included in the building design and/or are not willing to pay for the IAQ systems, then designers are not required by Kuwait law implement IAQ requirements.

Another barrier related to lack of awareness or perhaps a complete disregard for IAQ issues and requirement, is that contracts are awarded to friends who have no expertise about IAQ design or construction. This action ultimately causes that IAQ objectives are not tabled and met during design, construction or occupancy stages, and the client ends up with a building riddled with IAQ problems because the ventilation system was designed by a contractor or architect incompetent in IAQ requirements.

5.8.4 Lack of design integration

Because IAQ objectives are not tabled at the very beginning of the design of a project, it is likely that IAQ related concerns will be neglected due to the lack of integration or inclusion of the major players (architects, mechanical engineers, electrical engineers, IAQ specialists, HVAC specialist, etc.) whose activities have significant impact on the indoor air (IAQ) quality of the building. Some designers stated the importance of integration at the design stage but stated that this was not a regular occurrence. Ideally, IAQ issues or objectives (developed using as integrated design approach) should form part of the client's business case or basis of design (BoD) and therefore are accounted for in the design. Furthermore, if things are done in an integrated manner, IAQ objectives would be accounted for during value engineering when the building design is evaluated for delivery of technical and financial benefits.

As a lack of design integration is a barrier to good IAQ in Kuwait, there exists also barriers to integration in the design process. One of the major barriers to design integration is that IAQ specialist, HVAC specialist, as well as other consultants charge an additional fee in order to participate early on the design. There is an added cost to clients/building owners/developers for specialist to attend meetings and review of drawings. Designers (architects) are not able to justify this cost to the clients in ways that clients are comfortable paying the additional cost. As such, clients say ‘no’ to the integrated process. On the other hand, if designers can justify the integrated process was necessary and can show some tangible numbers as to how the process can result into cost savings for the client in the future, clients would be willing to pay stipend required to have the integrated process. In other words, it not enough for project managers or designers to promote the benefits of IAQ design achieved through an integrated process to clients, it imperative for designers or project managers to convince clients of the value of the engagement in terms of numbers and cost savings.

Another barrier to integration is the absence of an attitude of knowledge sharing and management. Many specialists and parties to a construction project do not want to integrate for fear of being irrelevant in the future. They feel that if they share what they know, their knowledge would be stolen and would not be called upon on future projects. Hence, they keep their knowledge to themselves and do not document it.

Jawdeh (2013) outlines the consequences of lack of integration of facilities managers in the design stage, who are one of the major players of achieving good IAQ in buildings. The facilities’ managers are more involved at post-construction stage. Basically, they take over the operation and maintenance of the whole building, including the ventilation system. Therefore, their input at the design stage is very essential. The consequences due to lack of integration of facilities managers (as well as IAQ and HVAC specialists) at the design stage are;

- “interruption to tenants
- access problems for maintenance, where HVAC equipment and ducts are badly designed

- dissatisfied customers,
- developing systems solutions inappropriate to requirements
- breakdown in air-conditioning
- unavailability of spare parts,
- operation and maintenance services affected,
- client's incurred cost and/or loss of profit,
- poor quality of documents (as built drawings, and operation and maintenance manuals etc.),
- absent or insufficient spaces allocated for facilities management staff,
- building management system control problems, chillers operation problems,
- designer's reputation negatively affected,
- façade cleaning problems, facilities management companies' bad reputation,
- facilities managers forced to experiment with new products, higher operation and maintenance costs,
- higher operation complexity (large amounts of keys and master key groups), inappropriate space allocations, insufficient system redundancy
- Inability to accommodate space changes (lack of flexibility)
- Lack of comfortable spaces for users
- Outdated materials
- Shorter facility life
- Systems integration problems (e.g. CCTC and access control integration, or fire alarm and lifts integration
- System inefficiency
- Wrong material selection
- Wrong systems installed"

It was revealed in Jawdeh (2013) that facilities managers found that the most significant consequence of lack of integration earlier in the design process, *"is the problem of access for maintenance. Whether the task is maintaining HVAC equipment, changing filters, replacing, light bulbs, maintaining pumps or attending a leakage problem, facilities managers face problems during occupancy phase when trying to access different systems."* Access was a problem, which clearly meant that architects or designers did not consider how their designs could affect the functions or activities of other consultants on the project.

Respondents in this research in the end, agreed that design integration is key to achieving good IAQ on construction projects and that it was necessary so that properly identified client requirement can be translated into useful design information. The state that the drivers of IAQ both in the construction industry and in the government must encourage the integrated design approach which lead to improvements in design and increases design efficiency with respect to good indoor air quality (IAQ).

5.8.5 Distrust of the competence level of local IAQ companies

In Kuwait, there is a distrust of the competence level of the local IAQ companies or engineers because IAQ is still very much a new discipline in Kuwait. Therefore, this serves as a major barrier to achieving good IAQ in Kuwait housing developments. According to one respondent;

"there are companies that call themselves IAQ specialist in Kuwait but in reality, they are bunch engineers masquerading as specialists"

Of course not all IAQ or HVAC specialist in Kuwait are incompetent, but that's the perception unfortunately. Therefore, most clients that want good IAQ and have made their project objective, do not consult a local IAQ company. They go to international IAQ companies that have a reputation of quality work. IAQ being a new discipline in Kuwait affects IAQ managers and specialists' performance in practise. The current lack of knowledge, practical application and implementation as well as academic education is directly related to the few number of IAQ manager or specialist with experience specifically with regards to design, construction, and post-construction (occupancy stage).

5.8.6 Habit and age

One of the hardest things to change in life is a 'habit' and habit comes with age. This statement implies that it is the older Kuwaiti construction professionals that are posing this barrier. When people are so used to doing something over and over again to such a point that a better alternative is side-lined. Eleven (50 and above) of the Kuwaiti professionals that participated in this research stated that they already have a habit of designing IAQ a certain way. Modern and contemporary IAQ system designs and codes are a little too complex for the older professionals, they said.

5.8.7 Low level of IAQ education amongst designers and engineers

Indoor air quality (IAQ) is a specialist field that often requires a separate education process from the overall architectural or mechanical engineering education. About 40% of the respondents have a bachelor's degree. Yet, they state that designers' and engineers' low level of education in IAQ is a big barrier to achieving good IAQ in Kuwait housing developments. At this point, they state that construction professional have to acquaint themselves with international standards and regulations of IAQ, such as *ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality*, and many others. Construction professionals in Kuwait, especially the architects and mechanical engineers can come together to drive the development of IAQ scientific and medical data to form regulations and standards for good indoor air quality (IAQ) in Kuwait.

Ventilation designers (Architects) need to develop an attitude of keeping up with current changes or news on IAQ locally and internationally through frequent research. Some respondents reported that the tendency of IAQ designers not adding to their learning after university was a problem and a barrier to good IAQ. Therefore, industry societies need to have IAQ frequent IAQ workshops and trainings of both the older professionals as well as the young ones coming fresh out of college.

In addition, the respondents stated that a barrier to good IAQ is that designers are too concerned with drawing pretty buildings and not thinking of its operability on a daily basis. They are sometimes arrogant and feel they are leaders of the project team and sometimes disregards legitimate suggestions that can improve the IAQ design. Fortunately, designers and engineers are somewhat aware of the negative consequences of poor IAQ and the late involvement of the major project players in the design stage, which results to problems in design output.

5.8.8 Lack of training

53% of respondents stated that lack of training on technical aspects of IAQ was a major barrier to achieving good IAQ in Kuwait. According to ASHRAE (2009) and (EC, 2003), for good IAQ to be successfully achieved on a project, it is important that all members of the project team be skilled in IAQ design and be involved early from the beginning of the project. If they do not have IAQ knowledge, the professionals must be sufficiently trained or briefed in order for them to be able to contribute to the ventilation design. Some of the respondents especially the Architectural and mechanical engineering companies suggested that the cost of giving extra training employees on indoor air quality (IAQ) was a major barrier to achieving IAQ. One of the respondents alleged that the main reason why good IAQ design is not standard in Kuwait at the moment, is because most architects, and mechanical engineers are satisfied with the status quo and are not interested in making good IAQ design standard since they get to charge more when they bring on a high-cost ventilation specialist.

In the survey, 10% of the respondents (mostly 50 years and above) stated that at their ages, they were not motivated to learn the technical aspects of good IAQ, interesting non-the-less. However, some younger respondents mentioned that they have taken the initiative to include good IAQ in the trainings they give their younger employees, only that the topic is not emphasized over the top. It is plausible that learning the technical aspects of IAQ can be daunting especially to older people. For example, learning afresh all the parameter indices of thermal comfort index or predicted mean vote (PMV), indoor air quality (IAQ), and energy consumption index, and gradient-based optimization, can be daunting. The calculations needed to ascertain the PMV index alone can be scary. To reiterate, the PMV index indirectly indicates the satisfaction of the thermal comfort for HVAC systems and is defined by the six most important thermal variables: "*human activity level, clothing insulation, mean radiant temperature, humidity, temperature and velocity of indoor air"* (Atthajariyakul and Leephakpreeda, 2004).

Furthermore, respondents also stated that finding the time for training was also an issue but recognise that it was very important that they have the knowledge. Therefore, the lack of push and will for construction professionals to find time to learn IAQ designs and processes sits as a barrier to achieving good IAQ in Kuwait.

5.9 Drivers of good IAQ in Kuwait

Now having discussed the barriers to achieving good IAQ design in Kuwait, what is equally important is the question "who should be responsible for driving the process and knowledge of good IAQ designs on Kuwait housing project?" The majority of respondents stated that the people responsible for achieving good IAQ on projects in Kuwait are the: engineers, architects, and designers, and government institutions like Kuwait Environmental Protection

Agency (KEPA), Kuwait Institute of Environmental Management (KIEM), Kuwait Municipality, Kuwait Institute of Science and Research (KISR) etcetera. One respondent responded:

"Usually Mechanical Engineers who go by ASHRAE standards, however I believe that architects need to play a stronger role and explore passive methods of natural ventilation. I know dust is an issue however we are not living on Mars we only get 50 days a year of dust and most of the year the weather is good in Kuwait."

Awareness of IAQ in Kuwait has increased because of the growing interest in green building design and also through personal certifications such LEED certification, where knowledge of IAQ is a prerequisite but it is not at the level that it should be yet. According to results from the survey, the following professionals are responsible for driving IAQ agenda in Kuwait.

- Clients/End user
- Architects and designers
- Consultants
- Contractors
- Manufacturers
- Professional societies (Engineers, especially mechanical engineers)
- Government institutions such as; Kuwait Municipality, Kuwait Environmental Protection Agency (KEPA), Kuwait Institute of Scientific Research (KISR); public health departments, etcetera.

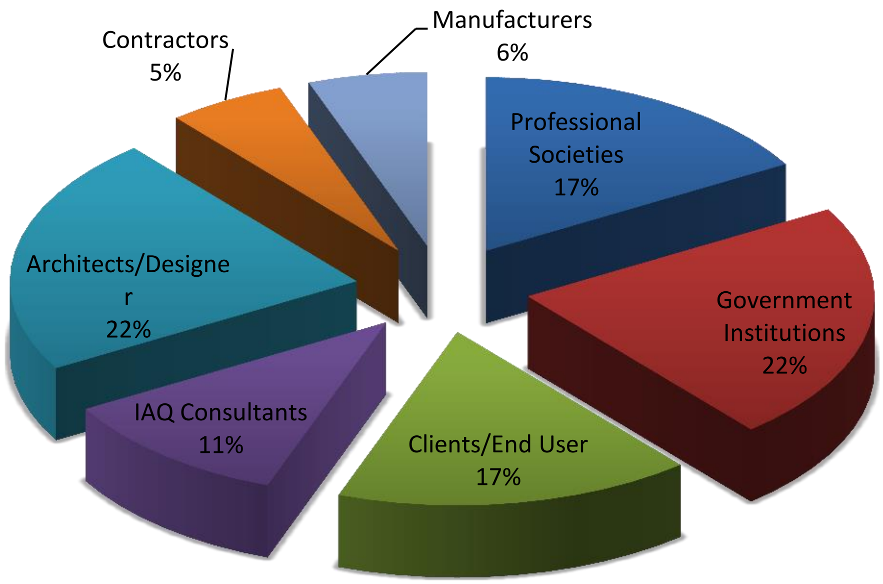


Figure 5.18: Drivers of good IAQ in Kuwait

Figure 5.18, shows that 22% of the respondents and another 22% also report that architect/designers and government institutions respectively should be the main drivers of good IAQ designs in housing developments. 17% report that clients/end-users and another 17% report that professional societies11 should drive the awareness and implementation of good IAQ. 11%, 6%, and 5%, report that the IAQ consultants, manufacturers, and contractors respectively, should drive good IAQ designs.

5.9.1 Clients/End-users

In Kuwait, most people are particularly aware that outdoor air pollution is harmful to their health (smoke, sooth, dust etc.) but are less aware that indoor air pollution is equally detrimental. Due to the climatic conditions of Kuwait, its hot arid climate, Kuwaiti residents tend to spend a lot of time indoors, and to make matters worse, buildings tend to be well sealed from the outside to increase the efficiency of air conditioning, thus increasing exposure to indoor air pollutants (Al Khames, 2014). The health effects of poor IAQ cannot be ignored. Therefore, Kuwait developers, and building clients, must be educated not only on including IAQ objectives from the start of their projects but also educate the end users on how to sustain and maintain good IAQ in their living spaces. At least end-users should be educated on the common indoor air pollutants and/or pollutant emitting products and substances, e.g. “smoking, combustion products from stoves, heaters, furnaces and fireplaces;

volatile organic compounds including formaldehyde, pesticides, solvents, cleaning agents, scents, hair sprays, paints and other finishes, glues, dry-cleaning fluids, aerosols and many others; fragrances in personal products, deodorizers, cleaning agents, etc.; and biologicals including animal dander, insects and moulds" (Al Khames, 2014).

This study shows that respondents feel that the end-user, client, building owner, must be one of the main drivers of good IAQ design on their projects. The study has also established that the lack good IAQ awareness on the part of the end-user means that they can find themselves suffering from some type of building related and life threatening illness in which, a good a IAQ design could have prevented. Ideally, the client/end-user/building owner, must recognise that they are in the best position to affect the ventilation design at every stage on the project because it is the owner of the building that ultimately pays for the project and can therefore tender the objective of good IAQ design from the very beginning as well as make modification and changes on the ventilation system's design. In reality though, the building owners or project owners in Kuwait seldom know much about good IAQ design. They trust that their consultants (architects and engineers) know what they are doing, and therefore, they leave the ventilation design to so called professionals. However, it is important that clients are educated on good IAQ so that the many benefits can be realised – some of which are; improved wellbeing, increased productivity, reduction or elimination of all building associated illness, etcetera.

5.9.2 Architects, designers and other construction professionals

The architects, designers and other construction professionals must take responsibility for driving the awareness of achievement of good IAQ designs in Kuwait developments. Many development and consultancy companies in Kuwait, have the resources, especially the big ones, to promote, train employees and implement good ventilation designs, whether, natural, mechanical of hybrid ventilation systems. These large development companies in the Kuwait construction industry have research and development (R&D) departments that can dedicate time and resources to take all the readings i.e. the scientific and medical data regarding IAQ at different locations in Kuwait. For example, the outdoor pollution reading in Bubiyan islands will be different from the pollution in inner city Kuwait. These results can then be documented and adapted on future projects or better yet, published for the consumption of the public. Furthermore, respondents believe that professional societies or industry associations can also drive the implementation of good IAQ designs. They could promote training of colleagues through workshops, seminars, conferences etc.

5.9.3 Government

From Figure 5.18 above, it is obvious that the respondents feel that the government must do more to increase the standard of IAQ to protect the end user. At the same time, the respondents feel the client/end user most equally ensure that good IAQ is achieved on their projects. According to ASHRAE (2009), *"Indoor air quality (IAQ) is one of many issues that building owners and developers must address to provide buildings that meet their needs and the needs of the building occupants. While building occupants do sometimes complain about poor IAQ, it is not always on the top of their list of concerns."* Therefore, clients must do more. However, this may be difficult to do for the client or end user who is not knowledgeable on the subject of IAQ.

One respondent suggests that:

"KISR should conduct serious and rigorous research and the outcome should turn into legislation and adopted by building code. There should be an awareness campaign and programs run to educate people who wish to build their homes. As soon as you apply for a loan to buy a land the government offers a free course to educate people on what to ask for when hiring an architect. Government should offer a free design audit service to ensure home owners get proper advice."

Table 5.15: The role of government in creating awareness of good IAQ practices

Topic	Respond level	Counts	%
The government plays an informative role in educating the public of the Health and environmental hazardous of not following and implanting IAQ rules "what's your rating of the role the media has played in Kuwait concerning IAQ awareness"	Very low	109	72.7
	Low	29	19.3
	Moderate	5	3.3
	High	5	3.3
	Very high	2	1.3
	Total	150	100.0

Table 5.15 shows the percentages of the responds on the question " The government plays an informative role in educating the public of the Health and environmental hazardous of not following and implanting IAQ rules "what's your rating for role of the government in Kuwait concerning the IAQ " about (72.7 %) of the sample responded very low, about (19.3 %) responded by low, (3.3 %) responded moderate, while (3.3 %) responded high and that only (1.3 %) responded by very high. The results show that the majority of the sample tends to respond in the low and very low area representing their satisfaction on the idea of this question.

The researcher believes by looking to the result of this question (8) statistical analysis. Which was regarding the government and its role regarding the indoor air quality. The respondents agree that the government plays very little or no role at all in raising people awareness in the issues of sick buildings syndromes or indoor air pollution nor indoor air quality, due to the fact that this area or subjects of IAQ is new concept. Most of the engineers stated that they are unaware of this concepts or regulation due to the fact they did not get enough education classes or training courses or certification on indoor air quality, as it is done in the western world.

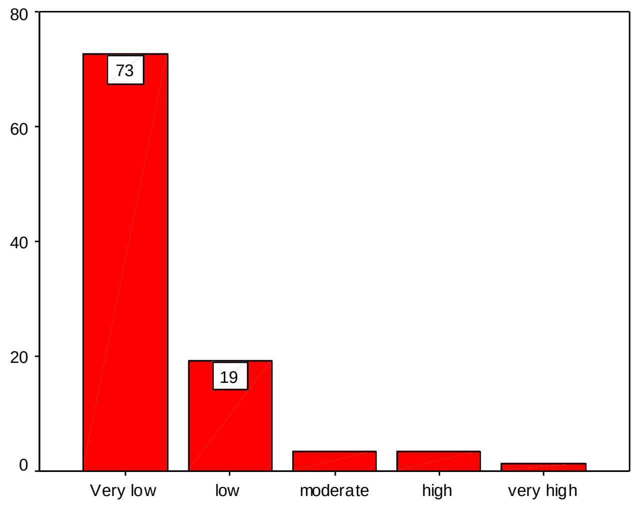


Figure 5.19: The role of the government in creating awareness of good IAQ practices

The government is responsible for creating awareness of good IAQ because of the potential health problems bad or poor IAQ can cause – sick building syndrome, asthma, e rhinitis and nasal congestion; epistaxis; pharyngitis and cough; wheezing and worsening asthma;

dyspnoea; severe lung disease; conjunctival irritation; headache or dizziness; lethargy, fatigue and malaise; nausea, vomiting and anorexia; cognitive impairment and personality change; rashes; fever and chills; tachycardia; retinal haemorrhage; myalgia; and hearing loss (Al Khames, 2014). All these are a major concern to any government, not to mention the cost incurred to the people as well as the government in tackling some of these health problems. Some respondents are emphatic that the awareness of good IAQ must come from top-down, from government to users, and not down-up. They propose that that the first step to this, is for the government to document the IAQ regulations and standards with the help of KEPA, KIEM, KISR etc. after that, they should put measures on how to enforce compliance. For example, including good IAQ design checks and the planning permission stage.

The respondents also stated that the government can be a bit slow in promoting and implementing new policies in Kuwait. Therefore, they do not see the regulations and standards hitting the industry anytime soon. However, international IAQ regulations and standards are available for construction professional with skill on the technical aspect of IAQ to measure and tailor those regulations to fit Kuwait environment – outdoor air pollution, temperature, air speed, etcetera.

5.10 Statistical analysis of results

To describe the results briefly, means and standard deviations were calculated using SPSS software package (version 16). The results are included in Table 5.16.

Table 5.16: Means and standard deviations for the surveys' questions

Question	Rating	Mean	Std
Kuwait government applies Mandatory tough laws concerning the implementation of IAQ in both design and construction housing “how do you rate the government enforcement of laws?	Very low	1.69	1.09
Government monitory agencies exist, follow up and monitors the implementation of IAQ in its housing projects “how do you rate their follow up during construction and delivery of projects?	Low	2.23	1.01
Private sector in Kuwait follows and implements IAQ rules in their buildings and housing projects “how do you rate their performance in following and implanting IAQ rules?	Low	2.29	0.91
Decision makers in Kuwait have a great understanding in implementing IAQ rules in all of their housing projects (how would you categorize it?)	Very low	1.75	0.88

Implementing IAQ rules in both design and construction phases is a common practice for anyone building a house or a project. (How would you categorize the understanding of IAQ for anyone attempting to build a house or project?) .	Low	2.03	0.68
Engineers have a very good and clear Understanding of IAQ standard rules and regulations in both design and construction housing projects " how do you categorize their understanding ?"	Very low	1.43	0.75
Firm laws exist in Kuwait to ban those who do not follow IAQ rules in design and construction phases (how would you categorize government enforcement of ventilation system and IAQ strategy?)	Very low	1.53	1.03
The government plays an informative role in educating the public of the Health and environmental hazardous of not following and implanting IAQ rules "what's your rating for role of the government in Kuwait concerning the IAQ "	Very low	1.41	0.82
Label scheme rules regulating construction materials manufacturing industry products exist (categorize how accurate is label scheme used to ensure IAQ rules are being applied for a good indoor air quality)	Very low	1.77	1.21
The government plays a very important role in monitoring and enforcing IAQ rules during the construction phase and after delivery of projects to ensure a good quality of indoor air exists (categorize government monitoring and enforcement of ventilation system and IAQ rules during and after construction?)	Very low	1.60	0.97

Table 5.16 indicates the values of means and standard deviation for each question in the survey. Checking the mean values it seems that all the values were in the low and very low responds. The greatest mean was observed in question no. 3 which states "Private sector in Kuwait follows and implements IAQ rules in their buildings and housing projects “how do you rate their performance in following and implementing IAQ rules? " (2.29) followed by the mean of question 2 which state "Government monitory agencies exist, follow up and monitors the implementation of IAQ in its housing projects “how do you rate their follow up during construction and delivery of projects?" (2.23)

The least mean was observed in question no.8 which states that " The media plays an informative role in educating the public of the Health and environmental hazardous of not following and implanting IAQ rules "what's your rating for role of media in Kuwait concerning the IAQ " (1.41) and that the semi last mean which was observed in question no. 6 which states that "Engineers have a very good and clear Understanding of IAQ standard rules and regulations in both design and construction housing projects " how do you categorize their understanding ?" (1.43).

The following figure shows the mean values representation for each question

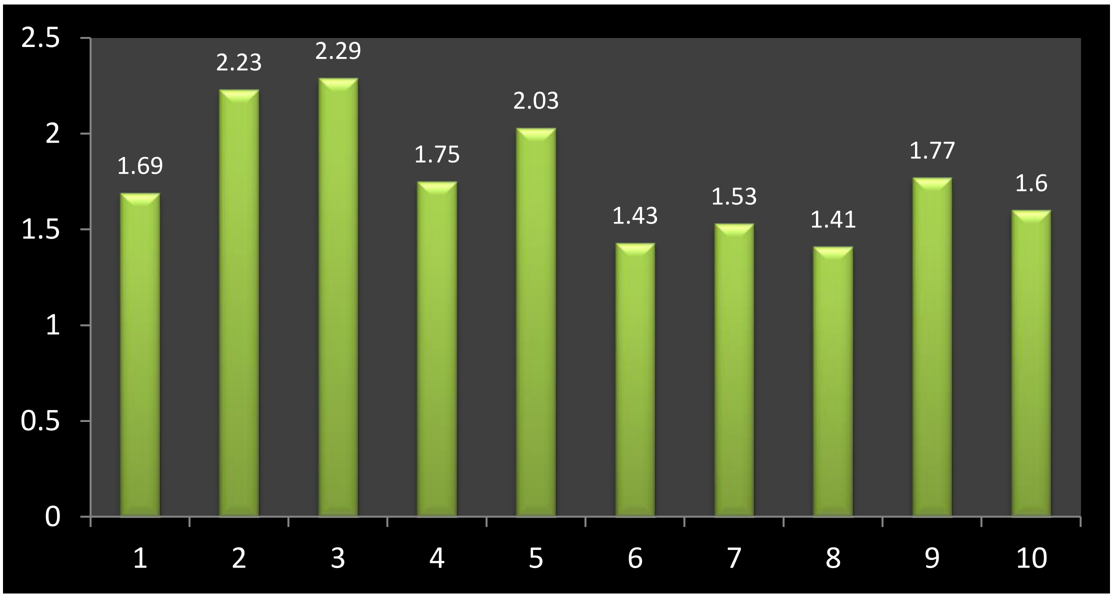


Figure 5.20: Mean values representation for each question in the survey

5.11 Summary

The findings revealed no documents written for Kuwait, that encompasses codes, standards, regulations and guidance for the implementation of good IAQ in Kuwait housing developments, or a framework for government enforcement of such. It was also revealed that there was a significant lack of awareness of indoor air pollutants and/or good IAQ both amongst occupants and construction professionals. The status quo in the housing development process did not enable integration amongst the project team and stakeholders at the design stage, hence team member's valuable input on achieving good IAQ at design stage is lost. Furthermore, the process did not emphasize the following at every stage of the project to ensure good IAQ: commissioning of the ventilation design and installation, which includes value engineering, proper sequencing and scheduling of activities to avoid dust or debris from contaminating the ventilation system, proper documentation and reporting to ensure the owner's project objectives are documented, achieved, checked, and carried over to the next stage.

The most common method of achieving good IAQ according to respondents is either through a dedicated department within the firm, or by hiring an external HVAC specialist/consultants. Usually, it involves both groups working together to achieve the set goal. According to one respondent, *"they* (Building services department) *design to proven criteria and work with reliable specialist HVAC contractors".* First, the criteria for good IAQ is set and strictly adhered to during the design stage; second, good contractors and suppliers knowledgeable in IAQ procedure and with strong quality control policies are selected for the construction of the project, lastly, a good operation and maintenance manual is prepared. This manual is to be complied with for the lifetime of the project.

The respondents state that these designs focus on: building orientation in accordance with the sun, proper natural ventilation including landscaped spaces wherever possible, reducing heat conduction through isolated blocks, using appropriate glass layers and proper thermal insulation wherever applicable, and so on. In addition to natural ventilation, respondents strongly advocate use of HVAC or other state of the art ventilation mechanism. One respondent recollects:

"As an architect I make sure that there is a strong natural ventilation strategy. In my last project we even introduce a traditional wind catcher in the rooms of the eco resort we designed to allow users to benefit from the sea breeze whilst maintaining privacy and keeping windows shut."

Furthermore, part of value engineering process for achieving good IAQ before and during construction, is to ensure that high toxic emitting materials are not included. That means, materials to be used must be certified as zero or low-emitting products. After construction, occupants must be advised to: avoid smoking indoor, or usage of harsh cleaners, and control appliances with exhaust if any; and to maintain AC ducts at intervals (using set guidelines in the manual). ASHRAE (2009) guide has a wealth of practical information on how to design and construct buildings with better IAQ without large financial investments or untested technologies.

The findings show that the barriers to achieving good IAQ in Kuwait housing developments are; cost and budget, government enthusiasm, lack of awareness, lack of enforceable codes and standards, lack of design integration, distrust of the competence level of local IAQ companies, habit and age, low level of IAQ education, and lack of training. Similarly, respondents report that the drivers of good IAQ in Kuwait housing are; the client/end-user, the government, architects, designers, IAQ consultants, construction professional societies, contractors and manufacturers. All the findings here will inform the development of the framework in the next chapter.

6 CHAPTER 6| FRAMEWORK DEVELOPMENT

6.1 Introduction

According to ASHRAE (2009); *"Indoor air quality (IAQ) is one of many issues that building owners and developers must address to provide buildings that meet their needs and the needs of the building occupants."* Habitable buildings have good IAQ. But what ensures that good IAQ is achieved is compliance with industry standards and regulations on ventilation. When builders and professionals ignore these standards, health issues related to sick building syndrome arise and result in significant health, loss of employee productivity, increased absenteeism in schools, as well as economic impact.

Another major issue that is of equal concern when good IAQ is neglected is the costs that are accrued by business owners because of lost work time; by occupants in hospital treatment of sick building syndromes and other IAQ related illnesses; by owners because of lost of use of building, expensive building or mechanical system repairs, legal costs, and bad publicity. The cost saving that can be made if IAQ is given more attention is clearly immense. Therefore, an important objective of this research study is to make sure that construction professionals, building owners and developers work with a framework in which IAQ objectives are put on the table at the very beginning of the development and design processes (ASHRAE, 2009). As such, it would be very hard for the architect and other project participants to ignore or forget IAQ requirement during construction and commissioning. ASHRAE (2009) emphasize this because the organisation recognises that "by the time a building's schematic design is complete, many opportunities to achieve good IAQ have been foreclosed, which can easily result in unintended consequences or expensive and inadequate "force fitting" of solutions. When IAQ, energy efficiency, and other project objectives are considered together at the initial design phases, design elements for each objective can be mutually reinforcing rather than at odds with one another."

Based on the research findings, Kuwait construction professionals and building owners acknowledge and appreciate the importance of good IAQ but are yet to implement or include specific IAQ objectives in the design and construction decision making process. The lack of this inclusion may lead to the rise of IAQ problems in buildings. To be fair, residential builders, developers, design professionals, and others employ basic measures to ensure good IAQ in buildings. For example, the use of openings to increase natural ventilation and/or choosing low pollutant emitting materials for construction help improve IAQ in buildings.

The absence of standards and regulations for achieving good IAQ in Kuwait housing developments make it difficult for compliance agencies to enforce IAQ regulations. However, there are many standards in existence that can be adopted, tailored and applied to Kuwait context such as “ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality.” These standards are well researched and documented.

However, the one question most construction professionals in Kuwait want to know is; even if IAQ standards and regulations exist, how is it to be enforced? This question is why this research is necessary. The research seeks to develop a framework, on which good IAQ can be achieved in housing developments, if followed diligently by the professionals and institutions involved. The framework is developed for use by building owners (both existing and prospective owners), developers, architects, design engineers, consultants (e.g. Quantity surveyors who do value engineering, and mechanical and electrical engineers), construction contractors, commissioning authorities, Kuwait municipality, responsible for planning permissions, facilities managers, and even manufacturers of construction materials. This framework will go a long way to see that future developments are designed and constructed with IAQ objectives in mind to bring about habitable and sustainable environments for the future people of Kuwait.

After the researcher went out into the field and conducted interviews and then consequently, surveys with professionals involved in housing development in the Kuwait construction industry, a new framework emerged. This framework covers the three phases of a construction project; design, construction, and post-construction (occupancy). The framework is structured around RIBA Plan of Works 2013 (based on a traditional method of procurement) and greatly influenced by ASHRAE (2009). According to ASHRAE (2009), *“the single most important step an owner or design team leader can take to reliably deliver good IAQ is to use effective project processes. Lacking these, even the most sophisticated suite of IAQ technologies may not deliver the desired results.”*

Effective project processes are expected to streamline design, construction and post-construction activities so that the best possible IAQ environment can be achieved. The current and most reliable processes to enhance IAQ management deemed by this research is a fusion between the RIBA stages (strategic definition, preparation of brief, concept design, developed design, technical design, construction, and handover) and ASHRAE project processes; using an integrated design approach and solutions, commissioning to ensure that the owner's IAQ requirements are met, and selecting HVAC systems to improve IAQ and reduce the energy impacts of ventilation (ASHRAE, 2009). In this framework the developed design and the technical design is combined and called 'detailed design' because in most Kuwaiti professionals' understanding technical design is detailed design and not a separate stage. In fact, the technical design (mechanical, electrical and specialist's drawings) are done simultaneous to the architectural, and structural design development.

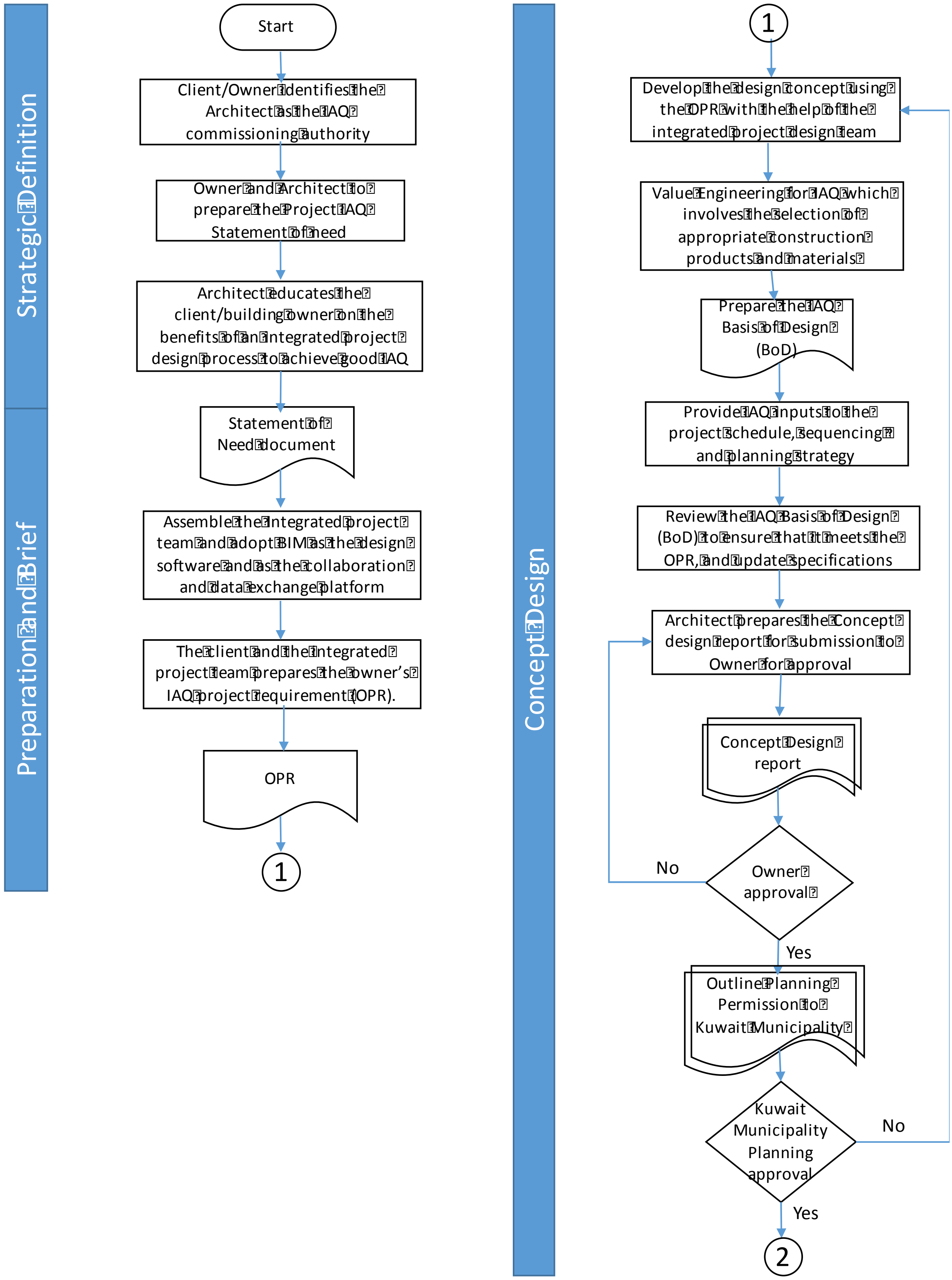
This was necessary because (a) the predominant method of procurement in Kuwait is the traditional method of procurement and the construction industry as a whole (Architects, designers, engineers, specialists, etc.) is trained based on the RIBA Plan of Works. Of course the RIBA plan of works is modified from time to time, but the changes are not significant and the idea of each stage remains the same. In this framework, the process for good IAQ achievement is shown through these stages as seen in Figure 6.1.

6.2 Leadership and Communication to ensure good IAQ

Commitment from the client and the lead consultant. Therefore, the implementation of IAQ strategies has to come from top-down and not down-up. The lead consultant must represent the interest of the client to ensure the achievement of the owner's project requirements (OPR) in the brief. It is the job of the lead consultant to find the right commissioning authorities if the quality assurance control requires a specialist. The IAQ requirements in the brief document has to be defined out clearly, because it is the document upon which the performance/success at design, construction and operational and maintenance stages will be benchmarked. In Kuwait, almost always, at inception as well as at other stages of the project, the building owner/client is more focused on time, cost, quality, and sometime schedules and programme, that good IAQ is not explicitly pursued. That is because of the lack of good IAQ awareness as seen in the findings from the last chapter. The result of this is; clients either compromise on good IAQ or assume its implied in the duties of the designer and contractor. If the client does not push IAQ as one or his/her major requirements most designers and engineers in Kuwait just prepare half-baked natural ventilation, sometimes hybrid ventilation designs that show that all the components are there, but in actuality, the components are not streamlined and/or the designs have little spacing, or there is a problem with access, or some component have been placed in the wrong place where they are now more of a danger to good IAQ than not. On the part of the contractors, most contractors in Kuwait build without making effort to close installed vents or even clean and commission after. Therefore, building owners move in to their houses thinking they have perfectly ventilated house, when nothing can be far from the truth. It is advised therefore, that the building owner make explicit, 'Good IAQ' requirements in the brief and emphasise it by communicating that focus to everyone on the project team at every project stage. According to ASHRAE (2009), *"Making the OPR explicit reduces the potential for costly misunderstandings. Defining the OPR in the pre-design phase gives the entire team a shared understanding of the owner's expectations and establishes unambiguous criteria for acceptance of the completed work."*

One of the many facts leaders of change have to face is the fact that most members of the team or organization have grown accustomed to doing things a certain and therefore, it may be hard unfreeze behavior (Hayes, 2002). According to Hayes (2002) *"unfreezing behavior involves alerting organizational members to the need for change and motivating or coursing them to let go of the traditional ways of doing things."* The client and the lead consultant (Architect) need to have to be firm, passionate, and have a serious commitment to achieving good IAQ and therefore, have to be firm on identifying the IAQ requirements in the brief and then monitor to see that the requirements are carried out.

However, in order for good IAQ to be achieved successfully, in Kuwaiti housing projects, the client and the construction professionals, especially the architect who is usually the client's representative, need to shift their attitudes and focus to designing and constructing with good IAQ in their agenda. Pushing the implementation of good IAQ practices and the identification of IAQ requirements at the brief stage will directly depend on the knowledge the building owner and the lead designer have about IAQ. The IAQ success on the project will then depend on how much the knowledge and the requirements are communicated and emphasized to the rest of the project team and contractor.


Strategic Definition
Preparation and Brief
Start
Client/Owner identifies the Architect as the IAQ commissioning authority
Owner and Architect to prepare the Project IAQ Statement of need
Architect educates the client/building owner on the benefits of an integrated project design process to achieve good IAQ
Statement of Need document
Assemble the integrated project team and adopt BIM as the design software and as the collaboration and data exchange platform
The client and the integrated project team prepares the owner's IAQ project requirement (OPR).
OPR
1
Concept Design
1
Develop the design concept using the OPR with the help of the integrated project design team
Value Engineering for IAQ which involves the selection of appropriate construction products and materials
Prepare the IAQ Basis of Design (BoD)
Provide IAQ inputs to the project schedule, sequencing and planning strategy
Review the IAQ Basis of Design (BoD) to ensure that it meets the OPR, and update specifications
Architect prepares the Concept design report for submission to Owner for approval
Concept Design report
Owner approval
No
Yes
Outline Planning Permission to Kuwait Municipality
Kuwait Municipality Planning approval
No
Yes
2

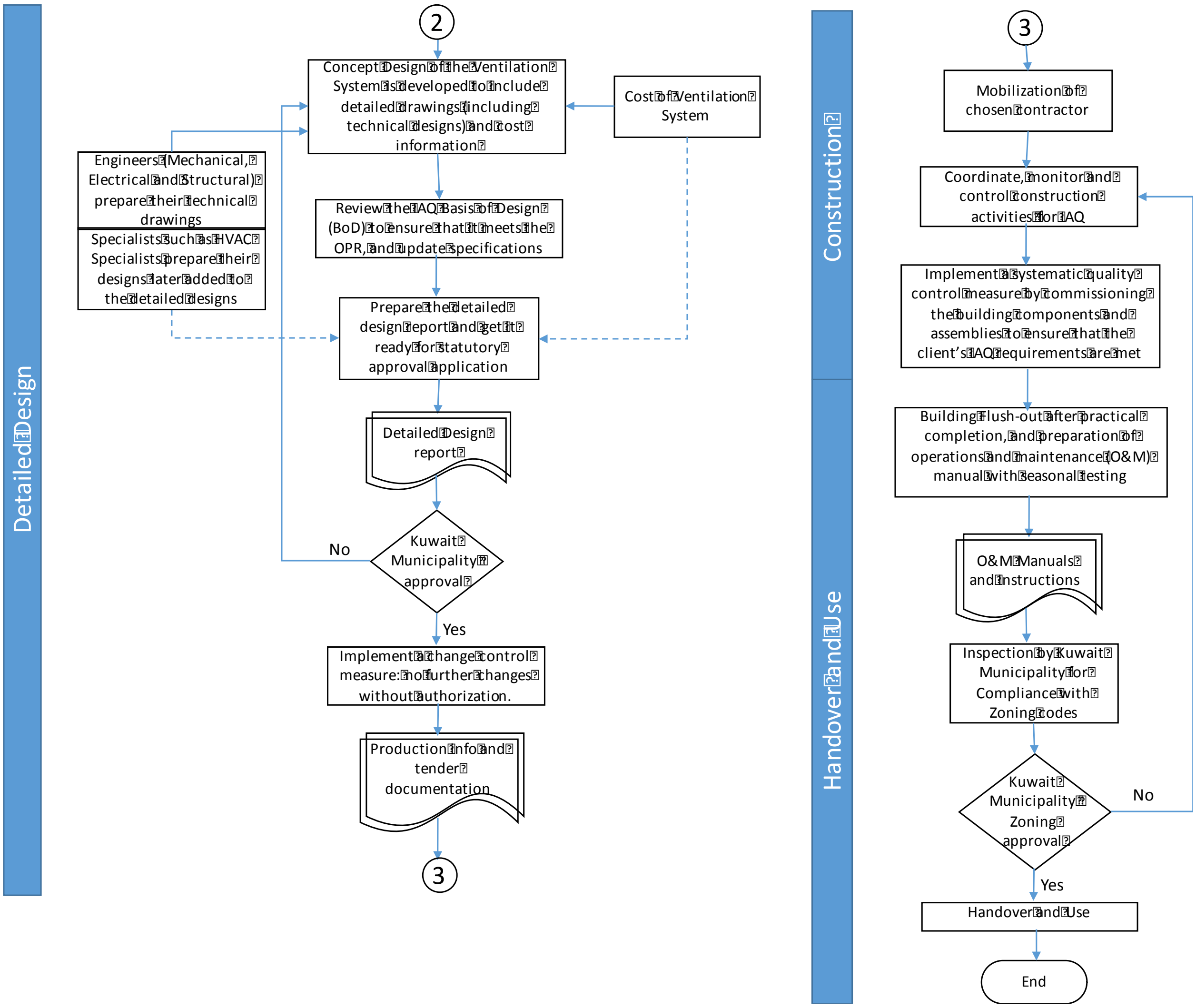


Figure 6.1: Flowchart of Framework for achievement of Good IAQ in Kuwait Housing Development at pre-construction, construction, and post construction

6.3 Strategic Definition

This is the first stage on the RIBA Plan of Works and in this context, it is the first stage when a Kuwaiti individual or a Kuwaiti developer decides they want to embark on a housing project. At this stage, discussions on the client's 'statement of need' and 'strategic brief' are held from which the 'preliminary business case' is developed. The client and his lead consultant, usually the architect, sometimes a project manager, give consideration to all the factors that can affect the envisioned project, including IAQ. The purpose of this exercise i.e. the strategic brief, is to strategically appraise the project, to consider alternative options – to decide whether the best approach to the project is a new build, an extension, relocation, or a refurbishment, whether the chosen site and surrounding location activities are fit for purpose or other options a better fit.

6.3.1 Quality Assurance

Here, the client does the necessary quality assurance and identifies the right person to lead the project execution and achievement of his/her objectives. In Kuwait, this lead consultant is usually the Architect. The client and the lead consultant then seat and ask important questions that will help them shape the scope of the project. The statement of need describes the owner's project requirements (OPR) in an outline form, which answers the question of whether the project should go on or not. According to Designing BuildingsWiki (DBW), Britain's construction industry knowledge base, the statement of need may include a description of the the need for the project, analysis of alternative options, the nature of the client, nature of client's operations, existing premises and likely future requirements, assumed budget (and the basis for the budget), assumed programme, as well as an assessment of the potential for future changes, amongst others.

6.3.2 Integrated Project Delivery Approach

The strategic considerations also include key Project Objectives such as 'good indoor air quality (IAQ)' as well as initial considerations for an integrated design approach i.e. assembling the project team; and Project Scheduling to facilitate not only the construction activities but also good IAQ. According to ASHRAE (2009), the day the owner/client/developer determines the need for a building is the day the building project scheduling needs to start. Therefore, questions need to be asked on timeframe, budget, purpose as well as the right project team to be assembled.

Given that Kuwait construction industry is new to an integration project team approach to designing and constructing a building, the education of the client on the need for integration has to start at this stage. Many clients will not understand why they need to involve consultants and other project team members early on on the project because that would mean paying them for that time as well. The cost factor is a major deterrent. However, if the project manager or architect educates and justifies the integrated approach by outlining the benefits as well as the cost of poor IAQ amongst other costs of not involving major players early on, many Kuwaiti clients would agree for the integrated approach to be implemented.

6.4 Preparation and Brief

The Preparation and Brief stage, is a very important stage because it is on the basis of the information collected here that the building will be designed. Therefore, it is imperative that the information gathered at the ‘preparation and brief’ be as accurate as possible in order for the concept design stage to be as productive as possible, and consequently achieve client satisfaction.

At this stage, the initial project brief should be written, and the feasibility studies and risk assessment, conducted to include; planning risks, programme and procurement strategy. The project brief is the document that defines the need for the development, the Owner’s Project Requirements (OPR), the budget needs, the required time of building occupancy needs to be determined. The project brief is developed from the statement of need, preliminary business case, and strategic brief, outline in the last stage – the Strategic Definition stage. In the second stage, Preparation and Brief, the business case is developed in greater detail for the preferred option after feasibility studies and options appraisals have been carried out so that a decision can be made whether to progress with the preferred option into the Concept Design stage. The business case may include, but not limited to; the owner’s vision, mission, and project objectives, feasibility studies confirming affordability, achievability, marketability, and profitability, of the project, as well as risk analysis, procurement options, design intent, schedules or programme, and financial forecasting. The document of the business case must be written in a clear and concise manner in a way that is easily understood even when read by different people of different backgrounds and professions (project team). It is also important the the OPR is written clearly and concisely at the brief stage. A concisely and clearly written OPR reduces the potential for costly misunderstandings and establishes a shared and unambiguous platform on which the entire project team reference the building owner’s expectations and the basis on which the completed work can be accepted (ASHRAE, 2009, RIBA, 2013).

Usually, Kuwaiti developers or building owners’ knowledge of good IAQ does not surpass a single requirement, that ‘the building must be properly ventilated.’ It is the responsibility of the architect to develop and expand that requirement further, which seldom happens. But now and again some developers do have some in-depth knowledge because of their experience. They may identify IAQ requirements with a bit more detail. Such as: air conditioning, moisture control, mold control, adequate ventilation and airflow, air filtration, humidifiers limiting the entry of outdoor and indoor contaminant sources, access for maintenance, contaminant exhaust, etc.

The project brief may include the following:

Table 6.1: Project Brief for Design and Construction items

Tasks	Items
A description of the client	• A description of the client's brand, culture and organisation • A description of the client's vision, mission and objectives • A description of the client's priorities and the criteria that will be used to measure success • Organisational structure and decision making processes • Changes to the client that the project will bring about • Interfaces with other projects • Client policies that may be applicable to the project (for example; transport policy, energy policy, natural ventilation policy, sustainability policy) • Client preferences for the project (for example; image, use of local materials, use of landscape etc.) and quality expectations (including health and safety, sustainability and design quality) • A description of the principles that will be adopted in the development of the design
Site information	• Building surveys. • Site surveys. • Information about ground conditions. • The location and capacity of utilities. • Access and other constraints. • Legislative constraints. • Existing planning consents.
Owner Project Requirements	
Spatial requirements	• Schedules of accommodation, areas and special requirements. • Schedules of users (including external users), their numbers, departments, functions, organisational structure and operational characteristics. • Spatial policies (for example open plan or cellular offices, daylighting requirements, temperature ranges and acoustic standards). • Required adjacencies, groupings and separations. • Zoning. • Circulation guidelines and identification of major circulation flows. • Phasing.

Technical requirements	• Structural strategy (columns and gridlines to be adopted, special loads, floor to ceiling heights). • Servicing requirements, including IAQ specialist requirements. • **IAQ requirements,** Comfort conditions and level of user control. • Acoustic requirements. • Equipment requirements. • Specialist requirements for furniture, finishes, fixtures and fittings. • Information and communications technology (ICT) requirements. • Requirements for specialist processes and plant. • Fire compartments. • Maintenance and cleaning requirements. • Likelihood of future change (for example staff numbers) and flexibility required. • Sustainability objectives and energy use targets. • Safety and security requirements. • Resilience to potential hazards or threats. • Waste and water management. • Pollution control. • Flexibility and future uses. • Durability and lifespan. • Other performance requirements. • Benchmarking information.
Component requirements	• Long-lead items. • Potential requirement for specialist design or specialist contractors design. • Cladding strategy and materials selection procedures.
Project requirements and other issues	• Planning requirements. • Outcome of any consultation processes. • Budget. • Project programme and key milestones. • Known risks. • Targets for post occupancy evaluation outcomes and other performance targets.

Source: Designing BuildingsWiki (2016)

6.4.1 Integrated Project Design

As the project brief is developed and increasingly becomes more detailed through the early design stages, its flexibility should increasingly reduce, and a form of change control procedures be implemented in order to prevent further changes without appropriate justification and authorisation (DBW, 2016). In preparing the business case, the lead consultant should solicit the services of some independent client advisers, such as accountants, business development managers, facilities managers, IAQ specialists IAQ commissioning authority, and other specialist. This calls for the integrated process. Therefore, the next step is to assemble the project team (design professionals, architects, interior designers, contractors, testing and M&E engineers, facilities managers, commissioning authorities, and others) and define each player's roles and responsibilities (integrated design process). At this stage, the lead consultant moves beyond educating the client for the need for integration and brings together the relevant players whose inputs and collective considerations and decisions will impact the design and good IAQ. The design platform and mode of communication, coordination, collaboration and data exchange should also be agreed. With the advent of Building Information Modelling (BIM), the software has proven to be adequate in design as well as a collaborative and date exchange platform for an integrated project team. BIM allows for clash detection, design interoperability and coordination of all designs submitted by the design team, as well as enable for any design deficiencies, errors, and inaccuracies to be spotted quickly and corrected. In the absence of BIM proficient project team, the Basis of Design (BoD) document should be sufficient for the project manager to track all the design concepts, calculations, decisions, product selection and applicable codes and standards used to achieve the project's IAQ requirements.

The need for an integrated process can not be over-emphasized. It is important that the project team is assembled since they will inform the the business case and the project brief. Granted that the prevailing project briefing, and design process in Kuwait is the traditional design process, where the different design elements are compartmentalized and linear rather than jointly designed (integrated) in an interactive way. The integrated process requires substantial commitment on the part of the client and the lead consultant to push the idea of good IAQ through an interactive process, by holding periodic meetings among relevant players in the project team to jointly design elements of the building that is common to them. The person responsible to ensure that this interactive process works properly is the lead consultant, project manager, or architect (in the case of Kuwait). The project team members to be involved early enough may include, but not limited to; the architect, mechanical and electrical engineers, IAQ specialist, HVAC specialist, quantity surveyor, facilities managers, lighting, interior design, and landscape specialists. It is the work of the architect to coordinate the team members and ensure that they communicate effectively and efficiently or the process fails and the building's good IAQ is foregone. A recommended way of making sure that the integrated project team is effective, is to have a start-up meeting where the lead consultant (architect) brings everybody in to discuss appropriate issues of: design coordination and integration, design interface for common data exchange and collaborative practices; BIM, CAD, and other data exchange platforms. Furthermore, the team should agree on communication lines, project documentation, ways of achieving good IAQ, agree on the programme, change control procedures, agree meeting schedules, discuss the project risks and their management, etc.

6.4.2 Commissioning of Owner's IAQ Project Requirements

Commissioning, is a systematic quality control procedure. It is mostly understood as a post construction activity in Kuwait. However, because of the integrated design and construction process, ASHRAE (2009) recommends that commissioning starts here, at the briefing stage. According to ASHRAE, commissioning *"is most effective and most cost-effective if it starts at project inception."*. This is because, the commissioning authority (the Architect or Project manager in the case of Kuwait context) can help *"the owner identifies and makes explicit all functional requirements for the project. Explicit documentation of the Owner's Project Requirements (OPR) reduces the potential for problems arising from different implicit assumptions about project requirements or failure to maintain focus on requirements as the project progresses."* On the other hand, if buildings are not commissioned properly, occupants may begin to experience deficiencies in the structure and failure of key systems such as ventilation systems. Furthermore, early commissioning ensures that all the major players are not off doing their thing in isolation which often results in disjointed and asymmetrical work. At the brief stage, the architect, who is usually the lead consultant, and also the commissioning authority, must help the client and ensure that all IAQ requirements are identified and included in the OPR because of the lack of IAQ knowledge on the part of most building owners in Kuwait. But the architect knows better because their profession and training even if, at the moment in Kuwait, the training in IAQ is not world class. Unless clients have had IAQ problems in the past, they would not have any knowledge of IAQ. Therefore, most client assume that because they've hired consultants (architects, engineers, contractors, and specialists) on their projects, IAQ should be achieved by default. In their mind, the consultants will design and construct to acceptable IAQ standards and regulations. But that is not always the case, otherwise, Kuwait would not be having an epidemic of IAQ issues at the moments; in both residential buildings and otherwise. The best strategy to achieve IAQ in buildings is to ensure that the project brief states the owner's project requirement (OPR) to includes all important functional requirements related to IAQ. According to ASHRAE guidelines 2009, the owner's IAQ requirements should fall within the following "eight IAQ objectives:

- Objective 1 – Manage the Design and Construction Process to Achieve Good IAQ
- Objective 2 – Control Moisture in Building Assemblies
- Objective 3 – Limit Entry of Outdoor Contaminants
- Objective 4 – Control Moisture and Contaminants Related to Mechanical Systems

- Objective 5 – Limit Contaminants from Indoor Sources
- Objective 6 – Capture and Exhaust Contaminants from Building Equipment and Activities
- Objective 7 – Reduce Contaminant Concentrations through Ventilation, Filtration, and Air Cleaning
- Objective 8 – Apply More Advanced Ventilation Approaches"

Commissioning cost is another issue the architect needs to consider since he is the person responsible to ensure good IAQ is achieved in the building. Now, since not every component of the building would be commissioned because of the high cost involved in doing that, the commissioning has to be prioritised according to the risk level. In other words, using a risk management technique, the architect and the project team identify which building component will be commissioned whose catastrophic or partial failures will result in loss of life, human health problem, or at best high financial cost in repairs. For example, too much moisture in the air due to moisture damage or failure to the HVAC to control humidity in the indoor air, is one of the major causes of sick-building syndrome problems. Therefore, commissioning of the "building enclosure" should be a major requirement in the OPR and of a high priority for IAQ commissioning at the construction stage. This process of choosing what component to commission using risk management method, goes on until the client and the architect agree that the exercise will satisfy the owner's project requirements.

6.4.3 Scheduling and Sequencing of works

The integrated process also helps with the Special Project Scheduling needs. The earlier the project team is assembled the earlier schedule input from all team members is available (ASHRAE, 2009). Critical to effective and efficient IAQ management is when the planning phase is started much earlier in the project and it's better to be started here at the project briefing stage. The planning should be constituting scheduling and sequencing of the building project in order to tackle any envisioned problems. The best way to tackle the problems and/or tasks of scheduling and the achievement of good IAQ, is with the aid of an experienced and knowledgeable project team, whose involvement must have been from the very beginning of project inception. The lead consultant (architect), who is also the commissioning authority acting on behalf of the client, along with the other team members, should also provide input on the project scheduling to ascertain that the process incorporates steps necessary to achieve good IAQ in the buildings. For example, specific dates for installation and inspection, and the proper sequencing or work to avoid moisture damage.

ASHRAE (2009) states:

"Involving the whole project team early in the scheduling process could also lead to proper construction material selection to match the sequencing and scheduling of the construction activities, eliminating long lead time for products for a short construction schedule or allowing the selection of the proper materials that will accommodate the required sequence of construction activities."

At the project brief, the architect should identify commissioning activities that need to be incorporated with the project programme of schedule. According to ASHRAE (2009), these activities should include, but not limited to, "the following:

- Design phase commissioning workshop
- Commissioning of the design review and issue resolution
- Commissioning of the review of value engineering
- Preparation of commissioning specifications for inclusion in the project manual
- Submittal review
- Pre-construction meeting
- Construction and testing of mock-ups
- Construction observation/on-site inspections while assemblies are open
- Testing, adjusting, and balancing (TAB) verification
- Functional testing"

6.4.4 Quality Assurance

Starting the quality assurance/control procedure at the project brief stage is more cost-effective because "it is much less expensive to correct problems in the design phase while they are still on paper than after submittals have been approved, materials and equipment have been received, and construction is under way (or even complete)" (ASHRAE, 2009). Below is a figure showing the decreasing ability of the project team to influence outcomes and the increasing cost of action as project proceeds from design, construction, to operations.

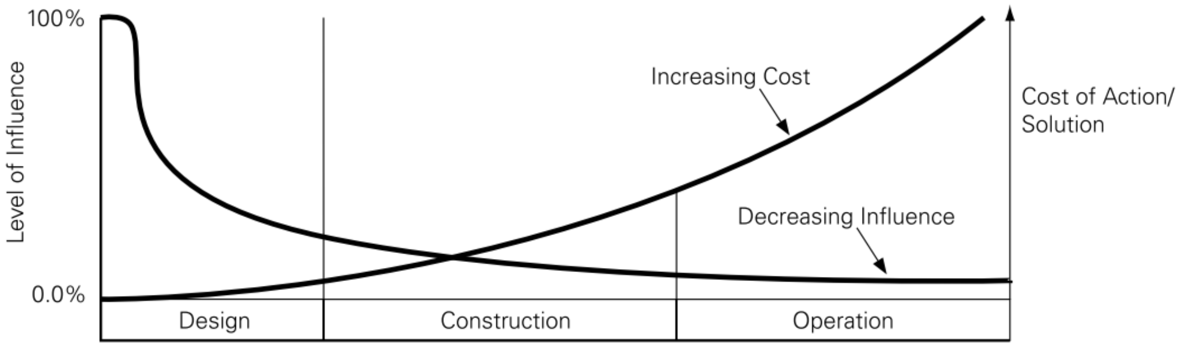


Figure 6.2: Decreasing ability to influence Outcomes and Increasing Cost of Action as Project Proceeds (Source: ASHRAE, 2009)

When much of the decisions are made earlier on, from the project inception/briefing stage, in an integrated form, that is, jointly with the other project team members, the more influence the decisions will have on the outcomes and the less it will cost to rectify changes. But when decisions are made later and later on the project, the less influence the decision will have on the outcomes and the more expensive it will be to rectify the changes. It is important for the major players, not to only give their inputs and IAQ requirements but also say why they want them included so that others as well as the designers can propose other alternative solutions and the best one can be chosen.

Respondents differed concerning to right time to include IAQ and HVAC specialists at the brief preparation, design, or construction stage. However, they later all agreed that the IAQ requirements have to be spelt out clearly early on the project. They also acknowledged that integration is necessary. The project team has to be brought in at the brief preparation stage but most especially IAQ specialist, HVAC specialist, and facilities managers as far good IAQ is concerned. These three specialist should be engaged as soon as possible for them to give inputs on; the preparation of the design brief, project programme and selection of alternative materials (value engineering) as well as design alternatives, review of detailed design before the contractor moves to site. This is necessary so as to reduce abortive work and make cost savings in the process. The level of influence that can be made on the design greatly decreases as the project progresses into further stages (ASHRAE, 2009). It is imperative that the major design players, (especially the IAQ specialist, HVAC specialist, and facilities managers) give the architects enough accurate, detailed and technical (both quantitative and measurable) information for them to produce the best designs that is fit for purpose and with good IAQ.

6.5 Concept Design

The concept design stage is generally, the stage after 'project brief' which in turn is derived from the feasibility studies and options appraisals report. After the project brief, and the brief document is handed over to the designers, they should then accurately represent the owner's project requirements on the designs by showing how all the components of the building fit together. This may be a presentation of multiple design alternatives that will lead to the development of the concept design. Integration is also important at this stage because all the major players especially those whose inputs affects IAQ, as far as this research is concerned, need to be present to ensure that the IAQ requirements stipulated in the brief are actually reflected in the concept designs. They also need to be present to evaluate the various design alternatives, assess their cost, feasibility, buildability, and effectiveness as it affects the owner's purpose as well as good IAQ. The inputs of the IAQ and HVAC specialists and facilities managers on the different mechanical, electrical, structural, and natural systems to be utilized later in the design of the building, are very important and must be documented in the concept design report that the designers will later prepare.

6.5.1 Integrated Project Design

The lead consultant along with the integrated design team should develop the design concept, outline specifications, cost plan, procurement method, programme and just-in-time logistics, and planning strategy. It is also at this point the the Basis of Design (BoD) is produced. The Basis of Design is a document that stipulates accurately, the *"concepts, calculations, decisions, and product selections used to meet the Owners Project Requirements and to satisfy the applicable regulatory requirements, standards, and guidelines"* (ASHRAE, 2009). According to ASHRAE (2009), "the BoD should include:

- System and assembly options, its description, and the selection reasoning
- Specialists Consultant, engineering, and architectural guidelines, codes, standards, and regulations for design developed by the design team or others

However, in Kuwait housing, all of these may be necessary as these housing developments are not only simple single residential houses but also big residential villas and high rise block(s) of flats. This level of detail is definitely required. In other words, a simple ventilation design system may suffice for a simple bungalow, but would not be enough for the big villas and multi-block of flats. Furthermore, this framework is proposing that the final user's operation and maintenance capability (budget, FM skills and size) be measured and the ventilation system design must be proportionate to that capability. The facilities managers will usually help in this respect provided that they are involved early on in the integrated project team. Because of the lack of knowledge and awareness of good IAQ requirements amongst Kuwaiti residents, the design of the ventilation system must be simple, in terms of operation and maintenance, more forgiving, that is, durable, and have easy access.

In Kuwait, hybrid ventilation systems (a combination of natural and mechanical ventilation) seem to be the predominant design for effective IAQ. Choosing the right HVAC system design is central to a building's indoor air quality (IAQ) performance because it will affect building's thermal comfort and energy use. The architect (lead consultant) and the integrated project team must decide the best HVAC system suitable for the building design and purpose. Some factors to consider when deciding on the system are:

- space limitations
- energy efficiency
- costs,
- acoustic impact
- heat resistance (due to Kuwait's high temperatures)
- robustness
- flexibility
- high particle filtration control (due to sand storms in Kuwait)
- controllability, redundancy
- space humidification control
- pressurization control (to reduce the risk of condensation and mold growth), etc.

It is possible that a number of system options or alternatives will appear appropriate, and so, it's the duty of the integrated design team to make a detailed analysis of the options and select the best one that meets the owner's project requirement (OPR). In order to do this successfully, the integrated project team has to be informed and educated about the HVAC systems. In Kuwait contexts, not many of the project team will have prior knowledge therefore, it the responsibility of the lead consultant (architect) to have the HVAC specialist educate the others on the various options so that everyone can make an informed decision. This is even more important when there is no clear favourite between the options, therefore, systems have to be systematically compared in order to select the optimum HVAC system that meets the IAQ requirements. According to ASHRAE (2009), while considering the best HVAC system, the analysis must consider the project's constraints/expectations or opportunities. These include:

- Site/local environmental opportunities (e.g., are the site and building program suitable for a mixed-mode ventilation system?)
- Budget constraints both in terms of first costs and operating costs
- Client/end user expectations
- Sustainability targets and rating systems
- Applicable codes and design standards
- Required flexibility (ability to add zones and plant capacity, etc.)
- Building constraints, such as floor space for equipment, maintenance space, plenum space, and roof space
- Heating, cooling, and humidity loads and space set-points
- Smoke control
- Maintenance capabilities and cost
- Other constraints

The lead consultant, who serves the interest of the client, must review the basis of design report on a regular basis to ensure that it meets the owner's project requirements. This review should include: general quality review, specifications, constructability and level of coordination between project team members. The design review should also be done every so often through out the project to reflect the development of the design.

6.5.2 Commissioning of Concept Design

Commissioning at the concept design stage requires the architect (lead consultant and commissioning authority) to review the Basis of Design (BoD) prepared by the design team and ensure that it meets the owner's project requirement regarding IAQ as well as other functions (OPR). Aside reviewing the BoD, the architect should; update the specifications as well as other important documents to include 'commissioning instructions', prepare a construction checklist, and training requirements. Here, (concept design stage), the architect and the project team need to ask questions of how the building is to be ventilated, on how to achieve thermal, and acoustic or noise control. The satisfactory answers to these questions should be effected on the concept design drawings and documented on the concept design report. In Kuwait, the villas as well as the block of flats housing developments are usually ventilated using a 'hybrid ventilation' strategy – that is, a combination of both natural and mechanical (HVAC) ventilation systems. It is imperative the that design of the ventilation system is not only to be fit for purpose but with some flexibility to allow for changes that will accommodate increased capacity. This flexibility can either be in the form of *"simple controls adjustments or installation of additional equipment to obtain additional ventilation as needed"* (ASHRAE, 2009). According to ASHRAE (2009), "the following details should be identified on the design concept drawings:

- Outdoor air intake locations
- Local exhaust and building exhaust locations
- Air cleaning and filtration
- Space air distribution
- Building pressure control
- Internal pressure control
- Microbial control
- Moisture and humidity control"

As a part of commissioning, the integrated project team should discuss how IAQ will be protected, enhanced, maintained, measured and documented during construction and occupancy stage. The answers to these questions should be documented as part of the construction stage commissioning.

6.5.3 Scheduling and Sequencing

In addition, scheduling and sequencing of construction activities identified in the project brief should be updated. This the exercise of making sure that construction materials and products that are selected be scheduled to be delivered just-in-time (JIT) to prevent any contamination or damage such as wetting. In addition, sensitive materials or products must be stored to prevent wetting or dust infiltration. If these, happen, then adequate time should be provided for cleaning the dust off the material or product and for them to dry properly. Starting the scheduling and sequencing earlier, i.e. from the concept design stage will ensure that the critical elements for IAQ management are incorporated in the programme. The scheduling must allow adequate time to complete the construction activities. Here, the integrated project team should help in the sequencing by given calculated timescales for completion of activities. As usual on a construction project, there may be unforeseen circumstances that may cause delays that may disrupt the schedule, therefore, the schedule must be monitored and updated regularly through out the project. Adequate time-scales must be given to each construction activity to be completed because a rushed project will almost always lead to poor IAQ in the building. In other words, completion on time doesn't always mean achievement of good IAQ.

Furthermore, a proper value engineering exercise should be carried out with scheduling and sequencing in mind, so that materials and products that can be damaged by rain water or moisture are not scheduled for use or installation before the building is tightly closed and protected from wetness or moisture damage. This is the point where the project team along with the client evaluate the selection of material and products to make sure that they are fit for purpose as well as meet the IAQ requirements. The integrated project need to address questions of how the materials and products selected will affect thermal comfort, lighting, and IAQ needs. To make the right decisions on materials and products during value engineering, the integrated project team should consider; first, the chemical or particles emission rate of the material or product, dust resistance in cases of sand storms, resistance to high temperatures since Kuwait has a very hot climate, and resistance to microbial growth in the case of moisture intrusion; and second, "the material's preventive installation procedures, in-place curing and flush-out" (ASHRAE, 2009). If this is not done judiciously, the project team may end up with materials with high pollutant emission, that will then compromise the client's IAQ requirement as well as incur high cost in future repairs. Although, most of these issues will be detailed in the 'developed design' stage, *"the earlier the decisions are made in the project phase the more influence the decisions will have and the more the costs of actions or solutions will be reduced."*

Integrated project team must include a facilities manager (company) that will participate in the planning, design, and commissioning of the building. The early involvement or participation of the facilities managers in the design, construction, and testing, will enhance the design and the achievement of good IAQ because they will provide input on how problems can be prevented before they show up at affect operations and maintenances stage. At the construction stage, the facilities managers benefit from seeing the details of the enclosure assemblies and the layout of the HVAC and plumbing systems to a degree that is often impossible after construction has been completed. According to ASHRAE (2009), inputs of the facilities managers should "include:

- access requirements
- sensors and connections required to enable operations and management staff to monitor performance;
- standardization of equipment and components that can reduce inventory, training costs, and the need for multiple maintenance procedures, thereby improving operations and management staff efficiency and reducing operations and management costs;
- owner directives driven by experience with product quality, repair response times, local parts availability, or other considerations;
- operations and management cost impacts of proposed value-engineering changes;
- realistic operations and management capabilities and limitations;
- operations and management documentation requirements and preferences;
- operations and management training needs;
- consecutive numbering of systems and equipment;
- consistent labeling of systems and equipment; and
- required adaptability for future changes and expansion"

6.5.4 Quality Assurance and Documentation

Lastly, the design team produces a concept design report (including further instructions) for the building owner or developer which captures the basic design concept for the preferred option for which the owner may choose to pursue further to 'detailed design' or developed 'design stage' (Designing BuildingsWiki, 2016). At this point, the development of the project brief, continues. However, once the final concept design report is prepared, the project brief should be frozen to avoid any unnecessary alterations or changes to the recommended and preferred design option.

At this stage, RIBA (2013) suggests that an outline planning permission can be submitted at the concept design is complete. Designing BuildingsWiki, (2016) explains the purpose of outline planning applications. They state that *"outline planning applications can be used to find out whether a proposed development is acceptable to the local planning authority, before substantial costs are incurred developing a detailed design. Outline planning applications allow the submission of outline proposals, the details of which may be agreed as "reserved matters" applications at a later stage."*

However, in most cases, at the concept design, detailed drawings of the IAQ ventilation system are not prepared. And therefore, Kuwait municipality may not able to assess IAQ compliance. Therefore, this research proposes that a second application be made to Kuwait municipality at the 'detailed design' stage but this time, its for 'statutory approvals.' The main approval required is 'building regulations' approval. The application should be made after the production of 'detailed designs' also known as 'developed designs'. Kuwait municipality should take advantage of this process to check compliance of the project to the building regulations of Kuwait.

6.6 Detailed Design

This is the stage where the Concept Design is developed to include detailed drawing of the architectural, structural engineering, building services designs including design input from specialist sub-contractors and suppliers, outline specifications, and cost information. At the end of this stage, the lead consultant (architect and commissioning authority) must check that the designs are complete, have met the client's project requirement, and that the design cost information are aligned to the project budget. By the end of this stage, it is expected that all the components of the building have the correct dimensions and are coordinated and described to show how they all fit together. Designing BuildingsWiki (2016) states that *"Detailed design should provide sufficient information for applications for statutory approval to be made."* Among the information that must be provided is information on how the building is to be ventilated whether only natural, only mechanical, or a hybrid ventilation system that uses both natural and mechanical ventilation systems. With the geographical location nature of Kuwait City (outdoor heat, and dust) and the many number of outdoor pollutant sources, residential buildings are generally given a hybrid ventilation, utilising both natural and HVAC systems. For example, the information submitted to Kuwait municipality must include ‘air conditioning’ information, describing how the temperature, humidity, and the quality of air in every room in going to maintained at the right levels to give comfort to occupants. Information on ‘air change rates’ must be included as well. The air change rate is the number of times the air in a room is replaced by fresh or treated air per hour or litres per second.

6.6.1 Integrated Project Design

Is important that while the design team develops the design further, the technical aspects of the design are development concurrently. By the end of Detailed design stage, designs by specialist contractors, such as IAQ and HVAC specialists, also need to be fully incorporated in the design. This research recommends that both developed design and technical design be categorised into one – detailed design. This is because both can run simultaneously and prepared together and made ready for statutory approval submittals to Kuwait municipality. Though sometimes technical designs may continue all through to construction stage, it is imperative that enough technical information be collected at the detailed design stage to get the statutory approvals.

The documents that would need statutory approvals from the Kuwait municipality are: structural safety, fire safety, ventilation and IAQ, resistance to contaminants and moisture, toxic substances, resistance to sound (acoustic comfort), sanitation, hot water safety and water efficiency, drainage and waste disposal, heat producing appliances, protection from falling, access to and use of buildings, and electrical safety (Designing BuildingsWiki, 2016). This is the chance the municipality has to check compliance of IAQ regulations and codes – at this point, there are no codes and regulations therefore, this research proposes that the municipality develops its IAQ codes and regulations and the criteria upon which they can check compliance.

6.6.2 Commissioning of Detailed Design

The IAQ specialist, HVAC specialist, and facilities managers should be involved in the brainstorming at the meeting and workshops in order to enhance design process by giving their inputs on the different alternatives designs, materials and products. At this stage these team members should also review the designs using checklists to make sure that the designs meet the owner's project requirement as well as statutory standards. Among the documents that these specialists especially facilities managers should review are: the architectural layouts, waste management systems, water distribution layout, access control systems, lighting layouts, mechanical, electrical and plumbing layouts etc. the facilities manager and the specialist subcontractors should check for appropriateness of material, equipment, sustainability aspects, energy saving, power and water consumption, utility services etc. (Jawdeh, 2013).

The architect should coordinate the integrated project team as well as the specialist subcontractors to prepare and submit their technical designs. At the beginning of this stage, the architect, as the lead consultant, should call for a detailed/technical design meeting of the all the team members including the specialist subcontractors, and responsibilities shared amongst them. It may help for the architect to prepare a design responsibility matrix, which shows the duties and responsibilities of the project team members. It is also important that the architect prepares the matrix in a manner that shows not only allocation of design responsibilities but also the order or sequence in which they should be prepared, which also sets the tone for the sequence of activities during construction. For example, a proper coordination of technical designs should show that ceiling tile grids must be installed before light fittings, smoke detectors and sprinklers can be fitted on/through them.

The technical designs along with the architectural, structural and electrical and mechanical services designs, and specifications, at the end of this stage, must show how all the building components fits together to provide a comfortable and well meaning environment for the future occupants. The lead consultant (architect and commissioning authority) should undertake regular reviews of the designs and specifications to make sure that there is proper integration between the technical designs. The facilities managers must also review the drawings before they are passed on to the contractor to ensure that all necessary facilities management requirements and specifications are incorporated. The client and lead consultant (architect) must make sure that enough information is supplied to ensure smooth sailing when documents are submitted for statutory approval to Kuwait municipality.

After detailed design is done, the lead consultant, with the approval of the client, should put a change control procedure. In other words, freeze the design and specification, before setting in motion the preparation of production information and tender documentation. The production information should be prepared by the architect and his team, which shall include best practice guidance on how the building(s) are to be constructed. It should include, but not limited to: design drawings, specifications, bills of quantities, schedule and sequence of works, etcetera.

6.6.3 Scheduling and Sequencing

The sequencing and scheduling of works, need to incorporate an IAQ project plan that addresses activities during construction that could affect the achievement of good project IAQ. In other words, IAQ should be included in the project schedule. The architect must make sure that the contractor pays attention to the IAQ project plan, include IAQ in the agenda at site meetings, and emphasize the need for achieving good IAQ on the project to the rest of the subcontractors.

If building information modelling (BIM) software is used as the design platform as well as the integrated data exchange interface between project team members, then BIM will aid in the automatic preparation of all the elements of production information; drawings, specifications, programme and even cost; from the coordinated designs, resulting in a reduction in errors, and in turn, costs savings. The tender documentation on the other hand, incorporates, but not limited to, the production information document, preliminaries, contract form and conditions, building information modelling (BIM) requirements, tender invitation etc.

6.7 Construction

6.7.1 Integrated Project Delivery

After the tender stage and a contractor is awarded or selected, the successful contractor receives and the production documents, and moves to site. The contractor builds according to the construction programme and the lead consultant (architect) monitors the construction process and respond to any design queries to ensure that the building is built according to the designs and specifications. Although the contractor takes over at this stage, the integrated design team, which includes the major players responsible for inputs on achieving good IAQ: the IAQ specialists, the HVAC specialists, and the facilities managers should stay on at the construction and attend site meetings so that they can resolve any challenges or problems that may arise regarding IAQ. In addition, by being on site and watching the installations of systems, and seeing the layouts of ducts, cables, access etc., it will better inform them during maintenance and repairs at the post-construction stage.

Within the production information documents that the contractor received at the end of the detailed design stage, is the IAQ project plan which outlines times for laboratory and functional testing on site, periodic inspections during construction, and training and development. It is critical for IAQ that the schedule gives ample time for activities to finish and dry before moving on to the next activity to prevent moisture, mold, and contamination problems. A perfect example of improper scheduling is given by ASHRAE (2009), and it's a case where the HVAC system is installed and operated during construction, thus allowing for construction dust and debris to be sucked into the machine and/or, ducts, thereby contaminating the system. As such, good IAQ is compromised. It must be made explicitly clear to the contractor to protect ductwork by sealing both installed and uninstalled ductwork to avoid dust and debris to be collected in them during construction. Most contractors in Kuwait do not pay attention to duct work. It is imperative that the architect emphasize the need for good IAQ to the contractor.

6.7.2 Scheduling and Sequencing

In the case of delays which has resulted in the project being late on its completion time, the project team may decide to expedite activities on the schedule. However, when doing so, it is imperative to protect the areas important to IAQ. At the meetings held to discuss compression of schedules, questions regarding its IAQ impacts need to be asked and answered. This should be on the meeting agenda. Activities that can not be compressed such as commissioning and functional testing must not be skipped. It must be allowed to go on on its time even if that would mean going over the completion date. IAQ must not be compromised because the health of people is at stake, not to mention the cost of repairs that the owner might incur. In situations where the building under construction needs to be cooled, ventilated, heated, or (de)humidified, to give workers comfort and enable them to be productive, the contractor must not use the permanent HVAC system just installed. The contractor should utilize temporary HVAC equipment for such purposes. The installed permanent HVAC system, even if it has filters, must not be used during construction to avoid the introduction of moisture, dust, dirt, and debris into the HVAC system.

6.7.3 Commissioning of construction activities and assemblies

Commissioning is important and therefore, the contractor must avoid closing up pipe and wall leaks before functional testing and inspection commences. At the end of detailed design stage, the architect should produce an IAQ checklist for the contractor's use, with which he/she can verify that they have installed the correct components. According to ASHRAE (2009), *"the checklists are supplements to the drawings and specifications and are intended to convey requirements in simple language, help contractors understand quality expectations and do their work correctly the first time and reduce punch-list items, rework, and call-backs… Construction checklists should be as short as practicable and the questions should be clear, specific, and wherever possible worded such that a "yes" response indicates compliance with requirements and a "no" response indicates a deficiency"*

The contractor must comply with the design to provide adequate access to systems for the facilities managers' use. Also enough time should be given to inspection of the systems. It is the responsibility of the architect and the project team to monitor compliance during site visits. To ensure that the contractor is working according to the approved designs, specifications, and client's requirements including IAQ requirements. The architect's inspections should either take place at milestones, which is according to the programme. That is, inspections of works or assemblies which are critical; to the start of another work, or to the installations of another assembly. This could be works that will be inaccessible after the next works starts, or works that need to covered such as, radon mitigation system before the concrete slab is poured. The architect must inspect and test these works/assemblies before they are covered or become inaccessible. Random checks or inspections are also permitted just to keep the contractor(s) on his/her feet. The architect should use the checklist as a guide to verify that items have been installed according to the owner's project requirement (OPR). The architect must raise queries or architect's instruction (AI), where the contractor has deviated from the drawings or client's requirements. The architect must also ensure that the contractor is using the checklist regularly to check that their works are in accordance with requirements and that the works are being signed off by responsible parties.

Given that not many Kuwaiti trades workers are familiar with commissioning, therefore early training, communication and coordination of contractor and subcontractors is critical for successful implementation of IAQ procedures in the construction process. The pre-construction meeting maybe the ideal place for such training and to address the timing and *"content of submittals, checklist procedures, functional testing procedures and contractor* *roles, retainage related to functional completion, and specific issues that may affect IAQ such as protection of equipment and components during storage, temporary use of HVAC equipment, and preservation of access for maintenance when installing other equipment."* (ASHRAE, 2009). The architect and his team have the responsibility of developing the functional testing procedure which will verify that the performance of the installed system, or assembly, and the interactions therein are in accordance with the project requirements. Functional testing must be completed before handing over. The construction checklist verification and submittal reviews, that took place during the construction process, are only preparations and measures to ensure that the assembly, system, component etc. gets a pass at the functional testing stage.

From the findings, some respondents suggested that the facilities management team, should participate in the testing and commissioning process because it will help them understand the actual building components' performance, which will enable them maintain the building more effectively and efficiently at post construction stage. This suggestion is in line with ASHRAE guidance on the role of the O&M's staff in *"facilitating effective operation and maintenance for IAQ"*. At the construction stage, facilities managers have a number of roles to play during commissioning and testing. They are: to ensure that the fitted or installed equipment/system is fit for purpose and is in accordance with the owner's project objective (OPR) to aid in the preparation of the operations and maintenance (O&M) manuals by ensuring that every asset and equipment is listed and the drawings are accurate, finally, to facilitate the legal process during handing over stage.

6.8 Handover and Close Out

6.8.1 Building Flushout

If adhesives were used and paint work is done or furniture has been moved in, it is important for the integrated project to give ample time in the schedule for building flush-out. The building flush-out is where harmful chemicals emitted by adhesives, paint or furniture works are removed from the building. Another thing the client's lead consultant (architect) can do is to obtain the chemical emission profile ratings of the adhesive, paint, furniture, or any product for that matter, from the manufacturer, and conduct the flush-out based on the ratings.

In Kuwait, flush-out will usually be done using outdoor air alone. Depending on the location in Kuwait, the outdoor air is full of pollutant, and really hot, thus the indoor comfort is compromised. However, after the flush-out, the installed HVAC system should be prepped for decontamination, or purification of the air. The system should also restore the comfort in the building be introducing cooled air. In other areas, the outdoor air might be sufficient for the building flush out without the use of the HVAC system.

6.8.2 Training of Client/Occupants

In addition, it is expected that the participation of the facilities managers during design would have considered the final user of the building and their operation and maintenance (O&M) capability. Most Kuwaiti residents are not familiar with O&M and therefore, need the ventilation system is easy to operate and maintain. On slightly complex buildings with complex ventilation systems, the project team, with the help of the facilities managers, must provide O&M documentation explaining how the system is to be operated and maintained for optimum output. Cases where the facilities manager is not familiar with the system, substantive training must be provided, emphasizing how systems need to be operated and maintained to achieve their design intent. In addition, the final users must be trained on how to operate the system and given instruction on how to call for help in the case of a breakdown. According to ASHRAE (2009):

"O&M training needs to explain the design intent of key systems, their intended performance, and how they need to be operated and maintained to achieve that performance. Training materials need to be included in the O&M documentation and need to provide enough information so that a new operator using them for self-directed study can understand how to operate the systems properly."

The facilities managers must schedule seasonal checks, cleaning and/or maintenance of the HVAC system according to the manufacturers recommendations in the instructions manual. Also, any warrantee issues must be sorted out quickly by lead consultant to ensure that the system performs effectively and efficiently as advertised. The lead consultant (architect) must continue to provide additional support to the facilities managers so that they continue to meet the owner's project requirement.

Before, handover, Kuwait municipality usually inspects the completed building for compliance with zoning and statutory codes and standards. This framework proposes that good IAQ compliance must be part of the checklist of the state inspection officer(s). Any building found with inappropriate of inadequate ventilation system must not be signed off. The client, and his team must be asked to fix the problem before handing it over to occupants. If the problem is with design, the architect must re-design the ventilation system to fit state requirements. If the problem happened at the construction stage, the contractor must fix the faulty work until it is satisfactory to the Kuwait municipality inspection officer. No matter whose fault it is, this type of change may cost the client a lot of money. That is why it's important to get it right from the first time, both at design and construction stages. Once the state officer is satisfied, the building is signed off and opened for occupants to move in.

6.8.3 Operations and Maintenance documentation

Preparation of manuals, documents and reports for the facilities managers' use is very important. This documents are also known as operations and maintenance documents. According to ASHRAE (2009), the operations and maintenance *"documentation is the mechanism by which the project team provides enduring guidance to the facilities staff as to how the building and mechanical systems must be operated and maintained."* The O&M documentation should contain the OPR, applicable codes, regulations, and standards; it must contain the design intent of the key systems, the rationale for the choices made or why they were selected, and how they to be operated and maintained in order to meet the design intent. The explanation of why certain systems were chosen is necessary because some facilities managers may decide to change systems or parts of the system to reduce maintenance cost without knowing why they were chosen in the first place. For example, a building might be located in an area with high outdoor ambient levels of fine particulate matter, and so is fitted with high rated filters. But this filters are usually on the costly side. So in order to reduce operating and maintenance cost for they occupant, the facilities managers, not knowing the reason for fitting the high rated filter, may switch to a less efficient filter, and in the process compromise the IAQ of the building. This happens especially when the facilities management company used at the occupancy stage is not the same as the one that participated in the design and construction stage, Providing O&M documentation is not the usual practice in Kuwait must be done if good IAQ is to be maintained during occupancy stage.

6.8.4 Training and support for facilities managers

Most facilities managers do not have training in engineering or architecture, therefore, forming part of the O&M documentation, should be the Basis of Design (BoD) document because it has detailed IAQ design specification which the facilities managers can study to help them provide the optimal IAQ. For example, within the basis of design (BoD) is the HVAC heating and cooling parameters, number of occupants (assumed) to be in a given area, ventilation rate per unit area, and/or ventilation rate per occupant. These, design parameters aid the facilities managers to know the required outdoor airflow rate needed to provide the IAQ and comfort levels for occupants. Unfortunately, in Kuwait facilities management training focuses on the large most visible part of the ventilation system, which is the HVAC unit itself. As against training on the whole ventilation system, BoD; air flow rates, heating and cooling exchange, ductwork (in in large residential block), OPR, building systems equipment and assemblies, etc. the training is sometimes conducted very briefly and in a noisy environment such that participants leave the training not able to remember much. Thus, training participants should be given little pamphlets or prints of the presentation documenting all the topics discussed in the training.

The framework is not definitive but it provides useful guidance and information for Kuwaiti construction professionals and future building owners on the importance of achieving good IAQ: the importance of early preparation and documentation, the importance of regular inspection and/or commissioning, and the importance of educating facilities managers and occupants. It is the desire of this research that this framework is adopted as soon as possible to control and reduce the current IAQ problem Kuwait facing, and enhance the health of people while saving cost to occupants and the government. It is also the desire of this research that the government invest time and money to generate application IAQ standards, codes and regulations for Kuwait, as well as enforcement procedures.

Framework for achieving good IAQ in Kuwait Housing Developments

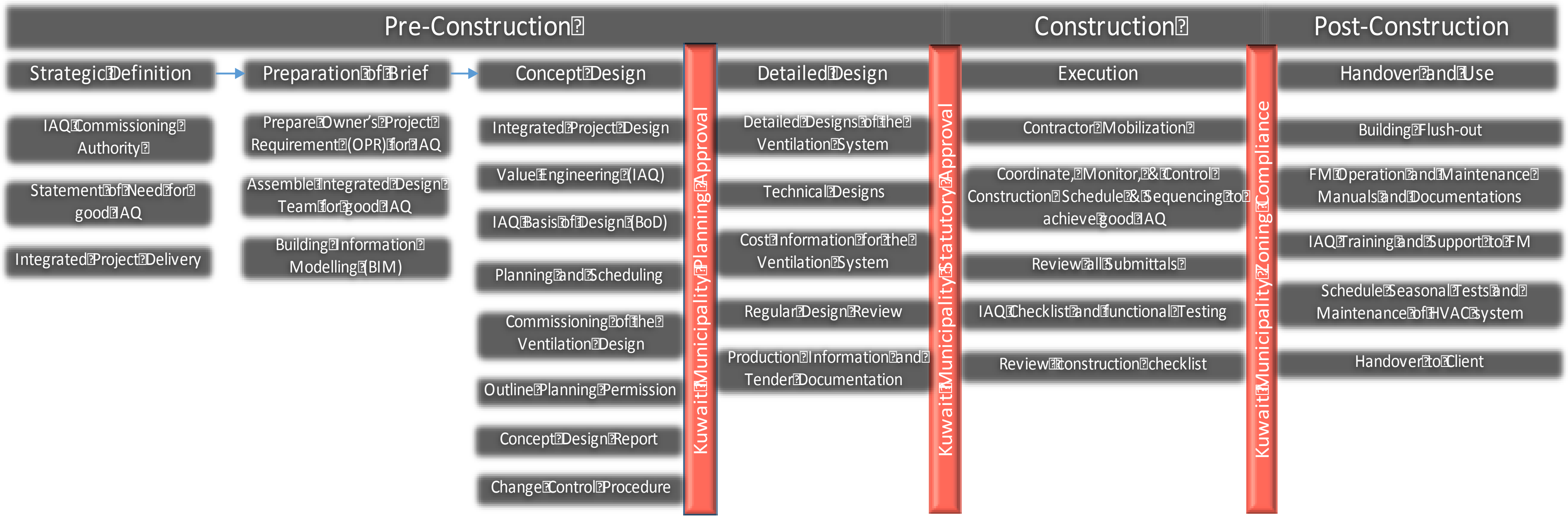


Figure 6.3: Framework for Good IAQ in Kuwait Housing Development

6.9 Summary

Although Kuwait currently does not have IAQ standards and regulations, it is possible to achieve good IAQ based on the proposed framework. However, there has to commitment on the part of construction, government, and clients (developers) to make a priority on project. Creating awareness amongst residents of the harmful effects of poor IAQ and the many benefits of health and increased performance of good indoor air quality. The change has to come from top-down rather than down-up.

Furthermore, the framework emphasizes the need for an integrated project team, where all the members that will be part of the project are assembled together early on on the project to give their input of design and construction. The client is advised to have the; architect, mechanical and electrical engineers, facilities manager, IAQ specialist and/or HVAC specialist as part the integrated project design team. The nature of the duties of these team members that influence IAQ changes depending on the stage of the project. The facilities manager, IAQ specialist and/or HVAC specialist assist the client in shaping his/her IAQ requirements and then collaborate with designers to make sure that the requirements are effected in the drawing. They also review the drawings regularly to ensure accurate representation of the requirements. At the construction stage, they participate in meetings, testing and commissioning, and also watch the layout of assemblies to ensure operability and that the IAQ designs are constructed accurately.

The framework, structures around RIBA Plan of Works 2013, shows that at the 'strategic definition' stage, the client being serious about IAQ selects a quality assurance manager or commissioning authority, who is usually the Architect, to make sure that the client's statement of need, and project requirements are accurately collected and achieved. The preparation of brief comes next, and it's where the architect assembles the integrated project team and together the develop the owner's project requirement further, whilst preparing the full business case. Building Information Modelling is recommended for the design team to achieve interoperability. The architect must coordinate the designs and exchange of the design data through the BIM platform. The integrated design team develops alternative designs at the concept design stage and present the preferred option to the client who then approves the design before it is sent to Kuwait municipality for outline planning permission. After approval the integrated design team develops the designs including technical designs for statutory approvals and the design is finalised and sealed with change control procedure put in place. The tender documentation and production information is done for the selection of a contractor. The contractor constructs the building following the OPR and IAQ checklist. The architect and the contractor commission the ventilation system to ensure functional validity. The building is flushed out, and handed over to the facilities managers (FM). The facilities management documents are prepared, and training and support is given to the FM and occupants on how to maintain good IAQ.

7 CHAPTER 7| VALIDITY AND RELIABILITY

7.1 What is validity and/or reliability?

When a re-test of a test yields the same results, that test is considered reliable. Achieving reliability in natural and scientific research is very easy because the research is mainly quantitative. On the other hand, achieving the reliability in qualitative research is not hard but needs more diligence in handling or analysing the data in order not to misconstrue the information given by respondents. In interviews, simple description language is needed so as not to extrapolate more into the data analysis. In doing this, the result can be consistent and reliability achieved. Similarly, a method is also considered reliable is two or more people use it and obtain the same results (McNeill and Chapman, 2005; Gillham, 2005).

Validity on the other hand, is the usefulness of a research endeavour. A research is considered invalid if it is useless to people. That is, it adds no value. Researchers must make sure that their work is valid. Validation is required of both quantitative and qualitative research works, although in various forms. It may be important to say that validation in quantitative research is easier because it is easier to show objectivity in quantitative research. On the other hand, qualitative researchers have to strive harder to show objective analysis and interpretation rather than the researcher's subjective views imposed on the data collected. There are different forms evaluations for validation. In qualitative research, validation can be done through; rich and detailed description of the context and background of the research, member checking (Creswell, 2003), a thorough description of methodology of the research, triangulation of data collection, considering previous research works to see if the results of the present study is consistent with the previous one, rich description of the analysis and findings, presenting opposing information which increases credibility, and peer debriefing (Shenton, 2004; Jawdeh, 2013). Validity is achieved by one or a combination of the above mentioned. On the other hand, validation in quantitative research can be achieved through error levels, measures of statistics, and the use of the right instruments.

Furthermore, there are two schools of thought on the concept of validity and reliability in both qualitative and quantitative research. On school of though believes that validity can be achieved by the forms of evaluations mentioned above are required to prove validity and reliability in a quantitative and qualitative research finding. The other school of thought believe that while, these forms of evaluations may serve as the the proper framework for evaluation of quantitative research, the may be inappropriate for evaluating qualitative research. This school of thought is of the opinion that the aim in qualitative research is an in-depth understanding of a given context, which means it may be difficult and almost impossible to achieve consistency (reliability) of results or one general objective response from participants (validity) (Finlay, 2006). Consequently, generalizability in quantitative research is much easier because of its perceived objective nature and its ability to be extended beyond the small sample to a larger population. In qualitative research, objectivity is achieved when the results of the research can be transferred to another context or group of people.

7.2 Evaluation of qualitative research

There is a consensus on the criteria for measuring validity and reliability in qualitative research. Many qualitative researchers believe if the research work can show honesty and credibility then it is reliable. A more criteria for evaluating qualitative research as given by Lincoln and Guba (1985) are; credibility, credibility, transferability, dependability, and confirmability (Jawdeh, 2013). Credibility tries to answer the question; does the research make sense? If the research evaluator can say 'yes, the findings are true' then the research is said to be credible. Transferability is the ability of the research findings being successfully applied to a different context or sample. The research must be so detailed in such a way that the reader can say that the research can is transferable. Dependability on the other hand, is the provision of reliable documentation of the happenings of the research from start to finish; all the decisions made, methods, adopted, and even mistakes, which can later to examined by a external body. A research is considered dependable is this information can be provided. Confirmability corresponds with objective interpretation in quantitative research. It is a self-evaluation technique where the research provided results obtained using a different method of data collection and analysis to see if the results conform with the earlier findings (triangulation) or present counter opinion to see how critic-proof the research findings are.

Let's look at the various forms of evaluation used in this qualitative research to achieve validation and reliability.

7.2.1 Member Checking

As mentioned earlier, this is one of the strategies or forms of evaluating the validity or reliability of or a research finding in qualitative research. In member checking, is where the research findings are sent to the members of the research sample or respondents (or a subset of the research sample) to check with them whether the findings are consistent with the context and that its accurately. When the members can unanimous say or most of them can say that the results are accurate then the research can conclude that the research findings are credible, valid and reliable, and not valid or reliable if the contrary holds to be true (Creswell, 2003).

This research used both interviews and questionnaires to obtain information which informed the findings and the development of the framework proposed in this research. A total of 150 people were sent questionnaires and a total of 13 people were reached for interviews. These are professionals in the Kuwaiti construction industry (architects, designers, engineers, etc.). Out of the 150 professionals used in the questionnaires, 47 were reached to participate in the validation exercise depending on email response gotten back. Of course all research respondents where invited to participate. This means that the validation exercise received a 31% response rate from questionnaires. On the other hand, out of the 13 respondents that participate in the interviews, 8 of them were able to be reached for the validation exercise depending on their availability at the time. This means that 5 respondents were not able to be reached. This gives an approximation of 62% participation rate for interviews at the validation exercise.

Table 7.1: Validation exercise participation rate

Method of data Collection	Response rate
Questionnaires	31%
Interviews	62%

With no failure, a hundred percent of the respondents said they appreciated the framework and that it would be most useful to the construction process, and the process of achieving good IAQ at all the stages mentioned in the framework. Many favourable comments were made about the structure and flowchart of the framework. The respondents stated that the research has captured the Kuwaiti situation very well at each stage. However, some respondents also gave some input, corrections, and/or suggestions for different stages of the framework. It was also a consensus of the need for Kuwait IAQ codes and standards. One respondent commented:

"It is very important for us to know the right codes and standards. A Kuwait guidance showing the threshold of volatile gases, or particulates as well as acceptable levels of emission rates on products and materials will make it easy for construction professionals to achieve good IAQ on projects more easily and will make Kuwait municipality effective in checking compliance."

Strategic Definition

At the strategic definition stage, most respondents agreed that this stage was useful in helping the client identify the need for the project (business case) and ensure quality assurance through out the project. Of course, in Kuwait, the person to help the client do this is the architect. One architect states:

"for most developers of housing in Kuwait, the need or aim of the project in the bottom-line – money. They are not really thinking about the occupants and their wellbeing. But looking at the framework, I agree that IAQ requirements should form part of the briefing stage"

Some respondents also suggested that this stage could be fused with the 'preparation of brief' stage and that the introduction of this stage might be confusing for many Kuwaiti professionals even though it is part of RIBA 2013. The research acknowledged their observation but encouraged them to appreciate that the new RIBA separates the 'strategic definition' stage from the 'preparation and brief' stage because it is important that a project is strategically appraised and defined before a detailed brief is created.

Preparation and Brief

On the preparation and brief stage, many of the respondents were familiar with this stage as it was part of the first meeting with the client. The only difference was the need to emphasize the need for an integrated project/design team and the use BIM. Many of the clients as well as the construction professionals are not used to working in an integrated fashion and therefore the framework proposing the integrated design model would need some change management. In addition, BIM is not something that is widely known.

"we've heard of building information modelling. But most engineers and architect are not familiar with it. It would be hard to implement BIM on projects now."

The researcher assured them that the study is well aware of the low use and low proficiency of Kuwaiti professionals in BIM, but emphasized that need for a platform collaboration. The researcher explained that a common interface for collaboration and exchange of data was imperative to an integrated design process, otherwise achieving good IAQ would not be successful. They were also informed that BIM has many benefits among which is design interoperability and coordination. Designers, engineers, IAQ specialists, HVAC specialists, facilities managers etc. have to brought on early on the project to influence design for better IAQ. It may be true that some of these professional may not be found locally or even competent if they exist, the framework, however, proposes that the client's architect finds competent IAQ specialists that they trust.

Other respondents showed great excitement for the framework. One respondent stated that:

"Clients are not aware of IAQ in Kuwait, and do not demand for any extra attention to it. Therefore, we (architects) *design the basic IAQ need for the building. But with this framework, we can educate the client on the need for better IAQ system in the building"*

Clients can easily be sold the idea of good IAQ because it deals with their health ad wellbeing especially if the client is the one to reside in the building. Some respondents also raised the issue of additional cost to the client for involving these project team members early on on the project. The research explained that there need not be any additional cost for the client if contract packages are designed properly. It was also explained that even if there is an additional cost, consultants must encourage the client to see the additional cost as an investment because the cost saving ensured by an integrated design team in preventing the many problems of poor IAQ will definitely offset the initial investment.

Concept Design

At this stage respondent agreed with every aspect of the framework and its detailing of step by step activities. However, the respondents acknowledged that IAQ has not always been part of their value engineering exercise but with the framework, this can be made more explicit at the meetings. Also IAQ review can be done more efficiently at the end of the stage before applying for outline planning permission from Kuwait municipality.

Detailed Design

At 'detailed design' majority of the respondents stated that the 'application for statutory approvals' from Kuwait municipality was too cumbersome and makes the process more complicated. One of the architects commented in response to this:

"why apply for 'outline planning permission' at the concept stage and then apply for 'statutory approvals' in the very next stage to the same organization? why not just combine the two and apply once?"

The research explained that planning permissions are quite different from statutory approvals and proposes that Kuwait municipality does both compliance checks. However, some engineers pointed out that the municipality will be able to check compliance just from concept design the do not need the technical designs.

"Since IAQ has been tabled from the beginning of the project, by the end of the 'concept design' stage, sufficient information would have been provided and document on the type ventilation system to be used whether only natural, only mechanical, or a hybrid ventilation system"

Construction

Many of the respondents expressed their thoughts on the current practices on site regarding IAQ. They accept that there has been a great neglect in covering ducts and the HVAC systems during construction. Also, little or no attention is given to commissioning after the project is completed. One architect states:

"Much has to be done in educating contractors to think about IAQ and the well-being of the end users. Also, once the HVAC system is installed, it is tested immediately. The system is hardly retested at the end of construction before handing over is uncommon"

Testing of the HVAC system after installation is good but it should also be retested at the commissioning stage which comes at the end of the construction using the IAQ checklist. In addition, ASHRAE (2009), discourages the operation of the system during construction because the system may collect dust of particulate materials and may compromise IAQ at occupancy stage.

Handover and use

It almost unanimous that respondents agreed with the framework that clients or occupants and facilities managers should be provided with some good IAQ training and support by giving them manuals and documentation. In addition, seasonal maintenance and cleaning must be set.

7.2.2 A thorough description of the research context

This is another strategy used to evaluate the validity of a qualitative research that was adopted in this research. The fulfil the criteria for transferability, qualitative researchers are encouraged to use all the data and secondary information available to them to provide a detailed description of the research settings and context (Lincoln and Guba, 1985). Therefore, this research made a thorough description of the Kuwaiti context regarding indoor air quality and air quality in general as seen in Chapter 2 and Chapter 3 and Chapter 5. The aim and objectives, rationale for the research, and the description of the current practices in Chapter 5 where an integrated design team is not utilised and IAQ is not made a priority from the start of the project, also adds more information on the reasons behind the research and gives the reader an idea of the Kuwait context regarding IAQ.

7.2.3 Thorough description of the research methodology

Chapter 4 of this thesis gives a detailed description of the research methodology. Various research methods were discussed in detail and then the best methodology was to achieve the research aims and objectives was chosen, and that is, survey and interviews. Furthermore, the justification or rationale of the study that was given earlier in Chapter 1, the literature review, and subsequently method of data collection (questionnaires and interviews) and analysis give a detailed picture of the research process. Because Kuwait is and Arabic speaking country, most of the interviews with the professionals was carried out in Arabic. The interviews were transcribed and coded for analysis as already Stated in chapter 4. The questionnaire data were written in English and later combined to the interview data to make the whole of the data collection. The notes that were taken during the interview and the transcriptions of the interviews are available for any third party verification. Therefore, this thesis meets the criteria for confirmability and therefore validity. This detailed description to the methodology means the research can be carried out again with similar outcomes, thus, verifying the integrity of the thesis.

7.2.4 Rich Description of Research Findings

Shenton (2004), and Creswell (2003) all recommend a detailed description of the respondents inputs, opinions, and/or experiences to attain credibility and hence validity. This thesis meets this criterion as it documents and reports the responses of the respondents through rich descriptions as well as presenting actual respondents' statements in quotation mark in order to give the reader a true feel of the respondents' experiences and perhaps relate to them. This research also makes use of diagrams and flowcharts to convey the information respondents give in virtual form. For example, the presentation of the current process of achieving IAQ in Kuwait housing developments shown in Figure 5.16.

7.2.5 Triangulation

The use of two methods of data collection (questionnaire survey and interviews) in this research to obtain similar results satisfies the criterion of credibility and confirmability. It also means the research findings are dependable. The interview data collection process is one of the main data collection techniques in qualitative research. Having interviews with Kuwaiti construction professionals about the best practices in achieving good IAQ and then distributing questionnaires to the same group (but in a larger scale) and obtaining the same results shows that the research findings are dependable, credible and thus, valid.

7.2.6 Presenting opposing information

This is another strategy for achieving validation in qualitative research. In any debate, an argument is only considered credible only when the opposing argument or view presented does not hold true. It is the same in research. In this research, when respondents' opinions are presented, if there was an opposing view point, that view point is presented as well. This adds to the credibility of the research for the reader. They reader feels confident that they are not only presented with one perspective but with two or more. This process also helps the reader get the whole picture of the topic being discussed. In this research, the architects, and the IAQ engineers did not always agree on the same subject. There was especially a dissatisfaction in the current IAQ procedure expressed by the facilities managers. The designs are seldom considerate of (post construction) operation and maintenance stage. This is due to the fact that currently, architects in Kuwait do not adopt the integrated design approach, and therefore do not consult facilities managers to give design inputs. Thus, in this thesis, the data in presented even when there are differences in opinions from the respondents.

One architect argued that at the integrated design stage, they do not need to consult the facilities managers. Rather, a consultant would suffice. When asked why? He stated that facilities managers are mainly like contractors, mostly concerned about making, and so would usually offer the lowest price to get the job. *"IAQ is their job but it's not their priority unfortunately"* he said. On the other hand, a consultant is concerned about the client's objectives and would strive to meet them. The researcher thanked the architect for his input but pointed out that some consultants can also be concerned about money. The objective of involving the FM early on, is because they would be responsible for operations and maintenance of the building and therefore need to be involved in the design process.

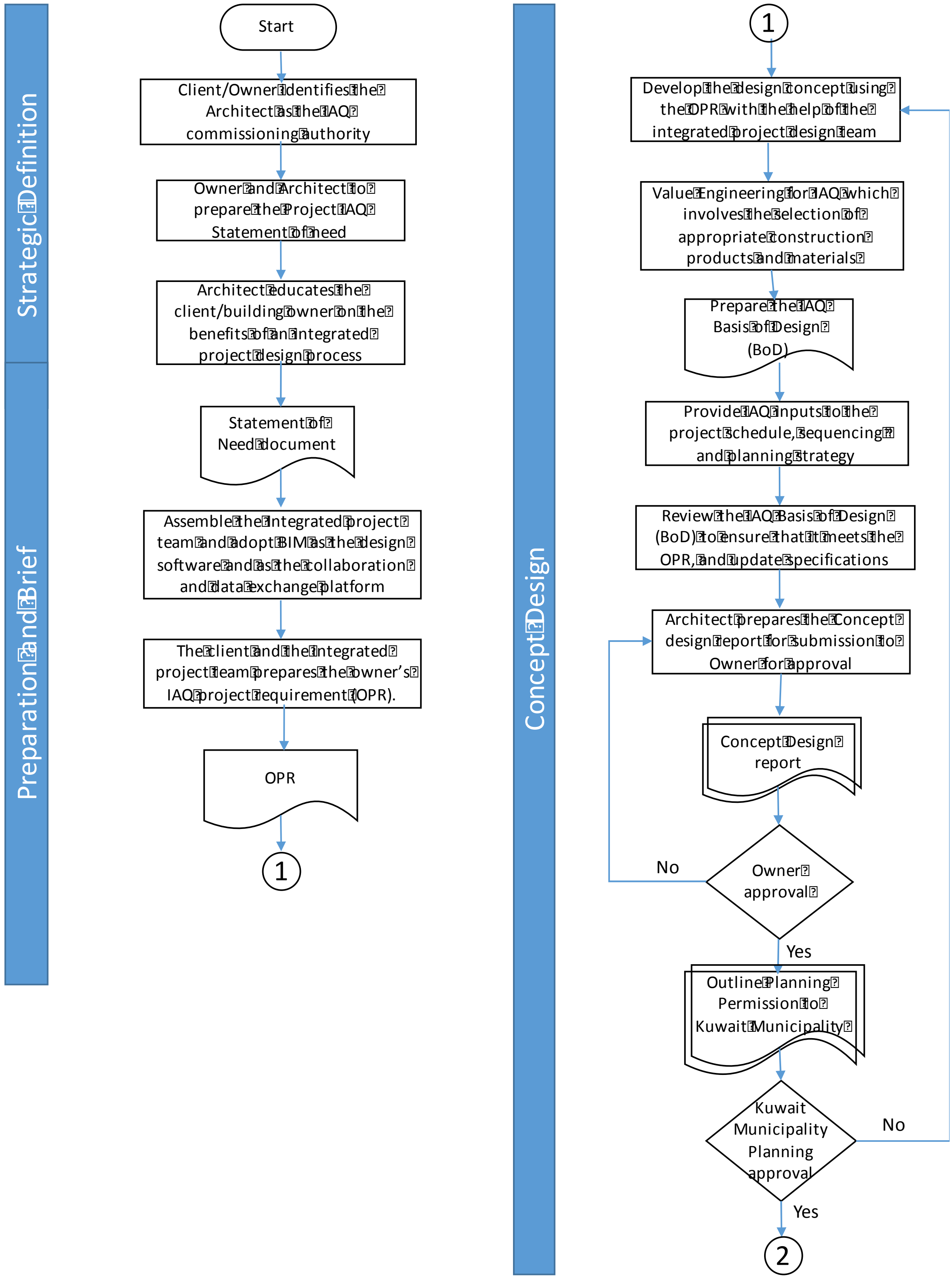
7.2.7 Examination of previous research findings

This strategy of achieving validity and reliability was used effectively in this research. The literature review presented a host of information which (after carrying out the data collection) corresponded to the research findings. In Chapter 5 and 6, related or showed the similarities of this research findings to the findings of other researchers and institution in the area of IAQ. By doing so, the study was able to confirm some of the findings with existing knowledge, identify gaps and new knowledge and develop solutions which has been embedded in the framework in chapter 6. When this strategy is applied successfully, it can be said that the thesis is credible.

7.3 Summary of Contributions of the Validation Process to the Research

The validation process was conducted to ascertain that the research findings are credible, dependable, confirmable and/or transferable. The respondents to the validation process have expressed that the IAQ framework was significant to filling the gap of good IAQ in Kuwaiti housing development that has existed and currently exists in Kuwait. They supported the proposal for an integrated design process to achieve good IAQ and confirmed that they are willing to adopt the strategy on other projects since the process has many other benefits and not exclusive to IAQ. They also expressed concern regarding the need for Kuwait IAQ standards and regulations, a guidance, in which the municipality can use to check compliance at planning permission stage.

In response to the criticism of respondents for suggesting a second application to Kuwait municipality for ‘statutory approvals’ at the detailed design stage, the research has taking heed of respondents input and has modified the framework to include only one compliance check by Kuwait municipality given that if the project team is faithful to the framework from strategic definition stage, by the time they get to the end of concept design stage, sufficient information would have been provided on the ventilation system to satisfy IAQ inspectors at Kuwait municipality. At outline planning permission, the planning officer states whether proposed development is acceptable to the local planning authority, before substantial costs are incurred developing a detailed design. Respondents proposed that statutory approval be combined with outline planning permission. It therefore means, that the integrated project design team must submit enough technical information along with the other architectural drawings for planning permission because Statutory Approvals is concerned with structural safety, fire safety, ventilation and IAQ, resistance to contaminants and moisture, toxic substances, resistance to sound (acoustic comfort), sanitation, water efficiency, drainage and waste disposal, heat producing appliances, protection from falling, access to and use of buildings, and electrical safety, etcetera. Here, the inspector from the Kuwait Municipality should check the design for IAQ compliance. All designs, BoD and OPR should be submitted to officer for thorough review. The inspector is to determine whether plans and designs meet acceptable standard for IAQ. If not, the project must not be allowed to proceed until the minimum IAQ requirements are met. The change can be seen in Figure 7.1 and Figure 7.2.


Strategic Definition
Preparation and Brief
Start
Client/Owner identifies the Architect as the IAQ commissioning authority
Owner and Architect to prepare the Project IAQ Statement of need
Architect educates the client/building owner on the benefits of an integrated project design process
Statement of Need document
Assemble the integrated project team and adopt BIM as the design software and as the collaboration and data exchange platform
The client and the integrated project team prepares the owner's IAQ project requirement (OPR).
OPR
1
Concept Design
1
Develop the design concept using the OPR with the help of the integrated project design team
Value Engineering for IAQ which involves the selection of appropriate construction products and materials
Prepare the IAQ Basis of Design (BoD)
Provide IAQ inputs to the project schedule, sequencing and planning strategy
Review the IAQ Basis of Design (BoD) to ensure that it meets the OPR, and update specifications
Architect prepares the Concept design report for submission to Owner for approval
Concept Design report
Owner approval
No
Yes
Outline Planning Permission to Kuwait Municipality
Kuwait Municipality Planning approval
No
Yes
2

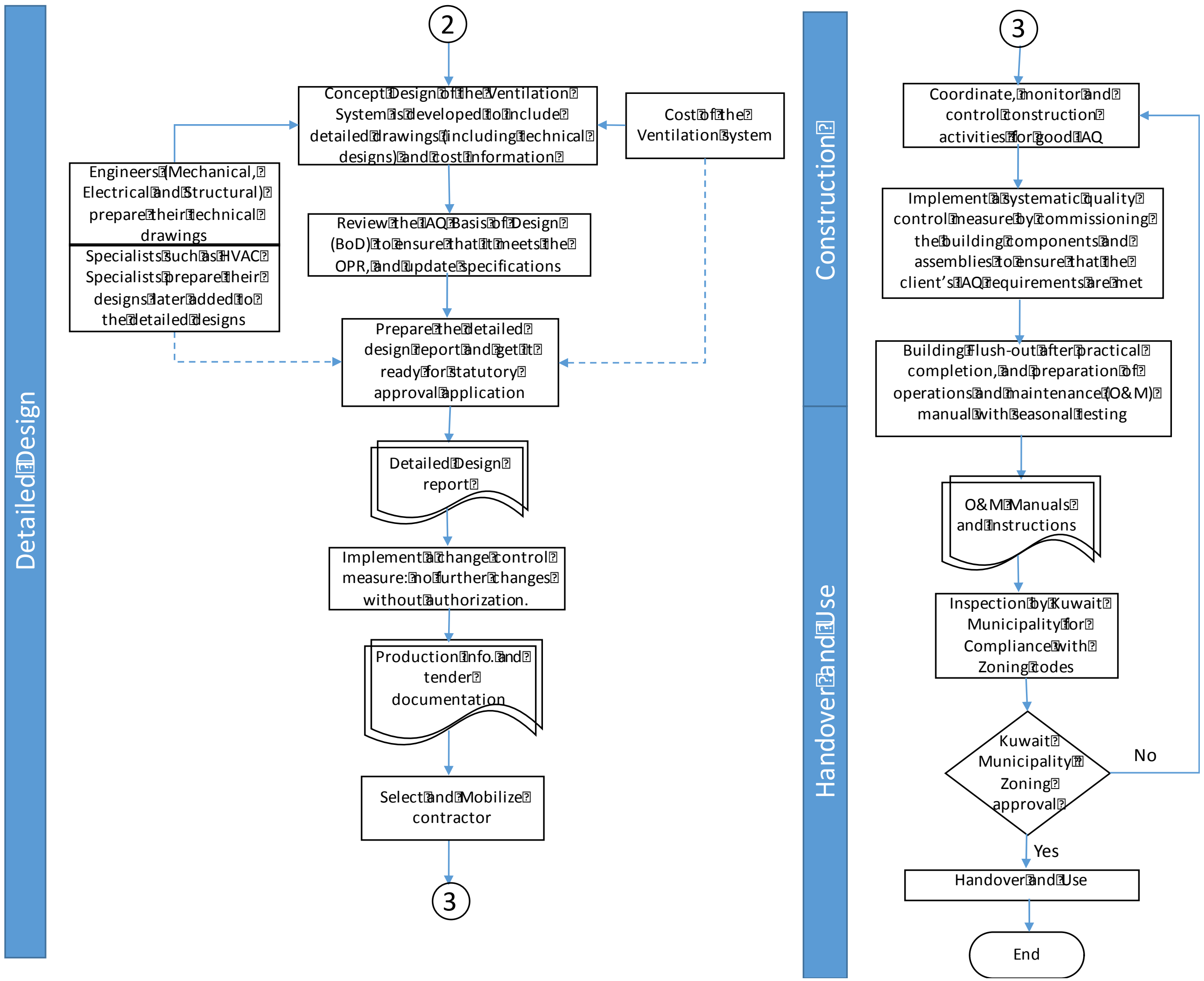


Figure 7.1: Final Flowchart for achieving good IAQ in Kuwait Housing Developments

Final Framework for achieving good IAQ in Kuwait Housing Developments

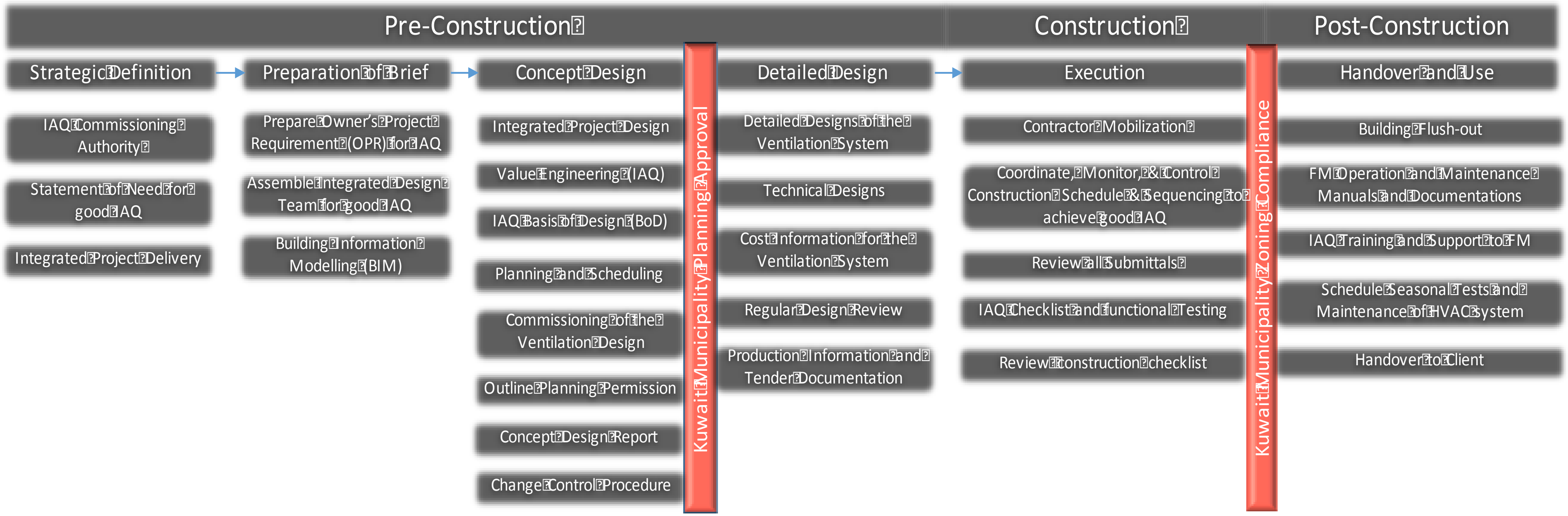


Figure 7.2: Final Framework for achieving good IAQ in Kuwait Housing Developments

Table 7.2 below gives a complete breakdown of the process along with excerpts from strategic definition stage to handover and close-out stage. It is a snap shot which construction professional to use when implementing good IAQ practices.

Table 7.2: Process for achieving Good IAQ in Kuwait Housing Development

Pre-construction				**Construction**	**Post-construction**
Strategic Definition	**Preparation and Brief**	**Concept Design**	**Detailed Design**	**Execution**	**Handover and Close-out**
Quality Assurance Manager: Identify the quality assurance manager who will become responsible for achieving the IAQ objectives. This would most likely be the Architect/Project manager. The quality assurance manager is also known as the commissioning authority **Statement of need** Prepare IAQ considerations and owner's project requirements (OPR) for IAQ at inception. The project lead consultant (architect) seats with the client to Prepare the need for the project, analysis of alternative options, preliminary programme, and budget for IAQ. That is, the functional requirements for the project. However, some owners may not know what requirements constitute good IAQ. Therefore, it is the job of the architect/commissioning authority to assist the client to prepare a robust checklist. **Integrated Project Team** Educate the client on the need for an integrated project team and develop a list of potential major project team members.	**Prepare the owner's project requirements (OPR):** the lead consultant, and also the commissioning authority, must help the client and ensure that all IAQ requirements are identified and included in the OPR because of the lack of IAQ knowledge on the part of most building owners in Kuwait. **Integrated Project Design Process**: Adopt Integrated design approach solutions rather than tradition approach. The lead consultant or Architect should assemble the project team (design professionals, interior designers, contractors, mechanical and electrical engineers, IAQ specialist, HVAC specialist, quantity surveyor, facilities managers, commissioning authorities, and others) and define each player's roles and responsibilities. The team should spend the next meeting developing the OPR and prepare scheduling and sequencing needs **Building Information Modeling**: Use (BIM) as it allows for clash detection, design interoperability and coordination of all designs submitted by the design team, as well as allows for any design deficiencies, errors, and inaccuracies to be spotted quickly and corrected.	**Integrated Project Design**: Adopt Integrated design approach solutions rather than tradition approach. This means getting the input of all stakeholders on the design and in value engineering with good IAQ on the agenda. **Value engineering** for IAQ which involves the selection of appropriate construction products and materials e.g. the proper HVAC systems **Prepare the Basis of Design (BoD)**: document that stipulates accurately, the "concepts, calculations, decisions, the HVAC system and assembly options, its description, and the selection reasoning, Specialists Consultant, engineering, and architectural guidelines, codes, standards, and regulations for design. **Planning & Scheduling**: Provide IAQ inputs to the project schedule. This involves different aspects; scheduling and sequencing of activities to allow for the proper timing of inspections for IAQ of systems and assemblies before they are closed off. This is to avoid, for example, moisture damage. This should be done with the help of the contractor so that he/she can understand and budget their role in the testing and quality assurance process.	**Developed Design:** Concept Design is developed to include detailed drawing of the architectural, structural engineering, building services; ventilation design, whether only natural, only mechanical, or a hybrid ventilation designs; design input from specialist sub-contractors and suppliers, outline specifications, and cost information. This design should include technical design from specialists. **Design Review**: Review of IAQ BoD to ensure that it meets the Owner's IAQ needs. team members should also review the designs using checklists to make sure that the designs meet the owner's project requirement as well as statutory standards. Among the documents that these specialists especially facilities managers should review are: the architectural layouts, waste management systems, water distribution layout, access control systems, lighting layouts, mechanical, electrical and plumbing layouts, appropriateness of material, equipment, sustainability aspects, energy saving, power and water consumption, utility services, etc I**mplement a change control measure:** no further changes without authorization.	**Coordination** of construction activity for IAQ. **Monitoring and control** of Sequences and scheduled activity to ensure the IAQ requirements are not compromised. **Review all submittals** e.g. variations and alterations to make sure that they are consistent with the Owner's project requirement (OPR) **Educate Kuwaiti trade worker on commissioning activities** **Commissioning:** Use construction IAQ checklist for verification of works completed by the contractor. Functional test for IAQ**.** **Continuous check and testing** of systems to ensure that IAQ requirements are achieved and not compromised. **Review construction checklist** for IAQ achievement	**Building Flush-out** **Provide operations and maintenance** manuals and documentation **Provide training and support** to facilities management company and occupants for the building to achieve its IAQ design intent. **Local Authority Approval**: Final Inspection by local authority inspector. Inspection in stages after construction by Kuwait Municipality inspector to ascertain that the building's IAQ targets are not compromised. This practice would be similar to the Health and Safety Executive (HSE) inspector in the UK. **Seasonal maintenance** and testing for IAQ. The facilities managers must schedule seasonal checks, cleaning and/or maintenance of the HVAC system according to the manufacturers recommendations in the instructions manual.

		Commissioning: the architect along with the project team should review the Basis of Design (BoD) to ensure that it meets the OPR, and update the specifications on the concept design. **Outline planning permission and statutory approvals:** Kuwait municipality checks if the proposed development is acceptable to the local planning authority, before substantial costs are incurred developing a detailed design. This check includes statutory compliance checks. Here, the inspector from the Kuwait Municipality checks the design for IAQ compliance as well as structural safety, fire safety, drainage and waste disposal, etc. All designs, BoD and OPR should be submitted to officer for thorough review. The inspector is to determine whether plans and designs meet acceptable standard for IAQ. If not, the project must not be allowed to proceed until the minimum IAQ requirements are met. **Prepare the concept design report** for the preferred option for which the owner may choose to pursue further to 'detailed design. I**mplement a change control measure**	**Statutory approvals:** for structural safety, fire safety, ventilation and IAQ, resistance to contaminants and moisture, toxic substances, resistance to sound (acoustic comfort), sanitation, hot water safety and water efficiency, drainage and waste disposal, heat producing appliances, protection from falling, access to and use of buildings, and electrical safety, etc. **Preparation of production information and tender documentation:** shall include best practice guidance on how the building(s) are to be constructed; design drawings, specifications, bills of quantities, schedule and sequence of works, etcetera. Tender action, selection of contractor and award of contract.		

ASHRAE (2009) explains the need for proper scheduling of activities to achieve good IAQ: *"Establishing a comprehensive and realistic project construction schedule and using sound management of construction activities will help ensure the achievement of good IAQ for a building project. A building owner can have the best intentions, the design team can provide a great building design, and the contractors can achieve their best execution, but if the schedule is too compressed or has sequencing issues or if construction activities are not well managed, the IAQ of the finished project will be compromised."*

8 CHAPTER 8| CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

This thesis has established, in detail, the extent of good IAQ knowledge and application in housing development amongst construction professionals in Kuwait. The research revealed that that knowledge and application was very low. It also revealed the need for Kuwait IAQ guidance and the need for integration early on on construction projects. Involving the major players (architects, engineers, IAQ specialists, facilities managers and consultants) from conception of the project in imperative for effective and efficient design of a ventilation system that achieves the building owner's IAQ project requirements, amongst other benefits of an integrated design approach. The integrated design approach is a new concept that is only starting to get known in Kuwait, therefore, its application in very limited and only amongst the multinational companies. In addition, there were no studies on the integrated approach in Kuwait. However, this research was able to capture the gap of integration in the current design and construction process of achieving IAQ in Kuwait and propose a framework which incorporates integration and compliance check point.

8.2 Research key findings

The literature review set out to explore previous research studies in the field of IAQ (both internationally and locally) and the process of achieving good IAQ at design, construction and occupancy stage in Kuwait. The findings revealed that there was no framework guiding the achievement of good IAQ in Kuwait housing projects. It was also revealed that there were only a handful of useful international documents such as *ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality*, and no documents were found written for Kuwait that encompasses codes, standards, regulations and guidance for the implementation of good IAQ in Kuwait housing developments. The data collection results also confirm this finding.

The results revealed that:

1. There is negligence on the government side to impose laws and regulations addressing the indoor air quality in design and construction of housing projects.

2. Decision makers do not have a clear interest in the implementation of indoor air quality (IAQ) standards and regulation in residential projects.

3. Private sector negligence of implementing indoor air quality standards and regulation in design and construction of housing project to achieve greatest return of profits.
4. Lack of awareness of the residential or housing projects occupants in the indoor air quality standards and regulation on the design and construction.
5. Media role is very weak in making public or housing residents aware of the health and hazardousness of indoor pollution, and the consequences on there lives.
6. Majority of professionals such as engineers or architects involved in the design and construction of housing projects, have little to low knowledge of indoor air quality standard or regulation.
7. There is no governmental or private agency monitoring, supervision, or certification of housing projects on design and construction stages on indoor air quality standards and regulation.

The results from the data collection showed that Kuwaiti construction professionals (architects, engineers, etc) have a 'very low' understanding of IAQ codes, standards, and regulations for design and construction of housing projects with natural ventilation design being the most common form of good IAQ strategy they knew. Consequently, there is a lack of: awareness of decision makers to the concept and benefits of good indoor air quality (IAQ) standards or awareness of the negative effects of poor IAQ on resident's or occupant's health.

Furthermore, housing occupants or residential project's end users lack the needed information and awareness about the indoor pollutant accumulation, the health consequences and how detrimental it is. most projects are designed randomly when it comes to site selections, some residential projects are located within close radius to industrial and petrochemical plant down stream, and projects are built on completion bases. Therefore, residential projects are designed for the aesthetic and structure look rather than inclusive health objectives. The design overlooks the indoors air quality issues and standards. The absence of governmental authority that supervises or monitor IAQ regulations enables homeowners to violate IAQ building codes. The vague building codes and the absences of crystal clear regulation in indoor air quality (IAQ) makes the private sector in construction strive towards maximizing space within houses or projects even though it violates indoor air quality to achieve the greatest profitability.

The findings also showed that the government of Kuwait does not have firm laws to monitor compliance of developers and/or contractors to good IAQ practices partly because there are no local standards and regulations. The government as well as the clients just assume that architects will design structures with the appropriate ventilation system. In other words, at the design stage, the Architect is responsible for, and will design for good IAQ in the buildings. At the construction stage, the contractor is responsible for good IAQ, and at the handover stage, the facilities managers or the occupants is assumed to be responsible. At planning permissions, Kuwait municipality only checks compliance with zoning laws with out checking IAQ compliance as well. That is why the framework recommends that IAQ compliance be included on the Kuwait municipality inspection officer’s checklist.

The findings also showed that more could be done during value engineering to ensure good IAQ on projects. IAQ is seldom as main priority on the agenda. The cost of IAQ was also mentioned to impede selection of ventilation systems that can handle the capacity of the building effective and efficient. It was also revealed that: bad design and construction, faulty installations and commissioning of building systems, moisture in building assemblies, poor outdoor air quality, moisture and dirt in ventilation systems, indoor contaminant sources e.g. building materials, furnishings, and foreign materials introduced into the building during operation, contaminant from indoor equipment and activities, inadequate ventilation rates, and ineffective filtration and air cleaning, all contribute to IAQ problems in Kuwait housing developments.

In addition, due to the absence of local IAQ standards and regulations, Label scheme rules regulating construction materials manufacturing industry products is non-existent in Kuwait, which is not the case in other developed countries like the United State of America, or Germany. Hence, construction materials imported from outside the country are not checked against IAQ standards, and the labels on most of the materials do not state explicitly what the contents are or what they’re made of. And if there is a label, it is so generic in the sense that it is so complicated for customers to understand or comprehend to make informed decisions on whether or not to purchase the material.

The findings also revealed that Kuwait construction industry is predominantly using the traditional method of project delivery as against integrated project delivery approach. Consequently, IAQ specialist, facilities managers, HVAC consultant etc. are not brought in at the design stage to give design input and solutions as well as information that can make good

IAQ in the post-construction stage sustainable. Collaboration at the design stage is nearly non existent due to lack of integration. The traditional project delivery method pervasive in Kuwait construction industry ensures that commissioning of IAQ assemblies are not done efficiently during design and construction. The valuable contributions of facilities managers, IAQ and HVAC specialists at the design stage are lost. This finding was confirmed by respondent in the data collection process. Designers seldom evaluate their designs to ensure that they meet IAQ project requirements, nor do contractors and/or facilities managers make use of IAQ checklist during construction stage to ensure the building performance in relation to its ventilation design. This lack of evaluation or commissioning, results in future IAQ problems at occupancy stage.

The findings show that the barriers to achieving good IAQ in Kuwait housing developments are; cost and budget, government enthusiasm, lack of awareness, lack of enforceable codes and standards, lack of design integration, distrust of the competence level of local IAQ companies, habit and age, low level of IAQ education, and lack of training. The “lack of enforceable codes and standards” is the number one barrier to implementing good IAQ practices in Kuwait housing largely because the Kuwait scientific and medical data in which IAQ standards and codes are based on are non-existent. Followed by a lack of awareness on the part of clients, professionals in the construction industry, and government institutions responsible for environmental protection. Some professionals feel that local companies competent in IAQ do not exist in Kuwait. “Cost” is also one of the main barriers behind most decisions regarding IAQ. Kuwaiti developers as well private individuals get discouraged once they learn that there would be a premium to pay attached to IAQ systems

Similarly, respondents report that the drivers of good IAQ in Kuwait housing are; the client/end-user, the government, architects, designers, IAQ consultants, construction professional societies, contractors and manufacturers. The government bodies that will do well in promoting good IAQ in Kuwait are government institutions like Kuwait Environmental Protection Agency (KEPA), Kuwait Institute of Environmental Management (KIEM), Kuwait Municipality, and Kuwait Institute of Science and Research (KISR). The promotion of good IAQ and integrated project delivery could be done through; conferences, seminars, and workshops, with designers, engineers, facilities managers, clients (developers and building owners), and other relevant stakeholders. Another major medium of driving the IAQ knowledge and skill is through ‘training’ of constructions professionals; architects, engineers, facilities managers etcetera, and also update the IAQ design curriculums in universities in Kuwait. These curriculums must include current local Kuwait medical and research data on IAQ, which will allow students to design according to Kuwait pollutant exposure levels. Therefore, design and construction students leave university with the right IAQ knowledge which they can put into immediate use when designing housing.

8.3 Contribution to knowledge

This study attempts to contribute effectively in filling the gap of knowledge concerning indoor air quality (IAQ) in Kuwait and the knowledge of construction stakeholders in understanding IAQ. The research also tries to understand the factors inhibiting project participants in Kuwait from using a healthy or proactive approach, (i.e. integrated design approach) in the design and construction of housing in Kuwait in order to achieve good IAQ. The findings show that there is no Kuwait standard and regulations on IAQ apart from the international standard ASHRAE, that governs good IAQ on projects in the United States. Therefore, this thesis emphasizes the need for Kuwait government to release a full proof Kuwait IAQ guidance. It also presents the many benefits of the integrated project design approach, where the major players of IAQ (facilities managers, IAQ specialist, HVAC specialists) are assembled early on on the project to influence design. The government and project stakeholders, especially the client and end users must strive to enforce the attainment of good IAQ on their projects.

The study also suggests an interactive interphase to aid collaboration of the various players; designers, facilities managers, etc. Building information modelling (BIM) has been recognised as such a collaborative platform that aids integrated project delivery at all stages of the project; design, construction, and occupancy stage. In addition, the information and the extent of detailing and documentation in BIM will help the facilities managers operate and maintain the ventilation system efficiently.

8.4 Recommendations of the research

1. Keep going - bringing the issue up in seminars and professional events. Take it up with a selected group of parliamentarians, and ministers.

2. Education and awareness campaign. When people are made aware of the dangers of cholesterol they can make educated choices on what they eat. The same goes for the air they breath.
3. Government should impose regulations and each building shall be certified before occupation thru measuring the IAQ. After occupation, awareness is the key of improving IAQ

4. Start by educating users and home and real estate owners through lectures then to the specialists' consultants and suppliers.

5. the importance of raising stakeholder's awareness in the field of indoor air quality in the state of Kuwait, especially those who are involved in the housing sector.

6. The importance of making training and educational seminars in indoor air quality for professionals involving in the design and construction of housing projects, also to government representative who are in charge the monitoring and commissioning projects, whether in the design and construction housing development in Kuwait.

7. Knowledge transfer, learning from other advanced countries in the field of Indoor Air Quality (IAQ) codes and regulation and standards such as (United State of America, Canada, and the European union).
8. Strict Law enforcement legislation in field of Indoor Air Quality (IAQ) for housing projects especially for private sector involved in design and constructing housing construction projects.
9. Establishing research and educational platforms between research centers and university researchers and professionals involved in housing sectors for mutual data exchange and to update data for researchers in indoor air quality (IAQ) in Kuwait.
10. Establishment of an independent entity that supervise and monitors, and commission or certifies projects especially housing development in Kuwait.
11. Educating citizens about Indoor Air Quality (IAQ) standards and consequents to human health and environment, with collaboration ministry of information.

12. Establishing a Label Scheme Agency that monitor construction material manufacturing, also imported products used in construction. to make sure products are harmless to consumer, also information is labeled on products, and not toxics nor hazardous.

13. The importance of establishing strict law that violate the laws or regulation of Indoor Air Quality (IAQ).

14. Make new studies and research in the field of Indoor Air Quality, and update the research centers of new data.

15. Installation of pollutant detectors in public closed areas such as (school's rooms where student attend – class room co2 detectors, governmental offices where public citizens usually have to visits), also insulation ventilation system with filtration in these governmental premises.

16. Due to the fact that residential area is located within close radius of most industrials areas, future residential area should not be within prevailing downstream of these industrial areas chimney smoke.

17. Emergency exit plan should be made for residential area located within close distance radius from petrochemical plant. by establishing early detection outdoor pollutant.

18. Educational courses and training for new architects and engineers involved in the design and construction of housing project, these courses should be taught in the university, and professional engineering society in the state of Kuwait

8.5 Further Research

Other research works that could emerge from this study are; first, a full implementation of this framework on a case housing project or project in Kuwait and measure the practical IAQ improvements as well as the improvements in the project delivery at design, construction, and post-construction (occupancy) stages. A full and better understanding to the framework and integration will be beneficial to construction professionals. In addition, a further understanding and implementation of BIM will be achieved in Kuwait. Furthermore, BIM adoption, adaptability, barriers and drivers, can be understood, documented and leaned from for future projects in Kuwait. A further study will also improve the application of the integrated project delivery method in Kuwait construction processes. At the end of the framework application, an evaluation of the usefulness, applicability, and difficulties can be addressed so that modification are effected to the framework for best practice.

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10 APPENDICES

Appendix 1: Definition of Terms

Definitions are from Waterfurnace (2016), KEPA, and Institute of Environmental Epidemiology (IEE, 1996). They go as follows:

ACMV system – refers to the air-conditioning and mechanical ventilation system of the building.

Acceptable indoor air quality – refers to air in which there are no known contaminants at harmful concentrations as determined by the public health authorities, and with which a substantial majority of the people exposed do not express dissatisfaction.

Air-conditioning: refers to the process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness and distribution.

Air temperature: refers to the dry-bulb temperature of the air surrounding the occupant.

Allergen — A biological or chemical substance that causes an allergic reaction. Common allergens include pollen, animal dander, dust mites.

Ambient Air – Atmospheric air outside the buildings and the place of work

Asbestos— The group of microscopic mineral fibers. They are light enough to remain airborne and can cause lung related illnesses.

ASHRAE Standard 52— A standard established by the American Society of Heating, Refrigerating and Air Conditioning Engineers, describing methods of testing and rating performance of air filters. Includes weight arrestance tests, dust holding capacity and dust spot efficiency

Asthma— A usually chronic inflammatory disorder constricting the airways characterized by difficulty in breathing.

Building-related illness: refers to any illness, which occurs directly as a result of human exposure to a specific health hazard present in the building.

Carbon Monoxide— An odorless, colorless gas that is the chemical result of the combustion process. Interferes with distribution of oxygen to the body. Low levels of carbon monoxide poisoning result in flu-like symptoms. High levels are deadly

Contaminant: refers to an unwanted airborne constituent that may reduce acceptability of the indoor air quality.

Dander— Small scales of animal skin

ERV— Energy Recovery Ventilator. A device which brings in fresh air into the home, simultaneously exhausting the same volume of air from the home. Removes humidity from the incoming air during cooling.

ETS— Environmental Tobacco Smoke. Secondhand smoke.

Formaldehyde— A common chemical found in adhesive or bonding agents for many building materials including carpets, upholstery, particle board, and plywood paneling. The release of formaldehyde into the air can be a cause of respiratory problems.

HEPA— High Efficiency Particulate Air filter. An extremely effective filtration system. Certified HEPA filters must meet an efficiency of 99.97% down to a particle size of 0.3 microns

HRV— Heat Recovery Ventilator. Heat from the outgoing air is transferred to the incoming air.

HVAC— Heating, Ventilation and Air Conditioning.

Indoor air: refers to the air inside a building, including air which is within a room and air which is removed from a room by mechanical means.

MERV— Minimum Efficiency Reporting Value. The new industry standard which sets a rated value on the ability of a filter to trap particles. The higher the MERV rating, the higher the filter's efficiency. A MERV 11 is high, 2-4 is low.

Micron— One millionth of a meter. There are 25,400 microns per inch.

Nitrogen Dioxide— Colorless, odorless gas that irritates mucous membranes in the eye, nose and throat. Causes shortness of breath in high concentrations. Prolonged exposure can damage respiratory tissue. Can originate from kerosene heaters, stoves or fuel oil heaters.

Occupied zone refers to the region normally occupied by persons within a space, generally considered to be between the floor and 1.8 m above the floor, and more than 0.6 m from the walls.

Organic Gasses— Originate from paints, paint strippers, solvents, air fresheners, dry-cleaned clothing, etc. Can cause detrimental health effects.

Outdoor air: refers to the air in the external surroundings

Ozone— Molecule composed of three oxygen atoms (in contrast to the air we breathe which contains two oxygen atoms).

Particles— Very small solid or liquid substances that are light enough to float suspended in the air.

Radon— Radioactive pollutants which originate from natural sources such as rock, soil, or groundwater.

Respirable Particulates— Pollutants in the air that can be inhaled, including those from smoking, fireplaces, industrial/agricultural process. Health effects include irritation of the eyes, nose and throat and respiratory infections.

Rhinitis— Inflammation of the lining of the nose.

Sick building syndrome – refers to an excess of work-related irritations of the skin and mucous membranes and other symptoms (including headache and fatigue) reported by occupants in residences or modern office buildings.

Sinusitis— Inflammation of the sinus membrane, especially in the nasal region.

Suspended particulate matter – refers to the mass of particles suspended in a unit volume of air when collected by a high volume air sampler.

UV Lights— Appliances that emit light energy in the ultraviolet wave length. Effective for killing bacteria. Less effective for killing mold. UV lights will kill (or render sterile) microorganisms. An effective filtration system is still required. Should be used with discretion.

Ventilation – refers to the process of supplying and removing air by natural or mechanical means to and from any space. Such air may or may not be conditioned.

Appendix 2: International IAQ Standard and Regulation

	COUNTRY	DESCRIPTION
1	NAAQS/KEPA	The National Ambient Air Quality Standards (NAAQS) were developed by the U.S. Environmental Protection Agency (KEPA) under the Clean Air Act (last amended in 1990). These enforceable standards were developed for outdoor air quality, but they are also applicable for indoor air contaminant levels. The concentrations are set conservatively in order to protect the most sensitive individuals, such children, the elderly, and those with asthma. By law, these regulatory values must be reviewed every five years
2	OSHA	The U.S. Occupational Health and Safety Administration (OSHA) developed enforceable maximum exposures for industrial environments. The standards were developed through a formal rule-making process, and the permissible limits can only be changed by reopening this process. The Permissible Exposure Limits (PELs) given in Table 5 are designed to protect the average industrial worker, but do not take into account the possible reactions of sensitive individuals (ASHRAE, 2004; OSHA, 2005). More information on these standards can be found at: http://www.osha.gov/SLTC/pel
3	MAK	MAK levels were developed in Germany by Deutsche Forschungs Gemeinschaft (DFG), an insitution similar to the U.S. National Institutes of Health and the U.S. National Institute for Occupational Safety and Health (NIOSH). These levels are set on a regular basis and receive annual reviews. The limits are enforceable in Germany, and are set for the general population (ASHRAE, 2004; DFG, 2005). More information is available at:http://www.dfg.de/en/dfg_profile/structure/statutory_bodies/senate/senate_commissions_and_committees/investigation_health_hazards/
4	WHO/Europe	The World Health Organization’s (WHO) Office for Europe, based in Denmark, developed guidelines to be used in non-industrial settings. These guidelines were developed in 1987 and updated in 1999. They are intended for application to both indoor and outdoor exposures, but are guidelines rather than an enforceable standard (ASHRAE, 2004; WHO, 2000). Further details of these guidelines can be found at:http://www.euro.who.int/document/e71922.pdf
5	NIOSH	Recommended maximum exposures for industrial environments have also been developed by the U.S. National Institute for Occupational Safety and Health (NIOSH). These guidelines are published in a set of criteria documents, which contain a review of relevant literature and Recommended Exposure Limits (RELs). These non-enforceable recommendations are not reviewed regularly, and in some cases levels are set above those needed for health reasons because commonly available industrial hygiene practices do not reliably detect substances at lower levels (ASHRAE, 2004, NIOSH, 2005). More information is available at: http://www.cdc.gov/niosh/81-123.html

6	**ACGIH**	The American Council of Governmental Industrial Hygienists recommends Threshold Limit Values (TLV®) as maximum exposures for industrial environments. The TLVs are set by concentrations. The recommendations are applicable for normal industrial working conditions (i.e. 40 hours a week), and for single contaminant exposure. These recommendations are guidelines, rather than enforceable standards, and are not selected to protect the most sensitive workers (ASHRAE, 2004; ACGIH, 2005). Further information is available at: http://www.acgih.org
7	**COSHR**	The Canadian Occupational Safety and Health Regulations (COSHR) establish requirements for maintaining a healthy and safe working environment, and form part of the Canadian Labour Code (HRSDC, 2005). Within the context of indoor air quality, COSHR requires that indoor contaminant concentrations be kept within the limits set by the ACGIH. The Canadian Labour Code and COSHR are requirements for Canadian Federal Government organizations, and are recommendations for other Canadian institutions. More information is available at: http://www.hrsdc.gc.ca/asp/gateway.asp?hr=/en/lp/lo/ohs/publications/overview.shtml&hs=oxs
8	**Hong Kong**	The Government of the Hong Kong Special Administrative Region established two levels of IAQ guideline values (8-hour average) that can be used to certify the indoor air quality of offices and public places. The guideline values were set for 6 individual chemicals, TVOC, PM10,airborne bacteria for Excellent Class and for Good Class IAQ (Hong Kong, 2003). More information is available at: http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf.
9	**Japan**	The Ministry of Health, Labour and Welfare of Japan produced guideline values for 14 organic compounds and TVOC in indoor air. The guideline values are the levels at which no adverse health effects would be caused in humans with the lifetime exposure. The guideline values are mainly based on chronic toxicity via a long-term exposure, except that of formaldehyde, which is given as a 30-minute average value based on toxicity via a short-term exposure. The value of TVOC is not based on toxicological information, but it is set to be as low as reasonably achievable as the result of investigations on indoor VOC concentration in Japan (MHLW, 2004).

Appendix 3: International Labelling Schemes for Low-VOC Emitting Products

	Labelling Schemes	DESCRIPTION
1	**Green Label (USA)**	Industry-designed and administered. Developed in 1992 by the Carpet and Rug Institute (the national trade association of carpet and rug industry) in consultation with US KEPA. The program specifies maximum emission rates for 4-PC, formaldehyde, styrene and TVOC following small emission chamber trials conducted by a single commercial lab
2	**Green Label Plus (USA)**	This is a revised version of the Green Label program developed to satisfy California's CHPS Criteria. Green Label Plus Testing and Product Requirements: Initial test - The carpet meets the environmental emissions criteria as outlined in Section 01350 (modeled concentration after 14 d test (10d condition + 96h chamber) not to exceed 1/2 of the current OEHHA CREL value found at 3www.oehha.ca.gov/air/chronic_rels/AllChrels.html).
3	**Green Seal (USA)**	Developed by independent non-profit organization of the same name. Based on ISO 14020 and ISO 14024, and US KEPA, and global ecolabelling network. Guiding principles and procedures are from Type I Environmental labelling (ISO 14024).
4	**Green Guard (USA)**	Developed from AQSpec List, which was first initiated in 1996. Product-by-productspecifications for emissions of formaldehyde, VOC, respirable particles, ozone, and other pollutants (include any California Proposition 65, US NTP or IARC carcinogens and reproductive toxins) using small environmental chambers. Tested to see if they meet "acceptable IAQ pollutant guidelines and standards" within a 5-day period of unpackaging
5	**Blue Angel (Germany)**	The first environmental label, created in 1977, now used by about 710 companies for ~3,800 products in ~80 product categories. The label is the property of the Federal Ministry of theEnvironment, Nature Protection and Nuclear Safety. It is sponsored and administered by the Federal Environmental Agency and the quality assurance and product labelling institute RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V.
6	**EMICODE (Germany)**	A group of German manufacturers of flooring installation products founded the "GemeinschaftEmissionskontrollierter Verlegewerkstoffe e.V." (GEV), or translated "Association for the Control of Emissions in Products for Flooring Installation ". The EMICODE ® system is based on defined analytical test chamber procedures and strict classification criteria. These criteria have been defined by the Technical Council of the GEV with the professional support of the environmental institute Miljö-Chemie, the Carpet Research Institute (TFI) and the Association for Environmentally-Friendly Carpets (GuT).
7	**GuT (Germany)**	The Association of Environmentally-Friendly Carpets was established in 1990. The original criteria includes prohibitions for certain substances (including pentachlorophenol, formaldehyde, vinylchloride, vinylacetate, benzene, certain pesticides, azo dyes, etc). Based on 24 hour chamber emission testing and odour testing (in compliance with the Swiss standard SNV 195651).
8	**Finnish M-1, M-2 (Finland)**	The first version of the emission classification was developed by the Finnish Society of Indoor Air Quality and Climate (FiSIAQ) in 1995 as part of Classification of Indoor Climate, Construction, and Finishing Materials. The first emission classifications were granted in 1996. In May 2000 the system changed its name into emission classification of building materials. Classifications are granted by the Building Information Foundation (RTS), a private foundation with representatives from

		43 Finnish building organisations, and Finland's leading information service for the building and construction sector. Carcinogens are identified vs. IARC.
9	**Indoor Climate Label (Denmark and Norway)**	The scheme was developed by the Danish Society of Indoor Climate in 1995 on the initiative of The Danish Ministry of Housing. Normative bodies for the system are the Danish Society of Indoor Climate and the Norwegian Forum of Indoor Climate Labelling. Chemical and sensory odour emission testing in cells or conventional chambers for 28 days is required. Results are converted to indoor air concentrations in a standard room. All products are declared with an "indoor-relevant time-value", which is based on of the time it takes the most slowly emitting individual substances to fall below their odour and irritation thresholds. Threshold values for odour and irritation used are those given in VOCBASE (Jensen and Wolkoff, 1996).
10	**Nordic Swan (Scandinavia)**	The Nordic Swan labelling system was developed in 1989 by the Nordic Council of Ministers and administered by the Nordic Ecolabelling Board. It is a voluntary program intended to enable consumers to select products that are the least harmful to the environment. Lifecycle assessment criteria are developed on a product-by-product basis. Chemical emissions impacting indoor air are assessed based on 28-day chamber tests.

Appendix 4: Ambient Air Quality for Residential Area in Kuwait

Pollutant / Unit	Hour*		8 hours		Day**		Year	
	ppb	mg/m^3	ppb	mg/m^3	ppb	mg/m^3	ppb	mg/m^3
Sulfur Dioxide (SO_2)	170	444	-	-	60	157	30	80
Hydrogen Sulphide (H_2S)	140	200	-	-	30	40	6	8
Nitrogen Dioxide (NO_2)	100	225	-	-	50	112	30	67
Carbon Monoxide (CO)	30000	34000	10,000	11500	8000	9000	-	-
Ozone (O_3)	80	157	60	120	-	-	-	-
Ammonia (NH_3)	#800	850	-	-	-	-	140	148
Hydrocarbon Compounds without Methanes	1/10 from specified rate in works environment (TLV's) 0.24 ppm for three hours from 6:00 – 9:00 morning (a.m)							
Suspended particulate matter (PM-10)	-	-	-	-	-	350	-	90
Dust – Fall out Matter	-	-	-	-	-	-	7.5 ton /km^2	
Lead	-	-	-	-	-	-	1.5 mg/m^3	
Chlorine ##	30.0 (30 min.)	100	-	-	10	30	-	

Source: KEPA (2012)

Notes:

* Average hour should not occur more than twice during the period of 30 days on the same site.

** Daily average (24 hours) should not occur more than once during the year.

Should not occur more than once per year.

- Should apply in residential dominated areas that lie on the border of industrial areas.

Appendix 5: Interviews Question

1. How would your categories your understanding of IAQ?
2. What is the rate of adopting good IAQ practices in Kuwait?
3. How do you evaluate the implementation of IAQ practices in Kuwait housing?
4. Have you implemented any IAQ practices? (Explain)
5. As a professional in the construction industry in Kuwait, have you been taught about IAQ?
6. What are the Kuwait standards and regulations of IAQ? And What standards or guidance do you subscribe to when designing for IAQ?
7. How does your company achieve good IAQ for the client or occupant on the project at Design, Construction, and Occupancy stages?
   - How do you achieve IAQ at Design stage?
   - How do you achieve IAQ at Construction stage?
   - How do you achieve IAQ at Commissioning and Occupancy stage?
8. How do you utilize design integration to achieve good IAQ on your projects - in design and construction stages?
9. As a certified designer (architect) have you been trained to address IAQ in buildings (housing)?
10. Does your company (organization) use any IAQ practices? If yes,
11. What are the advantages of utilizing the IAQ practices?
12. How has your process changed since you changed from traditional to healthy buildings practices?
13. What are the challenges or barriers you have faced adopting IAQ practices?
14. What are the obstacles preventing adopting IAQ practices?
15. What is your recommendation to overcome the IAQ barriers?
16. In the current Kuwait status, what do you think are, or should be the drivers "good IAQ practices" on housing projects in Kuwait?

Appendix 6: Questionnaire

1. Job description

2. Age

   20-29 30-39 40-49 50 and above

3. Gender

   Male Female

4. Years of experience

   5 years or less 6 - 10 years 11 - 15 years 16 years and above

5. Educational level

   B.A M.A PhD

6. Kuwait government applies Mandatory tough laws concerning the implementation of IAQ in both design and construction housing "how do you rate the government enforcement of laws?

   Very low Low Moderate High Very high

7. Government monitory agencies exist, follow up and monitors the implementation of IAQ in its housing projects "how do you rate their follow up during construction and delivery of projects?

   Very low Low Moderate High Very high

8. Private sector in Kuwait follows and implements IAQ rules in their buildings and housing projects “how do you rate their performance in following and implanting IAQ rules?

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐

9. Decision makers in Kuwait have a great understanding in implementing IAQ rules in all of their housing projects (how would you categorize it)?

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐

10. Implementing IAQ rules in both design and construction phases is a common practice for anyone building a house or a project. (How would you categorize the understanding of IAQ for anyone attempting to build a house or project)?

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐

11. Engineers have a very good and clear understanding of IAQ standard rules and regulations in both design and construction housing projects " how do you categorize their understanding?"

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐

12. Firm laws exist in Kuwait to ban those who do not follow IAQ rules in design and construction phases (how would you categorize government enforcement of ventilation system and IAQ strategy)?

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐

13. The media plays an informative role in educating the public of the Health and environmental hazardous of not following and implanting IAQ rules "what's your rating for role of media in Kuwait concerning the IAQ"?

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐

14. Label scheme rules regulating construction materials manufacturing industry products exist (categorize how accurate is label scheme used to ensure IAQ rules are being applied for a good indoor air quality)?

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐

15. The government plays a very important role in monitoring and enforcing IAQ rules during the construction phase and after delivery of projects to ensure a good quality of indoor air exists (categorize government monitoring and enforcement of ventilation system and IAQ rules during and after construction)?

Very low	Low	Moderate	High	Very high
☐	☐	☐	☐	☐