GUSTAVO ALCÂNTARA ELIAS

METODOLOGIA PARA AVALIAÇÃO DE PARÂMETROS AMBIENTAIS EM SERVIÇOS DE SAÚDE

METHODOLOGY TO EVALUATE PHYSICAL ENVIRONMENT PARAMETERS IN HEALTHCARE SERVICES

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Orientador: Prof. Dr. Saide Jorge Calil

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"É graça divina começar bem.
Graça maior persistir na caminhada certa.
Mas a graça das graças é não desistir nunca."
Dom Hélder Câmara

Dedication

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Resumo

O ambiente físico em hospitais deve oferecer condições adequadas em termos de iluminação, conforto térmico, qualidade do ar, nível de ruído e posto de trabalho. Se tais condições não são adequadas, os trabalhadores e os pacientes podem ser afetados negativamente. O objetivo principal deste trabalho é criar uma metodologia baseada fatores humanos e ergonomia para avaliar o ambiente físico em áreas de atendimento ao paciente. Para se realizar esta tarefa, a metodologia foi desenvolvida em seis passos. Primeiro, uma pesquisa na literatura foi realizada para determinar os parâmetros a serem avaliados, que foram, então, organizados em seis grupos: área de trabalho, ruído, iluminação, parâmetros ambientais, tomadas de energia, postos de gases medicinais. Segundo, foram definidos três métodos para avaliar os parâmetros selecionados: realização de medições, observações e pesquisa escrita. No terceiro passo, dois formulários foram criados para auxiliar na medição e observação dos parâmetros. A quarta etapa envolveu o desenvolvimento de uma pesquisa escrita sob a forma de um questionário a ser aplicado aos profissionais de saúde. O quinto passo consistiu na criação de um método para processar os dados coletados (medições, observações e pesquisa escrita). Finalmente, na sexta etapa, dashboards foram desenvolvidas para reportar os dados. A metodologia foi aplicada em salas de cirurgia, unidades de terapia intensiva e na sala de observação do departamento de emergência de um hospital público de Campinas, São Paulo, tendo gerado 11 relatórios. A análise destes relatórios mostrou que a temperatura, umidade relativa, concentração de Dióxido de Carbono e ruído em algumas áreas de cuidados de pacientes não estavam sempre em concordância com os limites estabelecidos. Pôde ser verificado por meio da análise das respostas da pesquisa, que alguns trabalhadores foram afetados negativamente por parâmetros como o ruído, iluminação e temperatura. Adicionalmente, houve queixas sobre as dimensões da área de trabalho, risco de escorregão, tropeço e queda; correntes de ar irritantes, odores desagradáveis e baixa qualidade do ar, bem como o número e posicionamento de tomadas e pontos de gases medicinais. A metodologia cumpriu os seus objetivos, tendo sido testada em diferentes áreas de cuidados ao paciente além de ter gerado resultados que permitiram o diagnóstico do efeito de parâmetros ambientais sobre os trabalhadores.

Palarvras-chave: ergonomia, fatores humanos, ambiente físico, parâmetros ambientais.

Abstract

The physical environment in hospitals should provide adequate conditions in terms of lighting, thermal comfort, air quality, noise level, and workplace. If such conditions are not appropriate, both workers and patients may be negatively affected. The main objective of this work is to develop a human factors and ergonomics based methodology to enable the evaluation of the physical environment in patient care areas. In order to do so, the methodology was developed according to six steps. First, literature research was performed to determine the parameters to be evaluated, which were, then, organized in six groups: work area, noise, lighting, environmental parameters, power outlets, medical gas outlets. Second, three methods to evaluate the selected parameters were defined: measurement, observation, and written survey. In the third step two forms were created to aid in the parameters measurement and observations. The fourth step involved the development of a written survey in the form of a questionnaire to be applied to healthcare staff. The fifth step consisted of the creation of a method to process the collected data (measurements, observations, and written survey). Finally, in the sixth step, dashboards were developed to report the collected data. The methodology was applied in the operating rooms, intensive care units, and in the emergency department observation room of a public hospital in Campinas, São Paulo, having generated 11 reports. The analysis of these reports showed that the temperature, relative humidity, Carbon Dioxide concentration, and noise in some patient care areas were not always in accordance with the established limits. Moreover, the fact that some workers were negatively affected by physical environment parameters such as noise, lighting, and temperature could be verified through survey answers. In addition, there were complaints regarding work area dimensions; risk of slip, trip or fall; annoying drafts, unpleasant odors, and air quality; as well as the number and positioning of power outlets and medical gas outlets. The methodology met its targets, having been tested in different areas of health care facilities and having generated results that allowed the diagnosis of the effect of some environmental parameters on workers.

Key words: Ergonomics, Human Factors, physical environment, environmental parameters.

List of figures

List of tables

Acronyms

ABNT – Associação Brasileira de Normas Técnicas

ANVISA – Agência Nacional de Vigilância Sanitária

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers

ASTM – American Society for Testing and Materials

BSI – The British Standards Institution

CE – Clinical engineer

CO_2 – Carbon Dioxide

EAS – Estabelecimento assistencial de saúde

EC – Engenharia clínicaED-OU – Emergency department – observation unit

EPA – Environmental Protection Agency

FGI – Facilities Guideline Institute

HEPA – High-efficiency particulate air

HF/E – Human Factors and Ergonomics

ICU – Intensive care unit

ISO – International Organization for Standardization

NFPA – National Fire Protection Association

OR – Operating room

RBC – Brazilian Calibration Network

RCA – Root cause analysis

RH – Relative humidity

SD – Standard deviation

STF – Slip, trip, and fall

TABLE OF CONTENTS

1. Introdução

Tradicionalmente, os hospitais têm sido a principal instituição do sistema de saúde. Prestam serviços de diagnóstico, emergência, intervenção cirúrgica, cuidados intensivos, neonatologia, dentre inúmeros outros (POTTER, 1993). As atividades hospitalares caracterizam-se por trabalho intensivo onde se exige dos funcionários alta produtividade em tempo limitado, não raro em condições inadequadas de trabalho, com possíveis problemas no ambiente, equipamentos e processos (ROSA, 1999).

A fim de permitir que os trabalhadores executem as tarefas de forma adequada, o ambiente físico deve oferecer condições relacionadas com a iluminação, conforto térmico, qualidade do ar, nível sonoro, local de trabalho e outros. A capacidade dos trabalhadores está relacionada às condições ambientais existentes no local de trabalho (HEDGE, 2005a). Se estas condições não são adequadas, problemas de saúde, insatisfação, fadiga e produtividade podem afetar os trabalhadores (ROSA, 1999). O paciente pode ser diretamente afetado pelas mesmas condições ambientais que afetam os trabalhadores. Além disso, uma vez que as condições ambientais podem afetar os trabalhadores, a qualidade do atendimento ao paciente também pode ser influenciada.

Ergonomia, também chamada de fatores humanos, é uma ciência que visa a integração entre as pessoas e seu trabalho. Centra-se no ser humano, levando em consideração suas capacidades e limitações, visando assegurar que as tarefas, equipamentos, informações e ambiente se integrem ao trabalhador (HSE, 2003). Um aspecto da ergonomia é o design do ambiente de trabalho para criar condições ambientais confortáveis, aceitáveis e que não comprometam o desempenho ou saúde do trabalhador (HEDGE, 2005a). Sabe-se que o ambiente de trabalho ergonomicamente projetado correlaciona-se com o aumento da produtividade e qualidade do trabalho além de benefícios para a saúde dos trabalhadores (STONE; McCLOY, 2004). Por outro lado, um ambiente não devidamente projetado pode criar ou contribuir para problemas de saúde, lesões, acidentes, estresse, baixa produtividade e insatisfação.

1.1 Objetivos

1.1.1 Objetivo principal

O objetivo principal deste trabalho é desenvolver uma metodologia baseada fatores humanos e ergonomia (HF/E) para avaliar o ambiente físico em áreas de atendimento ao paciente. Serão avaliados parâmetros referentes ao local de trabalho, iluminação, ruído, conforto térmico e qualidade do ar, tomadas e gases medicinais. Conforme mencionado, a metodologia tem por objetivo somente a avaliação dessas áreas e não a proposição de soluções para eventuais problemas encontrados.

1.1.2 Objetivos específicos

Criar formulários para realizar a avaliação;
Aplicar a metodologia em áreas distintas de atendimento ao paciente;
Verificar a influência do ambiente físico nos trabalhadores hospitalares.

1.2 Justificativa

Várias publicações têm descrito e analisado problemas no ambiente causados por condições insatisfatórias do posto de trabalho (NPSA, 2007; LEHTO; BUCK, 2008; BROGMUS, 2007; HASLAM, 2006), do ruído (IIDA, 2005; ALVARADO, 2012; EVANS; MAXWELL, 2005; CASALI; ROBINSON, 2003), da iluminação (WOLSKA, 2006; IIDA, 2005; SANDERS; McCORMICK, 1993; BOYCE, 2006), e de parâmetros ambientais (GIODA, 2003; QUADROS, 2008; CAIU-CARLSON, 2008; CDC, 2012; KWANG, 2000; MCDONALD, 2001; MCKEOWN, 2008; PARSONS, 2003; SANDERS; McCORMICK, 1993). Embora se saiba que o ambiente físico afeta significativamente os trabalhadores do sistema de saúde e os pacientes, em geral, o design de hospitais não é focado no ser humano. Em geral, a maioria das normas

adotadas nos projetos físicos de estabelecimentos assistenciais de saúde não considera critérios de ergonomia (REILING et al, 2004; VILLENEUVE et al, 2007). Como resultado, problemas no local de trabalho relacionados com projetos ineficientes afetam a saúde e segurança tanto dos trabalhadores quanto dos pacientes. Além disso, mesmo quando um ambiente é projetado ergonomicamente, mas não adequadamente mantido, os problemas tendem a aparecer mais cedo ou mais tarde.

A avaliação ergonômica dos ambientes hospitalares tem sido objeto recorrente de estudo (COSTA, 2005; SARAIVA, 2004; LIMA, 2004; SANTOS, 2004; ABRANCHES, 2005). No entanto, apesar do fato de que esses trabalhos têm obtido sucesso em identificar problemas ergonômicos nos ambientes analisados, a replicação de sua metodologia por pessoas não treinadas em HF/E é, por vezes, difícil. Comumente, um trabalho se concentra em um só ambiente (por exemplo, sala de cirurgia, unidade de terapia intensiva, unidade de observação), tornando-se difícil a aplicação de sua metodologia em outros ambientes, que talvez possam requerer uma abordagem levemente diferente.

As informações geradas pela metodologia serão capazes de mostrar como um parâmetro físico afeta negativamente os trabalhadores, lançando uma luz sobre as condições de trabalho existentes e estimulando o desenvolvimento de soluções centradas humano, contribuindo assim para o bem-estar de trabalhadores e pacientes.

1.3 Estrutura do trabalho

A tese é dividia em seis capítulos. O primeiro capítulo é esta introdução. O segundo capítulo, revisão de literatura, descreve fatores do ambiente físico e seus efeitos sobre as pessoas. O capítulo três explica como a metodologia foi desenvolvida. O quarto capítulo descreve o estudo de caso realizado. O capítulo cinco apresenta discussões relacionadas à pesquisa e o capítulo seis apresenta as conclusões.

1. Introduction

Traditionally, hospitals have been the main institution of the health care system. They provide services such as diagnosis, emergency medical care, surgeries, intensive care, neonatology and many other ones (POTTER, 1993). Hospital activities are characterized by intensive labor requiring high productivity in a limited period of time, often under inadequate working conditions and with possible problems related to the environment, equipment and processes (ROSA, 1999).

In order to allow workers to perform tasks appropriately, the physical environment should provide adequate conditions in terms of lighting, thermal comfort, air quality, noise level, and workplace. The health care workers' ability to perform their tasks accordingly is linked to the prevailing environmental conditions within the workplace (HEDGE, 2005a). If such conditions are not appropriate, those workers may be affected by health problems, dissatisfaction, fatigue, and low productivity (ROSA, 1999). The patient, on the other hand, can be affected both directly and indirectly by the same environmental conditions that influence the workers and by the poor quality of the service they may receive.

Ergonomics, also called human factors, is a science whose aim is to integrate people and work. It focuses on the human being, taking into account people's capabilities and limitations to assure that tasks, equipment, information and the environment meet the requirements of each worker (HSE, 2003). One aspect of ergonomics is the design of the workplace to create conditions that are comfortable, acceptable, and do not compromise work performance or workers' health (HEDGE, 2005a). It is known that an ergonomically designed work environment is connected to increased productivity and quality of work and it benefits workers' health (STONE; McCLOY, 2004). On the other hand, a poorly designed environment can create or aggravate problems such as illnesses, injuries, accidents, stress, low productivity, and dissatisfaction.

1.1 Objectives

1.1.1 Main objective

The main objective of this work is to develop a human factors and ergonomics (HF/E) based methodology to enable the evaluation of the physical environment in patient care areas. In order to do so, parameters regarding the work area, lighting, noise, thermal comfort, air quality, power outlets, and medical gas outlets will be evaluated. It should be mentioned that the methodology aims to allow the evaluation of patient care areas, and not to provide solutions to the problems that may be found.

1.1.2 Specific objectives

Create guidelines to perform the evaluation.

Apply the methodology in different patient care areas.

Verify the influence of the physical environment on health care staff.

1.2 Justification

Various publications have described and analyzed problems in the environment caused by poor conditions of the workplace (NPSA, 2007; LEHTO; BUCK, 2008; BROGMUS, 2007; HASLAM, 2006), by noise (IIDA, 2005; ALVARADO, 2012; EVANS; MAXWELL, 2005; CASALI; ROBINSON, 2003), by lighting (WOLSKA, 2006; IIDA, 2005; SANDERS; McCORMICK, 1993; BOYCE, 2006), and by environmental parameters (GIODA, 2003; QUADROS, 2008; FELL-CARLSON, 2008; CDC, 2012; KWANG, 2000; MCDONALD, 2001; McKEOWN, 2008; PARSONS, 2003; SANDERS; McCORMICK, 1993). Although it is known that the physical environment significantly affects healthcare workers and patients, in general, hospital design is not human-centered. In fact, most construction codes do not take into account

ergonomics criteria (REILING et al, 2004; VILLENEUVE et al, 2007). As a result, workplace problems related to inadequate design do affect workers' as well as patients' health and safety. Moreover, even when an environment is ergonomically designed but not properly maintained, problems will appear sooner or later.

The ergonomic evaluation of hospital environments has been a recurrent object of study (COSTA, 2005; SARAIVA, 2004; LIMA, 2004; SANTOS, 2004; ABRANCHES, 2005). However, despite the fact that these works have succeeded in showing ergonomic problems in the analyzed environments, the replication of their methodology by untrained personnel in HF/E is sometimes difficult. Usually, a scientific work focuses in only one environment (e.g. operating room, intensive care unit, observation unit), making it difficult to apply its methodology in other environments, which may require a slightly different approach.

The information generated by this methodology will be able to show how a physical parameter affects workers negatively, casting light upon the existing work conditions and stimulating the development of human-centered solutions, thus contributing to workers' and patients' welfare.

1.3 Work structure

This thesis consists of six chapters: the first chapter is the INTRODUCTION, where the need of assessing the environment conditions is shown; the second chapter, LITERATURE REVIEW, describes physical environmental factors and their effects on people; the third chapter explains how the METHODOLOGY was developed; the fourth chapter describes the RESULTS regarding the application of the methodology; the following chapter presents DISCUSSIONS related to the research; and the last chapter presents the CONCLUSIONS.

2. Literature review

2.1 Work

The Pope John Paul II said in the Laborem Exercens (1981) that through work man can transform society as well as himself. Society can be transformed by the development of science and technology, whereas the self can be transformed by the actions performed while working. Personal satisfaction may be found when, through work, a person uses his or her skills to serve a personal or community cause and also when social recognition from the worker's colleagues as well as from his or her superiors is built (FALZON, 2007).

To better understand work itself, it is important to explain the concept of work system. The ISO 26800 (2011) defines the work system as a "system comprising one or more workers and work equipment acting together to perform the system function, in the workspace, in the work environment, under conditions imposed by the work tasks". Smith and Carayon-Sainfort (1989) developed a work system model comprised of five elements: The person performing different tasks with aid of technology and tools in a physical environment, under certain organizational conditions. A diagram of such system is shown in figure 1. In a certain way, this model looks similar to the model presented above; however, the interactions between the system elements can be more easily seen. The elements of this work system will be further described focusing on healthcare.

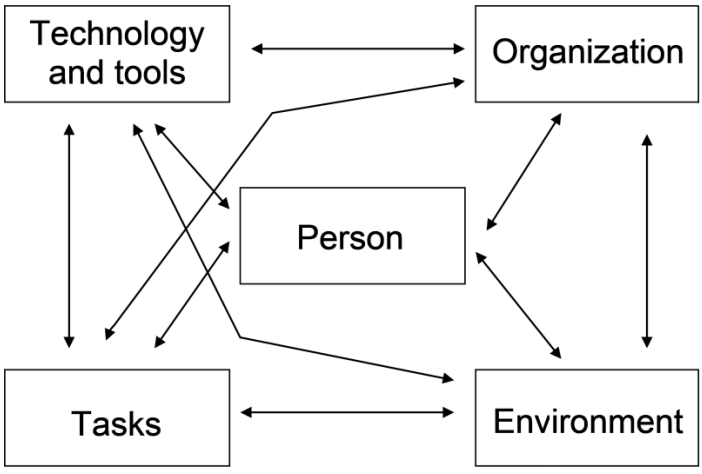


Figure 1 – Work system model

The person is at the center of the system and he or she can be a doctor, a nurse, a physical therapist, a receptionist, any other worker, or even a patient, in some analyses. The person has three main kinds of characteristics: physical, cognitive, and psychosocial ones. Physical characteristics are, for example, height, weight, strength, physical fitness, while the cognitive characteristics include knowledge, memory, information processing capacity, and expertise. The person's motivation, needs, and goals are examples of psychosocial characteristics (CARAYON, 2012).

The task can be defined as a set of actions the person performs to accomplish his or her goal. This task can be characterized regarding difficulty, content, variety, repetitiveness, skill utilization, autonomy and job control, clarity, uncertainty, demands, contact with others, and feedback (CARAYON; ALVARADO; HUNDT, 2012).

To perform the tasks, the person uses tools and technology which can vary in terms of complexity (from paper and pencil to a magnetic resonance imaging system), price (cents to millions of dollars), and use (administrative tasks, patient monitoring, patient therapy). There is a significant interaction between technology and the physical and psychological characteristics (CARAYON, 2012). For example, a badly designed piece of equipment may demand that the operator assume awkward postures causing musculoskeletal problems. Another device may have a clumsy menu system demanding excessive mental effort to set up required parameters.

The physical environment can be characterized by the following parameters: noise, lighting, temperature and humidity, air flow, air quality, vibration, space and layout. Our ability to perform tasks is linked to the prevailing environmental conditions in the workplace. Although the human body has adaptive physiological mechanisms that allow us to tolerate a range of physical environmental conditions, when these conditions exceed the limit of the body's adaptive mechanisms, performance, as well as health, is deteriorated (HEDGE, 2005a).

Organizational conditions influence the way a person performs tasks. Some of these conditions are: work schedules, organizational support (e.g., social support from supervisors and managers, resources provided during a technological or organizational change), communication, collaboration, coordination, decision-making structure, as well as role characteristics (such as ambiguity and conflict), training, rewards, benefits, performance evaluation, teamwork, and organizational culture (CARAYON; ALVARADO; HUNDT, 2012).

The work system imposes physical and/or mental loads on the individual. Examples of physical load are lifting, pushing and pulling, and patient handling, while mental load is related to problem solving, patient status evaluation, and decision making. Both loads can have physiological and psychological effects. Physiological loads may produce stress if they exceed the available physical resources, whereas psychological loads can cause emotional, behavioral, and biological consequences (ISO, 2004a; CARAYON; ALVARADO; HUNDT, 2012).

The perception of the load by the individual depends on his or her personality, past experiences, and social situation. This explains why people experience the work environment in different ways and why some people can deal more efficiently with certain conditions than others. However, if the loads affect the worker negatively, physical and mental problems may arise in the long-term. Physical problems can be musculoskeletal injuries, physical stress, and fatigue, while mental problems can be boredom, burnout, and depression (ISO, 2011; CARAYON; SMITH, 2000).

2.2 The environment

The importance of the environment in people's health and well-being has been known for centuries. According to the Hippocratic treatise *De aere aquis locis* (Airs, Waters, Places), written circa 400 B.C., the people's physical condition and the occurrence of diseases can be related to the seasons, the winds, and the quality of air and water (LAST, 2007; HIPPOCRATES, 400 BC; FRANCO; WILLIAMS, 2000). The treatise advises that, whenever a physician visits a city he has not been before, he should observe the environmental factors cited above, as well as the inhabitants' way of life (food, drinking, labor) to determine endemic diseases.

In the book *De Re Metallica*, written in 1556, Georgius Agricola points out that the air is so dry in some mines that the dust created by the digging penetrates into the windpipe and lungs causing breathing difficulties and asthma. He also cites that stagnant air existing in shafts or tunnels also causes breathing difficulties and even suffocation. As a solution to this

problem, the author proposes the use of ventilating machines, called by the Greek *pneumatikai*, to replenish the air in these places (AGRICOLA, 1950).

In 1700, the Italian physician Bernardino Ramazzini describes the effects of work and workplaces on about fifty different health professionals in the book *De Morbis Artificum Diatriba* (Diseases of Workers). He states that bakers, for instance, get sick more often than other "artisans", mainly because of the high temperatures of the ovens. The author observes that millers, on the other hand, suffer from deafness caused by the noise of water operated machines. He also notes that scholars who used nut oil lamps in bad ventilated places get intoxicated (RAMAZZINI, 2000; SKROBONJA; KONTOSIC, 2002). Ramazzini even proposes that physicians should ask their patients the question "What is your occupation?" during the anamnesis.

Florence Nightingale (1863) describes four problems that cause diseases in hospitals. The first problem is the large number of sick people in the same environment, increasing administrative, cleanliness, and proper ventilation needs. The lack of space per bed is the next factor mentioned: small space between adjacent beds can cause ventilation problems and affect the patient care. The third problem is the lack of ventilation. The author says that ventilation can affect patients' health and also the level of carbonic acid and organic matter in the environment. Finally, the last factor mentioned is the lack of light. She states that patients recover fast in lighter places than in darker ones.

Despite all those reports on the environmental effects on workers, little was done to prevent them. For example, during the industrial revolution it was common to find crowded workplaces, with bad lighting, high noise, and inadequate ventilation. These places were prone to accidents and diseases. Since profit seemed to be the manufacturers' main and only worry at that time and workforce was abundant, businesspeople did not feel motivated enough to provide satisfactory working conditions (ARAUJO, 2012).

2.3 Ergonomics

During industrial revolution, machines were designed without taking human beings into account. In fact, efforts were made to fit people into machines (MEISTER, 1999). For example, there was once one trial and error test to verify which individuals could fit into the

device. If the person met the machine's needs, he or she was accepted, otherwise he or she was rejected. The test was repeated until a candidate was approved. The worker was simply considered a nonessential but convenient element whose value was limited to operating the machine (MEISTER; O'BRIEN, 2002).

In the late 19th century, Taylor proposed the Scientific Management Theory, a process that used systematic methods of work analysis and design aiming at finding the optimum way to perform a given task (TAVEIRA; SMITH, 2006; TAYLOR, 1911). For instance, he was able to triple the amount of coal that workers shoveled by reducing the size and weight of coal shovels.

Following Taylor's theory, Frank and Lillian Gilbreth developed the time and motion study, a method used for the improvement and upgrading of work systems by eliminating unnecessary steps and actions. The Gilbreths applied their theory in bricklaying, allowing bricklayers to increase their productivity from 120 to 350 bricks per hour (MEISTER, 1999).

The World War II involved a great number of men and women, making it impossible to adopt the principle of choosing a few skilled individuals to fit a job. It became necessary to design the physical characteristics of equipment considering the advantages of human capabilities and avoiding human limitations (MEISTER, 1999). Research was done in order to accomplish these objectives mainly in the military field. After the war, civil industries began to apply the same design principles used in the army.

The events described above were some of the contributions of rising ergonomics or human factors, defined by the International Ergonomics Association (2001) as a "scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system performance". Ergonomics is a human-centered approach to design, meaning that "all designable components of a system, product or service are fitted to the characteristics of the intended users, operators or workers, rather than selecting and/or adapting humans to fit the system, product or service" (ISO, 2011).

When designing work systems, the interactions between the person and the other work elements such as tasks, environment, equipment and organization should be taken into account, since work stress is created by the effect of these interactions on the worker. As a result, work stress causes responses in the worker, named work strain, which depend on personal

characteristics such as size, age, abilities, skills, and other ones. Work strain can have positive (e.g. skill development) or negative effects (e.g. fatigue). Ergonomic work system design focuses on optimizing work strain by reducing negative effects and increasing positive effects on the worker (ISO, 2004a).

The ISO 6385 (2004a), describes the design of work system components: work organization, work tasks, jobs, work environment, work equipment (hardware and software), workspace and workstation. The work environment is of special interest and, according to the same standard, it "shall be designed and maintained so that physical, chemical, biological, and social conditions have no adverse effect on people, but serve to ensure their health as well as their capacity and willingness to perform the tasks under consideration." It has to be emphasized that the maintenance of work environment parameters within the limits is of utmost importance for the health and well-being.

The physical environment is a part of the work environment (ISO, 2011). Factors such as lighting, noise, climate, space, arrangement of space, and other ones constitute the physical environment and affect workers' safety, quality of care, and quality of working life, as well as patients' safety, stress, and satisfaction (ALVARADO, 2012). These factors will be described hereafter emphasizing its importance in health care.

2.4 Work area

The work area may be defined as an area inside a facility or building in which people perform their tasks, whereas the workplace can be defined as the place where the worker performs his or her activities, for instance, a desk, an airplane cockpit, a workbench, an assembly-line station, a surgical table, a patient bed. A work area may encompass more than one workplace and it is also possible that several people use the same work area at the same or different workplaces (LEHTO; BUCK, 2008). Considering all work area factors that influence both the worker and the way he or she accomplishes the tasks (ALVARADO, 2012; MARMARAS; NATHANAEL, 2006), the environment dimensions and the risk of slip, trip, and fall accidents are of particular interest and will be explained hereafter.

2.4.1 Dimensions

Workers need enough space to move around work areas and access everything that is needed while performing the tasks. Traffic areas, such as aisles, passageways, doors, entrances, ramps, and stairs, must be properly designed to allow convenient, unimpeded ingress, egress, and movement around a physical facility with no barriers on the way. Tools, parts, or other objects on traffic areas may use up much of the available space, and significantly interfere with people's ability to perform their tasks as intended. Adequate space does not guarantee appropriate performance, although poor performance is almost certain in its absence (LEHTO; BUCK, 2008; PHEASANT, 2003; MACLEOD, 2000).

Clearance problems are a frequent and significant issue in workspace design, sometimes making it difficult for a worker to access certain work areas. The space between and around equipment, the height and width of passageways, the dimensions provided for the knees, the legs, the elbows, the feet, and the head are some examples of clearance design problems (LEHTO; BUCK, 2008). Small spaces may hinder workers movement, leading to trips or bumps in the environment or even forcing the adoption of awkward postures, causing discomfort and reducing productivity (WICKENS et al, 2004).

2.4.2 Slip, trip, and fall

Slip, trip, and fall (STF) accidents in healthcare pose a risk for both the worker and the patient. In the United States, according to the Bureau of Labor Statistics (2012), in 2010, 14,160 STF events accounted for 24% of all work-related injuries in hospitals, requiring at least one day away from work. In nursing and residential care facilities, there were 15,660 STF events, accounting for 26% of all work-related injuries (COLLINS; BELL, 2010). The National Patient Safety Agency (NPSA) cites that about 200,000 patient falls were reported from September 2005 to August 2006 in the United Kingdom, estimating about 24 falls per week in one 800 bed acute care hospital, with associated health care costs of £92,000.00 per year (NPSA, 2007).

Slip occurs when the friction between the foot and the floor is insufficient to prevent movement between the two surfaces. It can occur either at the toe off or heel strike phases of walking (HASLAM, 2006). Environmental factors that usually cause slips are poor grip

or low friction between the footwear and the floor, liquid spillage or powders, uneven surfaces, small objects or clutter on the floor, insufficient lighting, and footwear (HASLAM, 2006; CHANG; GRÖNQVIST, 2006; LEAMON, 2000; LEHTO; BUCK, 2008). Leamon (2000) describes three types of slip: the microslip, which is shorter than 2 cm; the slip, usually 8 to 10 cm long; and the slide, which happens if the slip is longer than 10 cm.

Tripping happens when the foot is arrested by an obstacle or an object with continuing motion of the body, and it can cause serious injuries (LEHTO; BUCK, 2008). Tripping can be caused by small objects or clutter on the floor, cords and cables, low profile equipment and supplies (buckets, rolling stools, step stools, Mayo stands, boxes, etc.), protective and absorptive mats, and floor incongruities (LEAMON, 2000; LEHTO; BUCK, 2008; BROGMUS, 2007; HASLAM, 2006).

Falls usually result from slipping or tripping and can cause injury in both healthcare workers and patients (HERWALDT; POTTINGER, 2003; TINETTI, 2003; KERZMAN, 2004; LEHTO; BUCK, 2008). A review of about 150,000 patient falls, in the United Kingdom, in a period of 12 months has determined that about 66.5% (101,000) of falls caused no harm; 29.5% (44,800) caused low harm, requiring first aid, minor treatment, extra observation or medication; 3.3% (5,000) caused moderate harm, which required outpatient treatment, admission to hospital, surgery or a longer stay in hospital; 0.7% (1,000) caused severe harm, such as brain damage, fractures, or disability; and less than 0.1% (21) may have caused patients death (NPSA, 2007).

2.5 Noise

Sound is produced by vibration of the air molecules and is the objective cause of hearing. The sound intensity is expressed in decibels (dB) and calculated according to the following equation:

$$\text{Sound intensity (dB)} = 20 \log (P/P_{ref}),$$

where P is the sound intensity being calculated and P_{ref} is 20 μPa, the lowest amplitude of pressure oscillations in air detectable by the ear at a frequency of 1,000 Hz (WICKENS et al, 2004).

The average audible frequency range is 20 Hz to 20 kHz. A healthy young person has no trouble hearing sounds within this range, however the upper frequency limit drops with aging and older people usually cannot hear sounds above 10 kHz (BRIDGER, 2003; KANG, 2007). Auditory sensitivity is greatest between 500 Hz and 5 kHz, with 84% of speech energy taking place at frequencies below 1 kHz (FALZON, 2007; CHAPANIS, 1996; CHARLTON; O'BRIEN, 2003).

Noise has many definitions. Commonly, it is defined as an undesirable or unwanted sound (SCHOOL, 2006; KROEMER; GRANDJEAN, 2005). Burrows (1960) considers noise as an auditory stimulus or stimuli bearing no informational relationship to the presence or completion of the immediate task (SANDERS; McCORMICK, 1993). Hilton (1985) states that noise is a sound at the level above the recommended for hospitals and perceived by patients as undesirable.

Noise perception varies among people depending on the source (music, barking dog, equipment, crying children, etc), the intensity (decibel level), and the meaning each person attributes to it (like, dislike, important, irrelevant, etc) (KEARNEY, 2008). The noisiness of a sound often results from the subjective perception of how annoying it is (SCHOOL, 2006). For example, a teenager cannot feel bothered about rock music played at 90 dB but his or her parents may feel so. Another interesting example can be found in Medscape (2008): a mother of a child in treatment in a NICU felt his baby's crying as "music for her ears", since it meant that the crying was normal and the baby was going to be okay (MEDSCAPE, 2008).

In the mid-20th century, noise in healthcare environment was similar to that of a library. Nowadays, it seems that library noise is at the similar levels of the mid-20th century, while hospitals became a place of beeping, buzzing, banging, clanging, and shouting (GRUMET, 1993). Apparently, noise became an omnipresent aspect of healthcare, adversely affecting not only workers but also patients. Instead of reducing noise, people may get used to it, unaware of its harmful effects and trying to cope with it the best way possible (MEDSCAPE, 2008). Although noise can have positive effects (POULTON, 1978), hereafter the negative auditory and non-auditory effects of noise will be described, as well as its effects on patients and common noise sources at the healthcare environment.

Noise can mask other sounds, thus interfering with communication, hearing alarms, warnings and other signals, causing misinterpretation of instructions and even interfering

in care measures such as breath or chest sounds or blood pressures. It can also disrupt “inner speech”, making it difficult for a person to hear his or her own thoughts, as well as to concentrate. In addition, it affects cognitive performance, causes annoyance and irritation, and contributes to stress and fatigue. It can also lead to negative emotional reactions such as frustration, depression, apathy, anxiety disturbance, distress, fear and even burnout. Noise dissatisfaction is believed to negatively influence job and working environment satisfaction and work commitment, affecting performance and productivity (JOB, 1993; IIDA, 2005; ALVARADO, 2012; BERGLUND; LINDVALL; SCHWELA, 1999; HAINES et al, 2001; EVANS; MAXWELL, 2005; CASALI; ROBINSON, 2003).

Noise can cause physical problems, such as tinnitus (ringing ears) both in the short and long term; temporary hearing loss, referred to as temporary threshold shift; permanent threshold shift; and, in some cases, permanent deafness (WICKENS et al, 2004; FALZON, 2007; EVANS; MAXWELL, 2005; HELANDER,2006; POULTON, 1978; CASALI; ROBINSON, 2003; BRIDGER, 2003; SCHOOL, 2006). In order to prevent the latter effects, Brazilian standard NR 15 (2011) establishes a maximum daily exposure time for diverse noise intensities. For example, a worker can be daily exposed to noise of 85 dB for 8 hours, while this limit changes to 7 minutes if the noise is 115 dB. In addition to physical problems, physiological effects of noise include hypertension, heart irregularities, increase of tachycardia, extreme fatigue, and digestive disorders, most of these physiological effects being symptomatic of stress-related disorders (EVANS; MAXWELL, 2005; CASALI; ROBINSON, 2003). Figure 2 (KK INSTRUMENTS, 2012; EPD, 2012) shows an example of a sound level scale together with the subjective impression of certain sound levels.

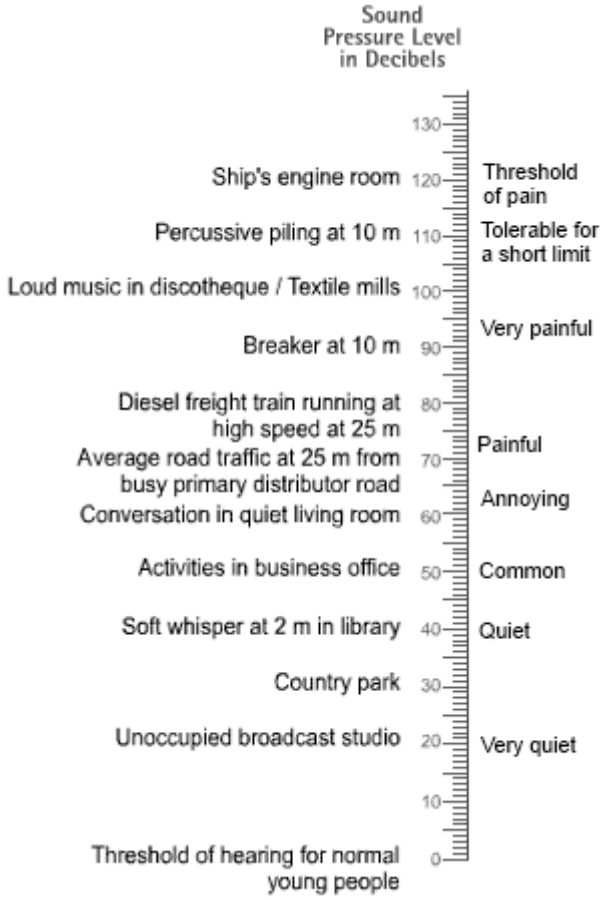


Figure 2 – Sound level scale and its effects on people in general

Short bursts of very high intensity sound (such as an explosion or gunfire), known as impulse noise, can also cause additional harm to the ear by rupturing the tympanic membrane (LITCHFIELD, 2003). Impulsive noise can also cause startle reaction, interfering with task performance and slowing reaction time for other tasks (MATSUMOTO; HALLET, 1994 apud BRIDGER, 2003).

Patients are usually more susceptible to noise effects than workers due to their condition. In fact, some studies show the negative effects of noise in the healing process (McCARTHY et al, 1991). Excessive noise can lead to increased anxiety and pain perception, irritability, prolonged convalescence and even ICU (Intensive Care Unit) psychosis (BAKER, 1984, 1993; BAKER et al, 1993; WILLIAMS, 1998; DRACUP, 1998). Sleep disturbance is another symptom, including reduced REM sleep, awakening in the middle of sleep, and increasing alertness (BERENS, 1999; TOPF, 1992; KRACHMAN, S.L., D´ALONZO, G.E.,

CRINER, 1995; KROON; WEST, 2000). Noise induced patient stress is reported in various studies (HEIDEMANN et al, 2011; PEREIRA et al, 2003; AKANSEL; KAYMAKÇI, 2008; HAGERMAN et al, 2005; STANCHINA et al, 2005; SCHMAKER, PEQUEGNAT, 1989). Physiological symptoms, such as elevated blood pressure in adults and higher heart and respiratory rate of neonates can be noise correlated (ONEN et al, 2001; BERENS, 1999; TOPF, 2000; BREMMER et al 2003; EVANS; MAXWELL, 2005).

There is a great number of noise sources in hospitals. In fact, 86 different noise sources were identified by MacKenzie and Galbrun (2007). Conversation seems to be a common cause of noise and annoyance due to both the sound level and the "irrelevant speech". Patients also generate noise by screaming, talking, and even snoring. Other sources include air conditioning systems, oxygen or compressed air hiss, TVs, telephones, announcement system, rubbish bins. In addition, equipment such as patient monitors, ventilators, anesthesia machines, infusion pumps, suction devices and its alarms also contribute to noise generation. The ambient reverberation also plays an important role, since it can enhance or attenuate noise (ALVARADO, 2012; SCHOOL, 2006; MEDSCAPE, 2008; MACKENZIE; GALBRUN, 2007).

There are standards and guidelines which establish noise levels in hospitals. The World Health Organization (BERGLUND; LINDVALL; SCHWELA, 1999) recommends that the noise level at night be no more than 40 dB(A) while the US Environmental Protection Agency (EPA, 2012) establishes 45 dB(A) as the maximum level. Table 1 below summarizes the noise level recommendations from the Facilities Guideline Institute (FGI, 2010) and ABNT (1987) for some hospital areas.

Table 1– FGI and ABNT noise level recommendations

Area	FGI – 2010 (dBA)	NBR 10.152 – 1987 (dBA)
Patient room	35-45	35-45
Multiple occupant patient care area	40-50	35-45
Operating rooms	40-50	35-45
Testing/research lab	50-60	40-50
Public spaces	40-50	40-50

Source: FGI, 2010; ABNT, 1992b.

2.6 Lighting

According to Sanders and McCormik (1993), Wolska (2006), and Lehto and Buck (2008), the general purpose of lighting is to ensure visual comfort, visual performance, and visual safety, making details easier to see and colors easier to discriminate without producing discomfort or distraction, and without the risk of causing negative effects on human performance, morale, and safety. In fact, over 80% of information about the surroundings is obtained through the eyes. Lighting conditions can be described by the following parameters, which determine whether the luminous environment is satisfactory or not: illuminance, luminance, color aspects (color appearance and rendering), glare, shadow, and flicker (WOLSKA, 2006).

Illuminance, also called illumination, is the concentration of luminous flux falling on a surface, that is, the incident flux per unit area, and its unit is lux. The equation $E=\frac{I}{d^2}\cos(\theta)$ states that the illumination **E** (lux) at a point on a surface varies directly with the luminous intensity **I** (lumen) of the source, the angle of incidence **θ** (the angle between the normal to the surface and the direction of the incident light), and inversely as the square of the distance **d** (m) between the source and the point (REA, 2000; KROEMER; GRANDJEAN, 2005).

The illuminance level required for visual task performance depends on the apparent target size and the degree of visual task difficulty. It affects how quickly, safely, and comfortably the worker can carry out the task. The illuminance level usually has a direct relationship with the task difficulty and an inverse one with the target size: the greater the visual difficulty, the greater the effect of illuminance. However, increasing the illuminance more than necessary does not make a difficult visual task easier (WOLSKA, 2006). On the contrary, it can cause adverse effects, such as glare, shadows, and visual fatigue, without increasing performance (IIDA, 2005). Variation of illuminance should be taken into account inside the visual task area and around it. Excessive changes of illuminance in the visual field may lead to visual distress and discomfort, and too much non-uniformity of lighting in circulation areas can cause poor visibility of obstacles and, eventually, accidents (ISO, 2002; WOLSKA, 2006).

The Brazilian standard NBR 5413 (ABNT, 1992a) recommends three illuminance values (low, medium, high) to several environments. The standard usually recommends the use of

the medium value, whereas the selection of the higher or lower value depends on factors such as the person's age and task factors, including complexity, speed, and luminance (explained below). On the other hand, ISO standard 8995 (ISO, 2002) recommends one value to illuminance, which can be changed at least one step in the scale 20 - 30 - 50 - 75 - 100 - 150 - 200 - 300 - 500 - 750 - 1000 - 1500 - 2000 - 3000 - 5000 lux. The factors that influence the illuminance adjustment are similar to those of NBR 5413. The recommended values for the same place can vary depending on the standard. For example, the NBR 5413 recommends 300-500-750 lux as the general lighting in the operating room while, according to ISO 8995, the recommended illuminance is 750-1000-1500 lux.

Luminance can be defined as the luminous intensity emitted or reflected by a surface, and its unit is candela per square meter (cd/m^2) (KROEMER; GRANDJEAN, 2005). Luminance distribution, on the other hand, can be described as either luminance ratios (contrast) of adjacent surfaces and surfaces viewed in sequence or as reflectance of major interior surfaces. The luminance distribution in the visual field controls the adaptation level of the eyes and affects task visibility. Excessively high luminance ratios can cause visual fatigue and/or glare; however, excessively low luminance ratios generally result in a dull and non-stimulating working environment (ISO, 2002; WOLSKA, 2006).

The quality of the color of light emitted by lighting sources is characterized by color appearance and color-rendering capabilities. The color appearance refers to the apparent color (chromaticity) of the light emitted by a given lighting source and is described by the correlated color temperature (Tcp) in Kelvin (K). There are three main groups of color appearance according to their correlated color temperature: warm (Tcp < 3300 K), intermediate (3300 K ≤ Tcp ≤ 5300 K), and cool (Tcp > 5300 K) (ISO 8995, 2002). Color rendering describes the appearance of the colors of the objects under a given light source compared with their appearance under a reference source. With better color rendering, colors appear more vibrant or close to natural, while poor color rendering can even distort color perceptions. A general color-rendering index, CRI or R_a, has been introduced to the objective identification of color-rendering properties. On a scale from 0 to 100, its maximum value of 100 represents excellent color rendering. Perceived color saturation is lower under lamps with poorer color rendering than under lamps having better color rendering (WOLSKA, 2006; LEHTO; BUCK, 2009).

Glare is produced by brightness, within the field of vision, that is sufficiently greater than the luminance to which the eyes are adapted, so as to cause annoyance, discomfort, or loss in visual performance and visibility. Glare occurs in direct and reflected ways: direct glare is caused by light sources in the visual field, whereas reflected glare, sometimes called veiling reflection, is caused by light being reflected by a surface within the visual field. Reflected glare can be specular (as from smooth, polished, mirror like surfaces), spread (as from brushed, etched, or pebbled surfaces), diffuse (as from flat-painted or matte surfaces), or compound (a combination of the first three) (SANDERS; McCORMICK, 2003). Moreover, glare may also be experienced as either discomfort glare or disability glare (ISO, 2002). Discomfort glare causes feelings of discomfort, annoyance, and irritation, without necessarily impairing the vision of details or objects. It increases with time and may contribute to fatigue. Disability glare impairs the vision of details or objects, since both visibility and visual performance are reduced without necessarily causing discomfort (WOLSKA, 2006).

Shadows are cast when light coming from a particular direction is intercepted by an opaque object. If the object is big enough, the effect is to reduce the illuminance over a large area. If the object is smaller, the shadow can be cast over a meaningful area which, in turn, can cause perceptual confusion (BOYCE, 2006). Shadows on the work surface may cause poor quality work, low productivity, eye strain, visual fatigue and even accidents (FUNDACENTRO, 2001).

Flicker is the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates over time. It usually causes distraction but it can also cause headaches or various visual complaints (ISO, 2002). A lighting installation which produces flicker will be almost universally disliked, unless it is being used for entertainment or in a localized area to attract attention. Flicker usually increases with the lamp's age, especially for fluorescent lamps, and can be avoided by replacing old lamps with new ones (WOLSKA, 2006; BOYCE, 2006).

It is known that lighting can have both positive and negative effects on the patient. A study by Walch and colleagues (2004) showed that a group of patients exposed to higher-intensity sunlight than the control group experienced less stress, took 22% less analgesic medication per hour, and thus contributed to a decrease of 21% in pain medication costs. Reiling and Chernos (2007) state that proper lighting is necessary to conduct an accurate assessment of

the patient, since the light source chosen can change patients' appearance, causing unnecessary concerns about potential changes in patient's medical condition. Joseph (2006) found that by controlling the body's circadian system, light impacts on the outcomes in health care settings by reducing depression in patients, decreasing length of stay in hospitals, improving sleep and circadian rhythm, lessening agitation among dementia patients, and easing pain.

2.7 Environmental parameters

Indoor air quality and thermal comfort should be provided to the occupants of the work environment. Commonly, ventilation is used to achieve these goals.

2.7.1 Indoor air quality

Clean air can be defined as the dry atmosphere air found in rural areas or over the ocean far away from air pollution sources. Air quality refers to the degree of pollution of the clean air, which is, the fewer air pollutants the cleaner the air (ZHANG, 2005). Indoor air quality, sometimes referenced as indoor environmental quality, refers to the quality of the air in an office or other building environment such as a school, a mall, or a hospital (CDC, 2012). Indoor air quality depends not only on outdoor air quality, but also on the activities performed inside the building (STATHOLOUPOU, 2008).

Airborne pollutants can be defined as any substance in the air that can harm the health and comfort of humans and animals, reduce performance and production of plants, or accelerate damage on equipment. Usually, the lower the concentration of pollutants, the better the air quality. They can be in the forms of solid, liquid, and gaseous substances emanated from various sources (ZHANG, 2005). There are several ways to classify air contaminants: chemical, physical, and biological; particulate and gaseous; biological and non-biological. Only the latter way will be briefly described hereafter, since a complete description of all contaminants would be time consuming and it is not the main objective of this work.

The non-biological contaminants include asbestos, carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde, nitrogen monoxide (NO), nitrogen dioxide (NO_2), sulfur dioxide

(SO_2), ozone (O_3), radon, tobacco smoke, particulate matter (a set of organic and inorganic substances including aromatic hydrocarbon compounds, trace metals, nitrates, and sulfates, dusts, fumes, solid material degradation, paper fragmentation, and similar materials), and volatile organic compounds (chemical compounds that contain at least one carbon and a hydrogen atom in their molecular structure and evaporate easily) (WHO, 2010; ZHANG, 2005; JONES, 1999). Symptoms caused by non-biological contaminants include, but are not limited to, irritation in the lungs, throat and eyes, respiratory diseases, pharyngitis, cough, respiratory infections, bronchitis, sneezing, pneumonia, pulmonary emphysema, skin irritations, lung cancer, headaches, nausea, dizziness and fatigue (GIODA, 2003; WOLKOFF et al, 1997; MCDONALD, 2001; SCHWARZBERG, 1993; EPA, 1994; FELL-CARLSON, 2008)

Biological airborne contaminants, also called bioaerosols, refer to any airborne biological particulate matter. They consist of microorganisms such as fungi (mold included), bacteria, viruses, protozoa, and algae. Bioaerosols may also be derived from plants (pollen and plant fragments), and animals (hair, dander, and saliva from dogs and cats; dust mites). In addition to the intact organisms (e.g., bacteria), their parts (fungal spores and fragments), components (endotoxins, allergens), and products (dust mite antigen-containing fecal pellets and fungal mycotoxins) may be included in the bioaerosol class (ASHRAE, 2009). Symptoms caused by biological contaminants include, but are not limited to, sinusitis, allergic rhinitis, stuffy or runny nose, asthma, fever, allergies, atopic dermatitis, cough, weight loss, muscle aches, stiffness, joint pain, loss of energy, breathing difficulty, sneezing, nausea, and infections (IEH, 1996; EPA 1994; ASHRAE, 2009; FELL-CARLSON, 2008).

Another important aspect of air quality is odor. It is formed mainly by the presence of volatile organic and inorganic compounds in the air, which are taken up by the olfactory mucosa and recognized by the brain as odorant (BELLI FILHO; LISBOA, 1998). Sources include tobacco products, bathrooms and toilets, building materials (e.g., adhesives, paints, processed wood, carpets, plastic sheeting, insulation board), consumer products (e.g., food, toiletries, cleaning materials, polishes), hobby materials, fabrics, and foam cushions. In offices, copiers, and computer printers may also produce odors. Electrostatic processes may emit ozone, which has a chlorine-like odor. In addition, humans emit a wide range of odorants, including acetaldehyde, ammonia, ethanol, and hydrogen sulfide (ASHRAE, 2009). In hospitals, for

example, the patient can emit odors caused by his or her health conditions (MOHAMADDI; O'MARA, 1996).

There can be considerable variation between individuals regarding the perceived pleasantness or unpleasantness of a given odor. Responses to odors may be determined by prior experiences and can include strong emotional reactions (FREY, 1995). Odors do not always induce adverse reactions, but in some situations they can cause irritation, distraction, nausea, dizziness, revulsion, headache, and loss of appetite (ASHRAE, 2009; QUADROS, 2008; CAIN; COMETTO-MUÑIZ, 1995; MOHAMADDI; O'MARA, 1996).

2.7.2 Thermal comfort

Thermal comfort is defined by ASHRAE (2004) and ISO 7730 (2005) as the condition of mind which expresses satisfaction with the thermal environment. Since there are both physiological and psychological variations from person to person, it is difficult to satisfy everyone in the same space. The environmental conditions required for comfort are not the same for everyone. However, extensive laboratory and field information has been collected in order to provide the necessary statistical data to define environmental conditions that a specified percentage of occupants would find thermally comfortable. Thermal comfort depends on four environmental factors: air temperature, mean radiant temperature, humidity, and air speed; as well as on two personal factors: metabolic rate, and clothing insulation.

According to ASHARE (2004), air temperature is the average temperature of the air surrounding an occupant. Humans react to the conditions within their environment to preserve their internal temperature within an optimal range of about 37 ^{o}C. For that reason, they are referred to as homeotherms. If the air temperature is such that the environment is considered cold, blood circulation to the skin is reduced by vasoconstriction to prevent heat loss, which can lead to a drop in skin temperature and an increase in complaints about the cold environment. It can also cause a reduction in performance. If the air temperature is such that the environment is considered hot, the body uses mechanisms such as vasodilatation and sweating to regulate its temperature. Vasodilatation can cause changes in blood pressure and sweating can contribute to

dehydration and even a drop in the individual's level of arousal (McKEOWN, 2008; PARSONS, 2003).

The mean radiant temperature can be defined as the temperature of a uniform enclosure with which a small black sphere at the test point would have the same radiation exchange as it does with the real environment (PARSONS, 2003). When mean radiant temperature exceeds skin temperature, heat transfers from the environment to the skin; on the other hand, when the skin temperature exceeds the mean radiant temperature, heat transfers from the skin to the environment. All practical thermal environments have an asymmetric radiation field to some degree. However, if the asymmetry is sufficiently large, discomfort may arise, for example, among people exposed to direct sunlight, heated ceilings, heated parts of devices, or large cold windows or walls (HAVENITH, 2005; PARSONS, 2003).

Humidity is a general reference to the moisture content of the air (ASHRAE, 2004). Often air humidity is expressed as relative humidity, i.e., the actual amount of moisture in the air compared to the maximum amount possible at that temperature (HAVENITH, 2005, PARSONS, 2003). Low humidity can result in dryness in noses and throats, dry skin and chapped lips (SANDERS; McCORMICK, 1993). A perceivable level of eye irritation is experienced by both contact lens wearers and non-wearers when the relative humidity is at or below 30%, the effect becoming pronounced after 4 hours of exposure. On the other hand, if a person cannot efficiently evaporate heat-induced sweat away from their body due to the high moisture content in the surrounding air, their thermal comfort declines (ALVARADO, 2012).

Air speed is defined as the average speed of the air to which the body is exposed (ASHRAE, 2004). Air movement across the body can influence heat flow to and from the body and hence body temperature. When the air speed exceeds certain limits, it can cause drafts, which influence individual's temperature perception and even cause discomfort. A draft originating from behind the body will be viewed as less acceptable than one originating in front of the body. The ankles and neck are more susceptible to drafts than other parts of the body and the colder the draft, the less pleasant it is considered to be by the individual. The perception of a draft depends on air velocity and its degree of disturbance, air temperature, area of the body exposed and the thermal state of the person (PARSONS, 2003). The standard NBR 16401-2 (ABNT, 2008b) establishes the maximum air speed for thermal comfort by using conventional air conditioning as 0.20 m/s during summer and 0.15 m/s during winter.

Another important aspect in this matter is the fact that metabolic activities result almost completely in heat that must be continuously dissipated and regulated to maintain normal body temperature. Insufficient heat loss leads to hyperthermia and excessive heat loss results in hypothermia (ASHRAE, 2009). Metabolic rate varies depending on the activity, the person (age, size, fitness), and the conditions under which the activity is performed (TOFTUM, 2005; McQUISTON; PARKER; SPITLER, 2005). For thermal comfort or low thermal strain, heat production and heat loss should be the same or close to each other, resulting in a relatively stable body temperature. Metabolic rates for a large number of activities can be estimated using tables describing activities, professions, postures, and other factors. The unit used to express the metabolic rate per unit of area is the met, defined as the metabolic rate of a sedentary person (sitting, quiet), where 1 met = 58.1 W/m^2. Met levels can vary from 1.0-1.2 for light or sedentary work up to more than 3.4 for hard work (HAVENITH, 2005; ISO 8996, 2004; ISO 7730, 2005, ASHRAE, 2009). A person with a high metabolic rate can perceive the environment as hot, whereas the same person with a low metabolic rate can perceive the same environment as neutral or even cold.

Clothes individuals wear will have an impact on their perception of how acceptable the environment is for the work they do. Clothing insulation varies between occupants in a space due to differences in clothing preferences, company dress code, season, etc. Once the worker wears clothes, a microclimate is created between the human body and the clothing internal surface. This microclimate should allow workers to maintain a satisfactory heat level by maintaining skin temperature and permitting the required amount of sweating (PARSONS, 2005; McKEOWN, 2008; TOFTUM, 2005). Each clothing material has an insulation value, expressed in **clo** units, which is related to the amount of trapped air within the weave and fibers and permeability of the material to moisture. In hot environments, evaporation of sweat is vital to maintain thermal equilibrium, and materials that interfere with this process can result in heat stress or even heat stroke. In a cold environment, if evaporation of sweat is prevented, a garment can become soaked with perspiration, thus reducing its insulating capacity and warmth (ALVARADO, 2012). A person wearing clothes with a higher insulation value would perceive the environment as hotter than if he or she were wearing clothes with lower insulation value. As an example, the typical values for clothing insulation when the outdoor environment is warm and cool are 0.5 clo and 1.0 clo, respectively (ASHRAE, 2004).

As stated earlier, the work environment should provide indoor air quality and thermal comfort to its occupants. Ventilation is a determinant of thermal comfort and, more generally speaking, of satisfaction with the indoor environment. Its main purpose is to provide fresh air to the environment, to remove accumulated noxious gases and contaminants, to remove heat generated in the working area, and to regulate the air temperature (BRIDGER, 2003). Usually, there are two main types of ventilation to accomplish these objectives: natural ventilation and air conditioning. Each type will be briefly described hereafter.

According to ASHRAE (2009), natural ventilation is the flow of outdoor air caused by wind and thermal pressures through intentional openings in the building. Under some circumstances, it can effectively control both temperature and contaminants in mild climates, but it is not considered practical in hot and humid climates or in cold climates. The arrangement, location, and control of ventilation openings should combine the driving forces of wind and temperature to achieve a desired ventilation rate and good distribution of ventilation air through the building. However, despite the fact that temperature control by natural ventilation is often the only means of providing cooling when mechanical air conditioning is not available (ASHRAE, 2009; WALKER, 2010), intentional openings cannot always guarantee adequate temperature and humidity control or indoor air quality because of their dependence on natural effects to drive the air flow.

Air conditioning is a combined process that performs many functions simultaneously. It conditions, transports and introduces air into the conditioned space. It also controls and maintains the temperature, humidity, air movement, air cleanliness, sound level, and differential pressure in a space within predetermined limits for the comfort and health of the occupants of the conditioned space (KWANG, 2000). Nevertheless, if not properly designed, operated, or maintained, air conditioning systems can cause health problems and discomfort due to poor control of the indoor air temperature and relative humidity, lack of outdoor air, poor air distribution, inappropriate air speed, inadequate air filtration, and increase in the air contaminants (FELL-CARLSON, 2008; CDC, 2012; BURGE, HEDGE, WILSON, 1987; KWANG, 2000).

2.8 Power outlets

Proper distribution of electrical power throughout a health care facility is critical to the safe and effective operation of this facility. The electrical system should provide appropriate power when and where it is required by the caregiver, the staff, or the patient, supporting the staff's ability to provide healing services and causing no harm. Electrical systems provide power to lighting and several types of equipment, such as heating, venting, air conditioning, laundry, cooking, communication, information technology, medical, and other (IEEE, 2007). Power is mainly delivered through wall mounted receptacles, also called power outlets or sockets. Regarding user interaction, power outlets should meet certain requirements (EARLEY et al, 2011; NFPA, 2012; IEEE, 2007; ABNT, 2004; ABNT, 2008a; WANG et al, 2011):

- For each area, there should be a number of power outlets to allow the connection of needed equipment. The lack of outlets can delay treatment and cause stress in health care personnel;
- The outlets should be positioned in order to allow easy use and access by the hospital staff and the patient, to minimize the interference with planned procedures, to avoid the bending and awkward postures needed to connect and disconnect a plug, and to allow proper maintenance when needed;
- When different voltages are used in the same area, the outlets with higher voltage should be properly labeled. This simple procedure can reduce the wrong connections of devices in an outlet with higher voltage, which could damage this device;
- When needed, distinct power outlets should be used in order to prevent plug insertions in sockets with a different voltage or current rating from that for which the device is intended. This requirement seeks to avoid misconnections and possible malfunctioning or equipment damage.

In Brazil there is no voltage standardization. It varies between states and, in some situations, within the same state. The most common voltages around the country are 127V/220V and 220V/380V (line-to-neutral/line-to-line). However, it is possible to find cities where the adopted voltages are 230V/115V, 240V/120V, 254V/127V, and 440V/220V (ANEEL, 2012). In

general, hospitals often use lower voltage outlets (127V), leaving just a few higher voltage ones (220V) available. However, some hospitals use only high voltage (220V) outlets.

In 2010, Brazil adopted the standard NBR 14136 (Plugs and socket-outlets for household and similar purposes up to 20A/250V a.c.) (ABNT, 2002) as a means of standardizing the several types of plugs and outlets that had been used in the country, as shown in figure 3. The standard adopts one type of outlet with 3 pin connectors, as well as two types of plugs with two and three pins, as shown in figure 4. The standard defines 10A plugs and outlets with pin diameter of 4 mm and 20A plugs and outlets with pin diameter of 4.8 mm, which makes it impossible to connect a 20A plug in a 10A socket.

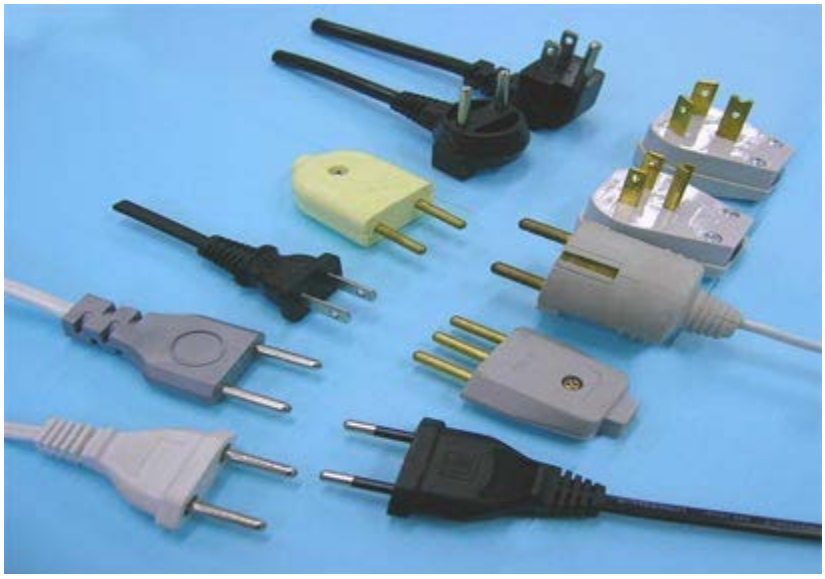


Figure 3 – Examples of power plugs in use in Brazil

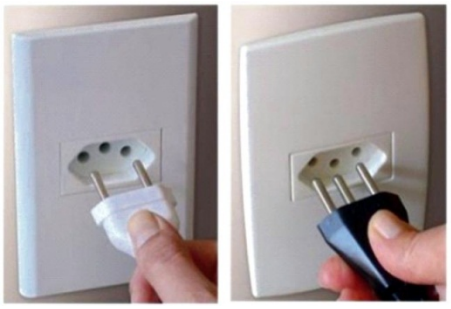


Figure 4 – Brazilian plugs and outlets as required by the standard NBR 14136

The standard NBR 13534 (ABNT, 2008a) states that distinct power outlets should be used in order to prevent plug insertions in sockets with a different voltage or current rating from that for which the device is intended. The only way clinical engineers can accomplish this requirement using the new power plugs and sockets standards is to use 20A sockets (4.8 mm) to 127V and 10A (4.0 mm) to 220V, which implies replacing the power cables of all 127V devices, since most of them use 10A plugs.

To connect the new and existing power plugs and outlets, a large number of adapters are in use nowadays. Figure 5 shows some models of available adapters. Two problems may arise from the use of adapters. First, if their quality is not good, a loose contact between the device and the outlet may appear, which may turn the device off and on intermittently. Second, the lack of adapters to connect the equipment may delay treatment, increasing the stress level of the workers.

Figure 5 – Power plug adapters available in the market

2.9 Medical gas outlets

Vacuum and medical gases such as oxygen, medical air, and nitrous oxide should be supplied to locations including operating rooms, intensive care units, emergency rooms, and wherever needed. They are critical in many patient care procedures. Gases can be supplied by cylinders and medical air system composed of equipment and piping. When a medical air system

is used, the gas is delivered through station outlets and vacuum is delivered through station inlets (NFPA, 2012), from now on called medical gas outlets.

Regarding user interaction, medical gas outlets should meet certain requirements, which are quite similar to the power outlets requirements (ABNT, 2012; BRASIL, 2002; FGI, 2010; NFPA, 2012):

- For each area, there should be a number of gas outlets to allow the connection of needed equipment without delaying treatment;
- The medical gas outlets should be positioned in order to allow easy use and access by the hospital staff, to minimize the interference with planned procedures and power outlets, and to allow proper maintenance when needed;
- Medical gas outlets should be legibly identified by the name of chemical symbol for the specific medical gas or vacuum provided to offer immediate connection from the piece of equipment. Figure 6 below shows an example of a medical gas outlet that, despite being identified with the standardized gas color it is not identified with the gas name, as required by the standard NBR 12.188.

Figure 6 – Unidentified medical gas outlet with the gas name

2.10 Written survey

A survey is a research method used to find out information (opinion, attitude, and behavior) about a subject mainly by using questionnaires. This information is usually gathered

either by having interviewers asking people questions and recording the answers or by having people reading questions and recording their own answers (BALOU, 2008; ALRECK, 2004; GROVES et al, 2004). The proposed methodology, described in the next chapter, uses a written survey in the form of self-administered questionnaire applied to the healthcare personnel. The questionnaires were developed based on the theory explained hereafter.

A questionnaire is an instrument used to conduct a survey whose purpose is to identify how people act, think or feel according to the aims of the research. Basically, it is a set of standardized questions, often called items, which follow a fixed scheme to collect individual data about one or more specific topics. It should be well designed, so that the obtained data enable the researcher to draw conclusions related to the items surveyed (TROBIA, 2008b).

Questionnaires are usually composed of three main parts: the introduction, the instructions, and the main body. The introduction explains the aims of the research and tries to motivate the respondents to cooperate with the survey. The instructions contain all the rules the respondents must follow in order to answer the questions (e.g., how to check the boxes, which part of the questionnaire has to be skipped in certain cases, etc.). The main body includes the questions themselves. In order to elaborate a questionnaire, the stages in figure 7 should be followed (HOLYK, 2008).

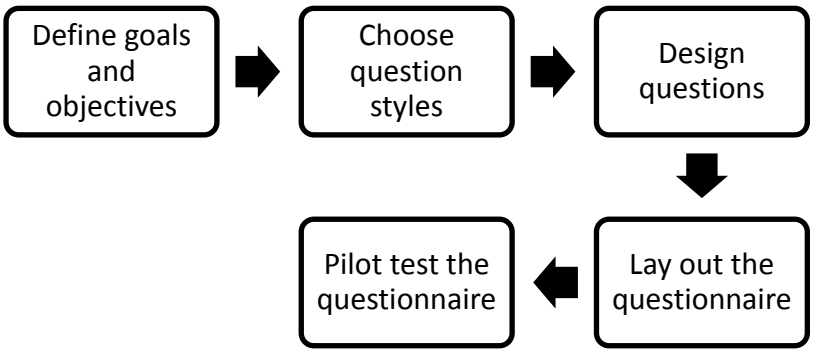


Figure 7 – Questionnaire elaboration stages

The first stage comprises the definition of the goals and objectives of the study, since a well-defined purpose determines the questionnaire formatting and question construction or ordering. To do so, the researcher should make a list of goals, trying to imagine the concepts and phenomena of interest, the population of the study, the sort of information he or she needs and

expects to get, the method of analysis of the questionnaire, etc (TROBIA, 2008b; ALRECK, 2004). Only after careful thinking, the researcher should design the questionnaire itself, considering that each question ought to be closely connected to the goals and objectives of the study. In addition, items should provide only meaningful and relevant information, which makes this stage extremely important (HOLYK, 2008). In fact, if the objectives are not properly defined, the questions developed may render useless or even wrong information (BASSON, 2008).

The second stage is about choosing appropriate question styles. There are two main types of questions: open-ended and closed-ended (or fixed alternatives). Open-ended questions provide no predetermined response categories and allow the respondent to answer with whatever information he or she considers relevant. An open-ended response format may result in a great deal of information, but this information may not be easily comparable or coded. Moreover, the collected data can be quite time-consuming and very costly to process. On the other hand, closed-ended questions ask respondents to select among a predetermined set of response categories. These response categories must be thorough and mutually exclusive. The closed-ended method reduces the cognitive burden of the respondent and enhances the ability to compare responses. The data are already coded (assigned a numerical value) and can be easily quantified, which saves data processing time and money (HOLYK, 2008; FODDY, 1993; SCHUMAN; PRESSER, 1996). However, if the researcher is not careful, the selection of response alternatives may bias respondents by framing thinking and by predetermining what is considered an appropriate answer. Nevertheless, it is possible to have both open-ended and closed-ended questions in the same questionnaire.

The next stage is question design. Questions should be clear in terminology and simple in structure. The recommendations below ought to be followed in order to design better questions (some of these items apply only to closed-ended questions) (ALRECK, 2004; DeVELLIS, 2012; HOLYK, 2008; GARLAND, 2006):

- Questions should use simple vocabulary;
- Their syntax should be simple, without subordinate clauses;
- They should not contain two questions in one (double-barreled questions);
- Questions must be concrete in terms of time and events;
- They should not lead the respondent to particular answers;

- The number of response alternatives should be limited, unless additional visual cues are employed;
- All the alternatives of response should appear acceptable, even the most extreme;
- The response alternatives should be exhaustive and mutually exclusive.

If the questionnaire is composed of closed-ended questions, it is also important to design the scales, which are used to obtain responses that can be comparable to each other. Alreck (2004) defines 16 different scales, some of which are much more common than others and whose effectiveness depends on the kind of measurement being performed. When preparing a questionnaire, however, there are many options of scales for any given question or information requirement, making it impossible to list a set of rules to dictate exactly what scale should be used in each situation, even if every circumstance could be anticipated. While the conventional scales are nearly always adaptable, other ones should be invented for special needs and circumstances whenever they are required (DeVELLIS, 2012; TROBIA, 2008b). In addition, when selecting a scale, the way it should be analyzed must also be taken into account. All in all, the choice of a scale is a researcher's decision.

The fourth stage comprises the questionnaire layout. According to Trobia (2008b), the layout of a questionnaire should reduce the cognitive burden of respondents and contain an intuitive and logical flow. For example, in most cases, questions on related topics should be grouped together and they should maintain the chronology of events. Questionnaire format should be as easy to understand and to use as possible. Questions should be individually numbered, clearly spaced, and visually distinct from each other. Ideally, important questions should appear early in a questionnaire to avoid the possible negative effects of respondents' fatigue on motivation, recall, and willingness to answer the questions. Generally, the ordering of items within a questionnaire follows this pattern: (a) general and neutral questions, (b) questions that require greater effort, (c) sensitive questions, and (d) demographic questions. In addition, in relation to appearance, questionnaires that appear more professional are taken more seriously by respondents (HOLYK, 2008; GARLAND, 2006).

The fifth and final stage is pilot testing the questionnaire. Before applying a questionnaire to the actual sample of respondents, it is necessary to carry out at least one pilot test (pretest) to verify if it can be easily understood and if it does not yield obvious bias effects

(ALRECK, 2004; HOLYK, 2008). Pretests can be carried out in many ways: recording the reactions of the respondents during the questionnaire answering, interviewing the respondents ex post, asking for a panel of experts' advice, or mixing these methods. The output of a pretesting phase can lead the researcher to (a) aggregate, specify, or better articulate the response alternatives, (b) revise or delete questions that raise many ''I don't know,'' ''I don't remember,'' ''I don't want to answer'' observations, specifications, explanations, or criticisms; (c) delete those questions that appear to have no variance; (d) integrate missing topics; (e) create a new order for the questions; and (f) verify the timing of the interview. After updating the questionnaire with the results of the pilot test, the questionnaire is ready to be applied (PRESSER et al, 2004; TROBIA, 2008b).

2.10.1 Questionnaire reliability

The internal consistency of a questionnaire is concerned with the extent to which the components of a measuring instrument are interrelated, that is, predict or produce the same or similar results (CRANO; BREWER, 2002). Cronbach's alpha is the most widely used method for estimating internal consistence reliability of questionnaires. It is a function of the average intercorrelations of items and the number of items in the questionnaire scales. Cronbach's alpha ranges between 0.0 and 1.0. The greater the value of alpha, the more the scale is coherent and thus reliable. Some authors have proposed a critical value for alpha of 0.70, above which the researcher can be confident that the scale is reliable while others have proposed the value of 0.75 or the stricter 0.80. If alpha is lower than 0.70, it is recommended that the scale be modified until the critical value of 0.70 is finally reached or hopefully exceeded (FIELD, 2010; KINBERLIN; WINTERSTEIN, 2008; TROBIA, 2008a; DeVELLIS, 2012). In this research, Cronbach's alpha was used to calculate questionnaire reliability, assuming that a value above 0.70 will indicate reliability. The way calculations were performed is described in chapter 4.4.1.

2.11 Reporting

As well as the questionnaires explained above, the methodology uses a data visualization method known as dashboard to report the data gathered. A brief description of dashboards is given below, whereas its use in the methodology will be explained in the next chapter.

Generating reports consists of arranging the collected data in a proper way to make the information understandable and easy to grasp (ALRECK, 2004). Few (2006) defines dashboard as "a visual display of the most important information needed to achieve one or more objectives". The information on a dashboard is presented visually, usually as a combination of text and graphics. It has been used in business to provide snapshots of most of the important figures needed to conduct effective business analysis (LEWIS, 2012). Figure 8 shows an example of a dashboard where is possible to see different types of data (e.g. 1- numerical; 2- graph; and 3- charts).

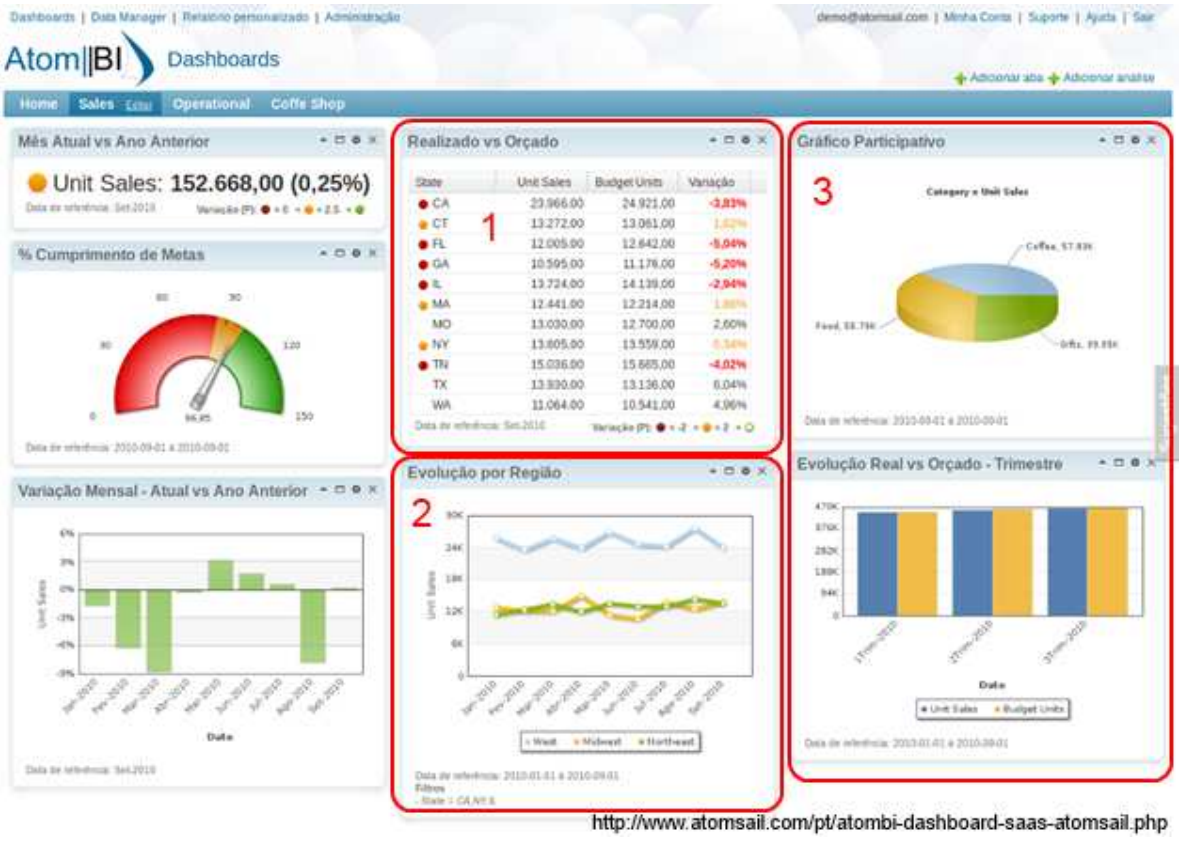


Figure 8 – Example of a dashboard

Dashboards are unique, designed according to one's needs. Well-designed dashboards deliver information that is well organized, condensed, specific to and customized for the dashboard's audience and objectives, displayed using concise and often small media that communicate the data and their message in the clearest and most direct possible way. There are general guides available when initially developing a dashboard (LEWIS, 2012; FEW, 2006; TUFTE, 2001; ALEXANDER; WALKENBACH, 2010; ECKERSON, 2001):

- Keep it simple;
- Forget about fancy formatting;
- Avoid using colors or background fills to organize your dashboards;
- De-emphasize borders, backgrounds, and other elements that define dashboard areas;
- Avoid applying fancy effects such as gradients, pattern fills, shadows, glow, soft edges, and other formatting;
- Do not try to embellish the dashboard with clip art or pictures;
- Skip the unnecessary chart junk:
    - Maximize the data-ink ratio by reducing the non-data ink and/or enhancing the data ink;
    - Remove or de-emphasize gridlines;
    - Remove borders;
    - Skip the trend lines;
    - Avoid unnecessary data labels;
    - Do not show a label if it is not necessary;
    - Remove any axis that does not add value;
    - Use color sparingly for maximum contrast to highlight important data;
    - Only use variations in colors if they encode a meaning;
    - Deemphasize design elements.
- Make the data standout from chart and dashboard background;
- Limit each dashboard to one viewable page or screen;
- Include only the information that is absolutely needed;

- Format numbers effectively;
- Express quantitative data at a level of precision that is appropriate to the task;
- Use titles and labels efficiently;
- Make sure that dashboard prints properly;
- Do not use flashy visuals and chart types when simple alternatives are capable of conveying the same message
- Organize the information considering its intended use.

3. Materials and methods

The methodology evaluates physical environment parameters in patient care areas due to the fact that, as explained in the introduction, patients are also affected by environmental conditions. Another reason for this choice is the fact that non-patient care areas, such as pharmacy, laboratory, sterilization, dietary and other facilities may have requirements for the physical environment that are either too specific or very different from patient care areas, making it difficult to include them, at the risk of making this methodology cumbersome and not practical.

According to Hedge (2005a), assessing the physical environment can be a complex task. Decisions have to be made about (1) what variables to measure, (2) where and when to take measurements, (3) what instruments to use and how to use them, and (4) how to interpret and combine objective measures of environmental conditions along with subjective reports of conditions. The proposed methodology handles the four factors described above, aiming at reducing the intrinsic complexity of physical environment analyses.

The methodology was developed based on the following premises:

- It has low implementation cost;
- It requires little knowledge of human factors and ergonomics on the applicant's side;
- It does not change the staff work routine or only changes it minimally;
- It allows proper visualization of the results;
- It is software based;
- It is based on Brazilian standards for setting some environmental parameters but can be applied worldwide as long as the regional standards are used.

Figure 9 shows the steps used to develop the methodology, whereas a more detailed description of each step is presented hereafter.

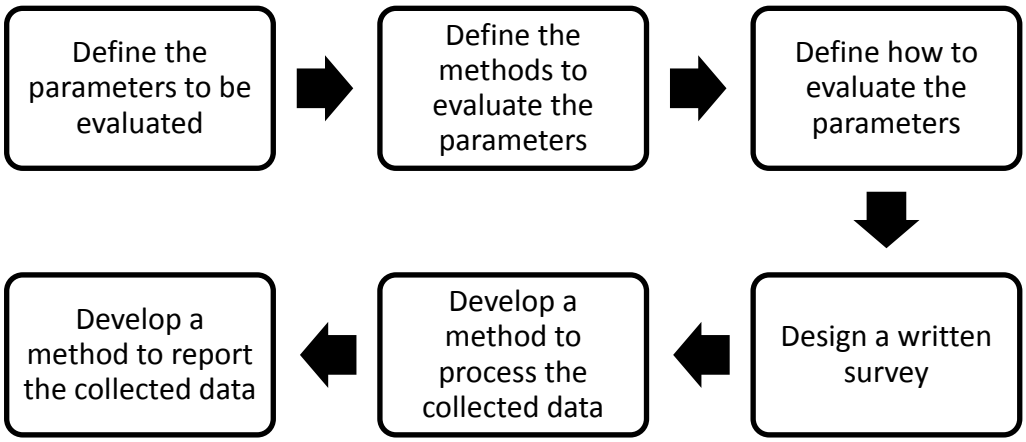


Figure 9 – Methodology development steps

To proper apply the methodology, it is advisable that the applicant have the following characteristics:

- Intermediate knowledge of spreadsheet software;
- Intermediate knowledge of general software;
- Ability to deal with electronic measurement devices;
- Basic knowledge of healthcare physical environment.

A clinical engineer (CE) commonly has the knowledge cited above, being recommended as a natural applicant. However any professional with similar knowledge is able to apply the methodology.

3.1 Define the parameters to be evaluated

Extensive literature research (books, standards, papers, laws, and resolutions) was carried out to list the parameters affecting the physical environment. Table 2 below shows the researched references. Since a myriad of parameters was found, making it very difficult to design a methodology to evaluate all of them within the period of a doctorate thesis, it became necessary to select just some parameters to be included in this methodology. Three main conditions were established for the parameter selection:

- Parameters that affect both the worker and the patient;
- Parameters that are present in the healthcare environment;

- Parameters whose evaluation complies with the methodology premises.

The parameters were selected and organized into six groups: work area (dimensions; slip, trip, and fall), noise (noise level, effects on the job, sources, caused symptoms), lighting (illuminance, flicker, natural lighting, reflex, glare, shadows, caused symptoms, influence in tasks), environmental parameters (temperature, relative humidity, CO_2 concentrations, drafts, odors, air quality, caused symptoms), power outlets (number of outlets, positioning, identification, interchangeability 127V-220V, use of extension cords, use of power plug adapters), and medical gas outlets (number of outlets, positioning, identification). The first four groups are commonly cited in the HF/E literature. The remaining groups, power outlets and medical gas outlets, are important elements of the hospital work area and can affect the clinical staff, despite not being as commonly cited in the literature as the other groups. Each group was color coded for easy identification during the application of the methodology. Selected parameters are shown in detail in table 3, chapter 3.2.

Table 2 – Researched references

Researched references			
ABNT, 1985a	ABNT, 2004	ABNT, 1992a	ABNT, 1985b
ABNT, 2005	ABNT, 1983	ABNT, 2000	ABNT, 1992b
ABNT, 2012	ABNT, 2008a	ABNT, 2002	ABNT, 2003
ABNT, 2008b	ABNT, 2008c	ABNT, 2008d	Alvarado, 2012
ANSI, 2006	ASHRAE, 1986	ASHRAE, 2003	ASHRAE, 2004
ASHRAE, 2007	ASHRAE, 2008	ASHRAE, 2009	ASTM, 2012
Belli Filho; Lisboa, 1998	Berglund; Lindvall; Schwela, 1999	Boyce, 2003	Boyce, 2005
Boyce, 2006	BRASIL, 2002	BRASIL, 2003	BRASIL, 2007
BRASIL, 2011	Bridger, 2003	Brogmus, 2007	BSI, 1991
BSI, 2000	BSI, 2003	BSI, 2011a	BSI, 2011b
BSI, 2011c	Carayon, 2012	Carayon; Alvarado; Hundt, 2012	Carayon; Smith, 2000
Casali, 2006	Casali; Robinson, 2003	Chang; Grönqvist, 2006	Chapanis, 1996
Charlton; O'brien, 2002	Colins; Bell, 2010	Dul; Weerdmeester, 2008	Earley et al, 2011
EPA, 1994	Evans; Maxwell, 2005	Falzon, 2007	FGI, 2010
Ganslandt; Hofmann, 1992	Haslam, 2006	Haslam; Stubbs, 2006	Havenith, 2005
Hedge, 2005b	Helander, 2006	Herwaldt; Pottinger, 2003	Hilton, 1985
IEEE, 2007	IEH, 1996	Iida, 2005	ISO, 1994
ISO, 1995a	ISO, 1995b	ISO, 1998	ISO, 2002
ISO, 2003	ISO, 2004b	ISO, 2005	ISO, 2008
Job, 2005	Jones, 1999	Kang, 2007	Kearney, 2008

Researched references			
Kerzman, 2004	Kroemer; Grandjean, 2005	Kwang, 2000	Leamon, 2000
Lehto; Buck, 2008	Litchfield, 2003	Mackenzie; Galbrun, 2007	Macleod, 2000
Marmaras; Nathanael, 2006	McKeown, 2008	Mcquiston; Parker; Spitler, 2005	Morse, 2009
NFPA, 2012	Parsons, 2005	Parsons, 2003	Pheasant, 2003
Poulton, 1978	Quadros, 2008	Rea, 2000	Rea, 2005
Rea; Boyce, 2005	Reiling; Chernos, 2007	Sanders; Mccormick, 1993	School, 2006
Tinetti, 2003	Toftum, 2005	Topf, 2000	Wickens, 2004
Williams, 1998	Wolska, 2006	Zhang, 2005	

3.2 Define the methods to evaluate the parameters

Leonard (2006), states that ergonomic methods are a core component in the successful practice of ergonomics. They are investigative toolkits used to assess user's and system's characteristics, as well as to evaluate the resulting requirements imposed on the capabilities, limitations and requirements of each one of them, user and system. According to ISO (2004a), both objective and subjective assessment methods should be used whenever possible. Considering the methodology premises as well as the parameters selected previously, three assessment methods were chosen to be used during parameters evaluation: parameter measurement, parameter observation, and written survey.

It is necessary to measure parameters such as temperature, relative humidity, and area, to verify compliance with previously established requirements. However, some parameters, such as identification of power outlets, objects in passageways, and lamp flickering, cannot be objectively measured and it is necessary to use observation to verify whether they are present in an environment or not. It is also essential to gather workers' opinion about the environment, since they are directly affected by environmental conditions and are able to give important contribution to the matter. In this research, a written survey was developed to do so. The evaluation of patients' opinion is not included in the methodology. Table 3 shows the six parameter groups (defined in 3.1), the selected parameters, as well as the method(s) used to evaluate them (measurement, observation, and written survey).

Table 3 – Parameters evaluated

Group	Parameter			Measurement	Observation	Written survey
Work area	Dimensions (width, length, height, distance, area)			**X**		**X**
	Slip, trip, fall	Slip, trip, and fall risk and events				**X**
		Cables and tubes in passageways			**X**	
		Buckets, seats, stairs in passageways			**X**	
		Floor	Non-slip		**X**	
			Uniform, without unevenness		**X**	
			Presence of liquids		**X**	
			Objects are visible		**X**	
Noise	Noise level			**X**		**X**
	Noise effects on the job					**X**
	Noise sources					**X**
	Symptoms caused by noise					**X**
Lighting	Illuminance			X		X
	Flicker				**X**	
	Natural lighting				**X**	
	Reflex					**X**
	Glare					**X**
	Shadows					**X**
	Symptoms caused by lighting					**X**
	Influence of lighting in tasks					**X**
Environmental parameters	Temperature			**X**		**X**
	Relative humidity			**X**		**X**
	Carbon dioxide concentration (CO_2)			**X**		
	Drafts					**X**
	Odors					**X**
	Air quality					**X**
	Symptoms caused by environmental parameters					**X**

Group	Parameter	Measurement	Observation	Written survey
Power outlets	Number of power outlets	**X**		**X**
	Power outlets height/positioning	**X**		**X**
	Power outlets identification		**X**	
	Interchangeability 127V-220V outlets		**X**	
	Proper power plug connection at the power outlet	**X**	**X**	**X**
	Use of extension cords		**X**	
	Use of power plugs adapters			**X**
Medical gas outlets	Number of gases outlet per gas type	**X**		**X**
	Medical gas outlet height/positioning	**X**		**X**
	Medical gas outlet identification		**X**	**X**

3.3 Define how to evaluate the parameters

In order to proper evaluate the parameters defined in table 3, two forms and a questionnaire were created. The latter are to be explained in 3.4, whereas the forms are explained here.

Hospitals have different patient care areas, which may have different requirements regarding parameters such as temperature and relative humidity limits, minimum work area, and minimum and maximum illuminance values. For instance, the standard NBR 7256 (ABNT, 2005) defines the temperature limits in the operating room as 18 ^{o}C to 22 ^{o}C, in the intensive care unit as 21 ^{o}C to 24 ^{o}C, and in the neonatal intensive care unit as 22 ^{o}C to 26 ^{o}C. Since the methodology is intended to be applied in any patient care area, it is necessary to select one area to be evaluated at a time, in order to determine the specific parameter requirements, so that the values found by measurement can be properly compared to the reference values for this area. The areas to be analyzed could be selected based on factors such as workers complaints, management requests, or the awareness of the need.

It is also necessary to establish a time period to collect the data. Some parameters may change with time. For example, environmental parameters such as temperature and noise may vary depending on the time of the day, the number of people in the room, and the clinical

procedures being performed. Moreover, measurements taken in short periods of time may not be accurate enough to represent the environment's real conditions.

Form 1 was developed to determine the specific parameter requirements for the selected area. These requirements may be the parameter's minimum value (items 3, 7, and 8), the parameter's maximum value (item 4), or the parameters range (items 5 and 6). In item 1, the area in which the methodology is going to be applied should be defined. In item 2, a time period to perform the measurements should be determined (there are brief usage instructions following item 2). Items 3 to 8 refer to the parameters whose requirements should be determined. In order to properly fill in these fields, a reference should be consulted, usually a regional, national or international standard enforced either by law or resolution, and the parameter values found on such reference should be written down in the appropriate field. It is advisable to consult more than one reference. Here, the first reference suggested to fill in the form is a standard or resolution enforced by Brazilian government and other ones could be a simple matter of choice. The justification for such advice is that standards can become outdated and other references may recommend more strict limits. This form consists of a Microsoft Word file, making it easier to edit the parameters according to the needs. For example, some patient care areas define dimensions such as distance between beds, distance between the bed and the wall, as well as area per bed, and all these parameters can be easily edited.

Form 1 – Determine parameter requirements

Determine parameter requirements

1. Select a patient care area to perform the analysis: _____
2. Set a time period to take the measurements: _____

- Considering the selected area in 1, conduct a literature search (standards, resolutions, guidelines, books, papers) to determine the reference values for the parameters below.
- If you consult another than recommended reference, write it down in "Other" field.

3. Dimensions

Source: ❑ RDC 50/2002 ❑ Other: _____

Area	_____ m^2
Length	_____ m
Width	_____ m
Height	_____ m
_____	_____ m

4. Noise

Source: ❑ NBR 10152/1987 ❑ Other: _____

Noise level: _____ < dB

5. Illuminance

Source: ❑ NBR 5413/1992 ❑ Other: _____

Environmental illuminance: _____ < lux < _____

6. Temperature and relative humidity

Source: ❑ NBR 7256/2005 ❑ Other: _____

Temperature	_____ < °C < _____
Relative humidity	_____ < % < _____

7. Number of power outlets

Source: ❑ RDC 50/2002 ❑ Other: _____

Number of power outlets	_____ outlets
Number of X-ray power outlets	_____ outlets

8. Number of medical gas outlets

Source:❑ NBR 12188/2012 ❑ Other: _____

Oxygen	_____ outlet(s) / _____
Nitrous oxide (N_2O)	_____ outlet (s) / _____
Vacuum	_____ outlet (s) / _____
Medical air	_____ outlet (s) / _____

- Copy the found dimension type (area, width, height, etc.) into the item **3. Dimensions** in the form "Measuring and observing parameters".
- If the line-to-neutral and line-to-line Voltage are different from 127 V and 220 V respectively, write down the proper values in item **6. Power outlets** in the form "Measuring and observing parameters".

The literature cited in table 2 was researched to determine how the parameters listed in table 3 are to be measured and observed. Based on the gathered information, a second form was created to guide the applicant during the process of measuring and observing the parameters. It consists of three parts: the first one contains a header with the fields place, date, start time, end time; the second one is a set of instructions on how to set up the devices used to perform measurement of temperature, relative humidity, CO_2 concentration and noise; and the last part comprises fields where the measured values, as well as the observations regarding the parameters are to be written down.

Temperature, relative humidity, CO_2 concentration, and noise (items 1 and 2) are to be measured first, provided that the devices used to measure these parameters are set up appropriately to perform the measurements during the established time period. Next, the environment dimensions should be measured, followed by the observation of parameters regarding the floor. In item 5 (lighting) the existence of lamp flickering and natural illumination in the environment ought to be observed. and illuminance, determined. In item 6, the height of power outlets is to be measured and the 127V, 220V, and X-Ray power outlets, quantified. Furthermore, the identification of 220V and X-Ray power outlets, as well as the interchangeability of 127V $\leftrightarrow$ 220V power plugs, the use of power plug adapters and power cord extensions should be verified. Finally, in item 7, the number of medical gas outlets and the height of each outlet ought to be written down in proper fields. In addition, whether the outlet is properly identified with its gas name should be verified.

Form 2 – Measure and observe parameters

Measure and observe parameters

Place: _____

Date: _____/_____/_____ Start time: _____:_____ End time: _____:_____

- The devices used to record the parameters in items 1 and 2 should be set up before starting the analysis, without interfering with tasks and allowing for proper circulation. If possible, ask a member of the staff about the best places to set up the devices and observe the following recommendations:
    - Thermometer/Hygrometer: Positioned at strategic locations within the occupied zone where the workers are known to perform their tasks, in points that are 1.1m above the floor for seated workers and 1.7m above the floor for standing workers. The sample time should be set to every five minutes or less;
    - Hygrometer: Positioned at a location within the occupied zone with the same set up for the thermometer;
    - Carbon Dioxide meter: Positioned 2.0m away from any occupant;
    - Sound level meter: Positioned as close to the worker as possible and at least 1.0 m from the walls or other major reflecting surfaces, 1.5 m to 1.7 m above the floor and approximately 1.5 m from windows, with frequency-weighting network set to "A" and time-weighting set to "Slow";

1. Temperature, relative humidity, Carbon Dioxide (CO_2) concentration

Record the following parameters during the time period:
Air temperature (T_{air})
Relative humidity (RH)
Carbon dioxide concentration (CO_2)

2. Noise

Record noise level during the time period.

3. Dimensions

Area	_____ m^2
Length	_____ m
Width	_____ m
Height	_____ m
_____	_____ m

4. Floor

It is non-slip	❑ Yes ❑ No
It is uniform, without unevenness	❑ Yes ❑ No
It is reflective	❑ Yes ❑ No
There are liquids on the floor	❑ Yes ❑ No
There are buckets, seats, or any other objects in passageways	❑ Yes ❑ No
There are cables and tubes in passageways	❑ Yes ❑ No
Objects on the floor are visible	❑ Yes ❑ No

5. Lighting

There is lamp flicker	❑ Yes ❑ No
There is natural illumination	❑ Yes ❑ No

Environment illuminance: _____ lux

6. Power outlets	
Power outlets height	_____ m
Number of 127 V power outlets	_____ power outlet(s)
Number of 220 V power outlets	_____ power outlet(s)
Number of X-Ray power outlets	_____ power outlet(s)
All 220 V power outlets are identified	❑ Yes ❑ No ❑ N/A
X-Ray power outlet is identified	❑ Yes ❑ No ❑ N/A
It is possible to plug an 127 V device in an 220 V power outlet	❑ Yes ❑ No
It is possible to plug an 220 V device in an 127 V power outlet	❑ Yes ❑ No
Power plug adapters were used during measurement and observation period	❑ Yes ❑ No
Power cord extensions were used during measurement and observation period	❑ Yes ❑ No

7. Medical gas outlets			
Number of medical gas outlets			
Oxygen	_____ gas outlet(s) /_____		
Nitrous oxide (N_2O)	_____ gas outlet(s) /_____		
Vacuum	_____ gas outlet(s) /_____		
Medical air	_____ gas outlet(s) /_____		
Medical gas outlet height			
Oxygen	_____ m	❑ N/A	
Nitrous oxide (N_2O)	_____ m	❑ N/A	
Vacuum	_____ m	❑ N/A	
Medical air	_____ m	❑ N/A	
Medical gas outlet is identified with the gas name			
Oxygen	❑ Yes	❑ No	❑ N/A
Nitrous oxide (N_2O)	❑ Yes	❑ No	❑ N/A
Vacuum	❑ Yes	❑ No	❑ N/A
Medical air	❑ Yes	❑ No	❑ N/A

Table 4 below shows the measurement devices to be used, their recommended specifications as well as the standards which demand these specifications. Since standards regarding light meter range were not found a range of up to 20,000 lux that seems suitable to most environmental illuminance measurements was suggested. However, the light meter accuracy was determined according to NBR 15215-4 (ABNT, 2004b) as being 10%.

Special attention should be paid to the accuracy requirement. It is possible to use a device with lower accuracy than recommended, but the lower the device accuracy, the lower the measurement reliability, which can influence data interpretation. It is also recommended that the device in use be calibrated in a certified laboratory, which is important due to measurement

uncertainties. In addition, it is possible to use a piece of equipment that measures more than one parameter at the same time, for instance: a thermo-hygrometer or a Carbon Dioxide concentration meter which also measures temperature and relative humidity.

Table 4 – Specification for the equipment to be used in the measurement

Device	Specifications	Standard
Thermometer	Range: 0 °C a 70 °C Resolution: 0.1°C Accuracy:± 0.8 °C Data-log with 30s sampling rate	ANVISA RE-9
Hygrometer	Range: 5% to 95% Accuracy: ± 5% Resolution: 0.1% Data-log with 30s sampling rate	ANVISA RE-9
Carbon Dioxide meter	Range: 0 – 5000 ppm Accuracy: ± 50ppm + 2% reading Resolution: 1ppm Data-log with 30s sampling rate	ANVISA RE-9
Sound level meter	Type: At least Class 2 According to IEC 61672 or IEC 651 Data-log with 1s sampling rate	NBR 10151
Light meter	Range: 0 – 20.000 lux Accuracy: ± 10% Cosine and color corrected Data hold	NBR 15215-4

Measurements are to be sufficiently made away from the boundaries of the workplace and away from any surfaces to allow for proper circulation around measurement devices (ASHRAE, 2004). In addition, when performing the measurements, it is recommended that the devices be set up as follows (ASHRAE, 2004; ASHRAE, 1986; ABNT, 2008b; ASTM, 2012; ABNT, 2005, BRASIL, 2011; BSI, 2003):

- Thermometer: Positioned at strategic locations near the workplace where the workers are known to perform their tasks, in points that are 1.1m above the floor for seated workers and 1.7m above the floor for standing workers. The sample time should be set to every five minutes or less;
- Hygrometer: Positioned at a location near the workplace with the same set up for the thermometer;
- Carbon Dioxide meter: Positioned 2.0m away from any occupant;
- Sound Level Meter: Positioned as close to the worker as possible and at least 1.0 m from the walls or other major reflecting surfaces, 1.5 m to 1.7 m above the floor and approximately 1.5 m from windows, with frequency-weighting network set to "A", and time-weighting set to "Slow";
- The measurement of illuminance should be made according to the adopted regional or national standard. Here it was used the NBR 5382 (ABNT, 1985a).

During the application of the method, described in chapter 4, the measurements were performed using the devices listed in table 5 below.

Table 5 – Devices used to perform the measurements during methodology application

Device	Manufacturer – Model	Specifications
Steel tape measure	Starrett	Range: 0 to 5m
Laser distance meter	Extech – DT300	Range: 0.05 to 50m Accuracy (up to 10m): ±1.5mm
Thermo-hygrometer	Reed – SD2010	Range: 0 °C to 50 °C Accuracy:± 0.8 °C Range: 5% to 95% Accuracy: ± 3% reading +1% RH
CO_2 concentration meter	Extech – SD800	Range: 0 to 4,000 ppm Accuracy: ≤1,000ppm ± 40ppm >1,000 to ≤ 3,000ppm ± 5% reading
Sound level meter	Extech – HD600	According to IEC 61672 Range: 30 dB to 130dB Accuracy: ± 1.4 dB

Device	Manufacturer – Model	Specifications
Sound level calibrator	Extech – 407744	94 dB – 1KHz Accuracy: ±0.8dB
Light meter	Extech – EasyView 30	Range: 0 to 400,000 lux Accuracy: ± 3% reading + 0.5% FS

3.4 Design a written survey

A written survey using self-administered questionnaires was created to gather workers opinion regarding the environment. The questionnaire was developed according to the five stages described in chapter 2.10 (1. Define goals and objectives, 2. Choose question styles, 3. Design questions, 4. Lay out the questionnaire, 5. Pilot test the questionnaire), and to the references in table 2, as well as to Alreck (2004), Brace (2004), Crano and Brewer (2002), Creswell (2003), DeVellis (2012), Foddy (1993), Fowler (1995, 2002), Presser et al (2004), Saris and Gallhofer (2007), Tourangeaus (2000), Trobia (2008b), Garland (2006), Holyk (2008), and Basson (2008). The five stages are described below:

1. The main goal of the questionnaire is to discover how the workers perceive certain parameters in the environment (e.g. noise, temperature, air quality) and also to determine the physical, mental, and emotional effects of these parameters on their health and well-being (e.g. headache, difficulty in concentrating, irritation);
2. Closed-ended questions were chosen to reduce respondents' cognitive effort and to make it easier to process the collected data;
3. Three types of scales were chosen: verbal frequency (e.g. never, rarely, sometimes, often, always), semantic differential (e.g. dry/humid, low/loud, small/big) and multiple responses. A total of 31 questions were elaborated following the recommendations cited in chapter 2.10: it has simple vocabulary and syntax; it does not contain two questions in one; it is concrete in terms of time and events; it does not lead the respondent towards particular answers; the number of response alternatives is limited; all the alternatives of response appear acceptable; the response alternatives are exhaustive and mutually exclusive;

4. The questionnaire layout has the following structure:
    - A header containing the place, date, time and ID (identification) fields. A unique number (or code) should be assigned to the ID field of each questionnaire. There is no field for respondent identification, in order to avoid possible embarrassment;
    - A brief usage instruction;
    - Numbered questions grouped according to the same structure of table 2 (work area, noise, lighting, environmental parameters, power outlets, medical gas outlets), with the same color coding;
5. The pilot test of the questionnaire were conducted as such:
    - First, the questionnaire was present to the audience during a meeting of biomedical engineering graduate students at the CEB/Unicamp (Biomedical Engineering Center/Campinas State University). The questionnaire was modified according to some suggestions regarding the structure, questions, and scales.
    - Next, a field test was conducted in three operating rooms of a public hospital. Eleven questionnaires were applied. These questionnaires included four additional questions regarding question understanding, question wording, answering problems, and comments to improve the questionnaire. After the analysis of the answers, its final version was elaborated.

While the Portuguese version of the questionnaire is shown in Appendix 1, the English version of it is shown in figure 10. The objectives of the 31 questions are as follows:

- Questions 1, 4, 5, 14 – to learn how the work area, noise, and lighting affect workers while performing their tasks, making it possible to draw comparisons between the environmental measurements and workers perceptions;
- Questions 2, 6, 12, 15, 17 – to learn how the workers perceive the environment regarding the STF risk, noise, lighting, temperature, and relative humidity;
- Questions 3, 8, 13, 22 – to learn if the floor, noise, lighting, and environmental parameters have caused them any symptoms. The limit of 15 days was chosen aiming to know about the occurrence of recent events and avoiding unnecessary cognitive effort;

- Question 7 – to learn about the noise sources in the environment;
- Questions 9, 10, 11 – to learn about the occurrence of reflex, glare, and shadows in the environment. Since there may be multiple workplaces, it is not feasible for the researcher to determine their occurrence;
- Questions 16, 18, 19, 20, 21 – to learn how the workers are affected by environmental parameters such as temperature variations, drafts, stuffy sensation, odors, and air quality;
- Questions 23, 29 – to learn if the number of power outlets and medical gas outlets is sufficient to perform the tasks;
- Questions 24, 30 – to learn if the positioning of power outlets and medical gas outlets allows easy access;
- Question 25 – to learn whether the power outlets allow a firm connection to the power plug;
- Questions 26, 27, 28 – to learn about the use, availability, and quality of power plug adapters;
- Question 31 – to learn about the identification of medical gas outlets.

Place: _____ ID:_____

Date: _____/_____/_____ Time: _____:_____

Check the answers that best represent your opinion about **this environment** regarding the following items:

Work area

1. The work area to perform the tasks is	Very small ☐	Small ☐	Fair ☐	Big ☐	Very big ☐
2. Regarding the risk of slipping, tripping or falling, the **floor** has	No risk ☐	Little risk ☐	Medium risk ☐	High risk ☐	
3. You have suffered a slip, a trip or a fall in the last 15 days (check all that apply)	No ☐	Slip ☐	Trip ☐	Fall ☐	

Noise

	Never	Rarely	Sometimes	Often	Always
4. Environmental **noise** bothers, disturbs, or annoys you during work	☐	☐	☐	☐	☐
5. You feel that **noise** in this environment has a negative impact on your job	☐	☐	☐	☐	☐
6. The **noise** level in this environment is	Very low ☐	Low ☐	Fair ☐	Loud ☐	Very loud ☐

7. Check all the **noise** sources that bother you in this environment

☐ Conversations
☐ Phone conversations
☐ Loud conversations
☐ Equipment
☐ Air conditioning system
☐ External noise
☐ Other
☐ None

8. The **noise** in this environment may have caused any of these symptoms in the last 15 days (check all that apply)

☐ Difficulty in hearing or understanding during conversations
☐ Need to speak up during conversations
☐ Difficulty of hearing audible signals
☐ Difficulty of concentrating during tasks
☐ Irritation
☐ Mental fatigue
☐ Other
☐ No symptom

Lighting

	Never	Rarely	Sometimes	Often	Always
9. **Reflex** occurs during tasks	☐	☐	☐	☐	☐
10. **Glare** occurs during tasks	☐	☐	☐	☐	☐
11. **Shadows** are produced during tasks	☐	☐	☐	☐	☐
12. Regarding **lighting**, you perceive the environment as	Too dark ☐	Dark ☐	Fair ☐	Bright ☐	Too bright ☐

13. **Lighting** may have caused any of these symptoms in the last 15 days (check all that apply)

☐ Visual fatigue
☐ Eye irritation
☐ Watery eyes
☐ Headache
☐ Nausea/dizziness
☐ Irritation
☐ Other
☐ No symptom

14. The environment lighting provides proper conditions to perform the tasks	Never ☐	Rarely ☐	Sometimes ☐	Often ☐	Always ☐

Environmental parameters

15. Regarding **temperature**, you feel	Comfortable ☐	Slightly uncomfortable ☐	Uncomfortable ☐		Very uncomfortable ☐
16. **Temperature** variations in the environment bother you	Never ☐	Rarely ☐	Sometimes ☐	Often ☐	Always ☐
17. Regarding **humidity**, this environment is	Dry ☐	A little dry ☐	Fair ☐	A little humid ☐	Humid ☐
18. You are bothered by annoying **drafts**	Never ☐	Rarely ☐	Sometimes ☐	Often ☐	Always ☐
19. The environment seems **stuffy**	Never ☐	Rarely ☐	Sometimes ☐	Often ☐	Always ☐
20. The environment presents unpleasant **odors**	Never ☐	Rarely ☐	Sometimes ☐	Often ☐	Always ☐
21. **Air quality** in this environment is	Very poor ☐	Poor ☐	Fair ☐	Good ☐	Very good ☐
22. **Air conditioning** or **air quality** may have caused any of these symptoms in the last 15 days (check all that apply)	☐ Headache ☐ Nausea/dizziness ☐ Difficulty in concentration ☐ Eye irritation ☐ Watery eyes ☐ Rhinitis ☐ Sneezing ☐ Nasal congestion		☐ Runny nose ☐ Dry throat ☐ Cough ☐ Dry or irritated skin ☐ Perspiration ☐ Other ☐ No symptom		

Power outlets

	Never	Sometimes	Always	Not sure
23. The number of **power outlets** is sufficient to connect the devices	☐	☐	☐	☐
24. The positioning of **power outlets** allows easy access to them	☐	☐	☐	☐
25. **Power outlets** allow tight connection to power plugs	☐	☐	☐	☐
26. You need to use power plug **adapters** to connect devices to the power outlets	☐	☐	☐	☐
If checked **never** in the question above, go to question 29				
27. The **adapters** are available when needed	☐	☐	☐	☐

28. The quality of the **adapters** is	Very poor ☐	Poor ☐	Fair ☐	Good ☐	Very good ☐

Medical gas outlets

	Never	Sometimes	Always	Not sure
29. The number of **medical gas outlets** is sufficient to accomplish the tasks	☐	☐	☐	☐
30. The positioning of **Medical gas outlets** allows easy access to them	☐	☐	☐	☐
31. It is easy to identify the **medical gas** (Oxygen, medical air, Nitrous oxide, vacuum) in the outlet	☐	☐	☐	☐

Figure 10 – Questionnaire to be applied to the workers

3.5 Process the collected data

The methodology generates four types of data: 1 – single measurements of parameters such as area, distance, height, illuminance; 2 – continuous measurement of temperature, relative humidity, CO_2 concentration, and noise; 3 – observations of parameters, including liquid spillage, identification of power outlets, floor characteristics; and 4 – questionnaire (written survey) data. Continuous measurement and questionnaire related data need further processing in order to be properly reported, leading to the creation of the methods described in 3.5.1 and 3.5.2.

3.5.1 Continuous measurement data processing

Data regarding continuous measurements (temperature, relative humidity, CO_2 concentration, and noise) should be processed as follows:

- The mean ($\bar{x}$), standard deviation (SD), maximum (max) measured value, minimum (min) measured value, and amplitude (max-min) value should be calculated;
- The mean value of noise should be calculated using the formula

$$L_{Aeq} = 10.\log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{\frac{Li}{10}}\right),$$

  where $\mathbf{L_i}$ is the sound pressure level in dB, and **n** is the number of readings (or samples) (BSI, 2003).
- The standard deviation (SD) of noise measurements should be calculated by using the previously found value $\mathbf{L_{Aeq}}$ as the mean in the known formula

$$SD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \ ;$$

3.5.2 Questionnaire processing

Questionnaire processing involves the calculation of frequency distribution regarding the 31 questions. For instance, the frequency distribution of the item 9. *Reflex occurs during tasks*, may be Never – 5, Rarely – 3, Sometimes – 1. A statistical software was selected to perform this calculation.

The statistical software PSPP was selected to process the data from the questionnaire. It is a free software for Windows, Linux, and MAC OS X, which can be downloaded from http://www.gnu.org/software/pspp/. The software requires that variables be defined to allow data entry and analysis. This process is shown in detail in appendix 3.

In order to facilitate data entry by the user, it was developed a code-sheet containing the numbers to be associated to each scale in the questionnaire. While an excerpt of this code-sheet is shown in figure 11 below, it is fully shown in appendix 2, and an example of its use will be given in chapter 4.5.

Work area

1. The physical area to perform the task is	Very small (-2)	Small (-1)	Fair (0)	Big (1)	Very big (2)
2. Regarding the risk of slipping, tripping or falling, the **floor** has	No risk (0)	Little risk (1)	Medium risk (2)		High risk (3)
3. You have slipped, tripped or fallen in the last 15 days (check all that apply)	No (0)	Slip (1)	Trip (2)		Fall (3)

Figure 11 – Code-sheet excerpt

The questionnaire data are to be entered with the help of the code-sheet. For each questionnaire, the value corresponding to each answer is to be typed in the respective field. Figure 12 shows an excerpt of the software data entry screen which is showed to the user. The red rectangle displays the variables previously defined in the software. Each variable is related to one question. For example, the *Work_area* variable refers to the question "The work area to perform the tasks is"; the variable *Risk_STF* is related to the question "Regarding the risk of slipping, tripping or falling, the **floor** has" and so on.

Each row, highlighted in the orange rectangle, corresponds to the data of one questionnaire. In this case, it is related to the questionnaire whose ID is '2'. The person verifies

the answer in the questionnaire and types a number associated to it in the corresponding field according to the code-sheet. The upper part of the figure shows the numerical values for the answers. In the lower part, it is possible to see that the software can show the respective label associated to each value.

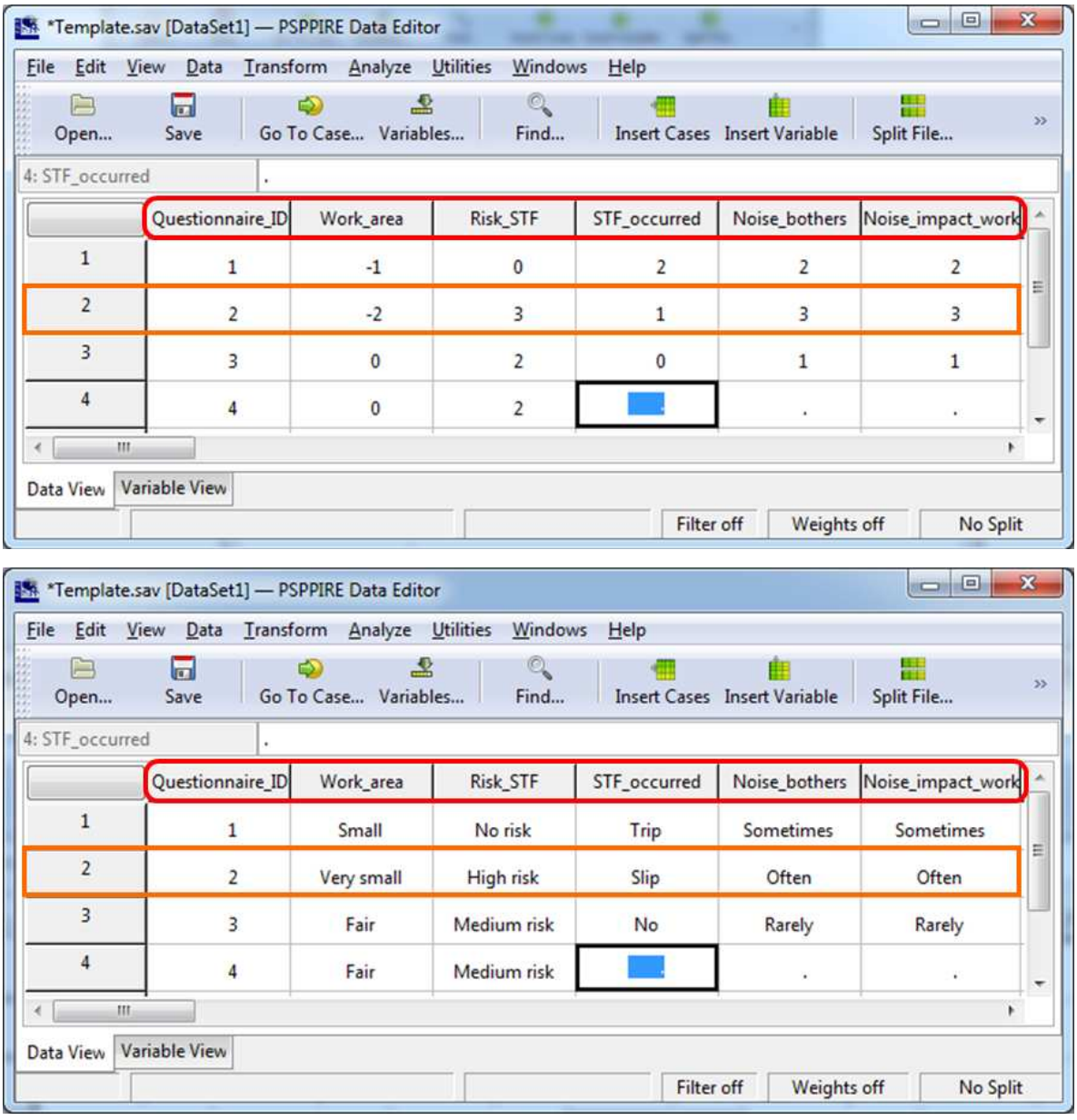


Figure 12 – PSPP data entry screen

The option 'Analyze → Descriptive statistics → Frequencies' is to be used to calculate the frequency distribution for the proper variables. Figure 13 shows an example of the generated results of these calculations. The software reports a six column table for each analyzed variable. The column *Value Label* indicates the label of the answer associated in the questionnaire (e.g. very small, small, fair, big, very big) while the column *Value* shows the numerical value associated with the answer (e.g. -2, -1, 0, 1, 2). The frequency distribution of the answer is shown in the *Frequency* column while its percent value is shown in *Percent* column. The *Valid Percent* and *Cum Percent* columns are calculated excluding the not answered questions, but are not used in this methodology. In fact, the information used in data visualization comes from the Value Label and Frequency rows, highlighted in figure 13.

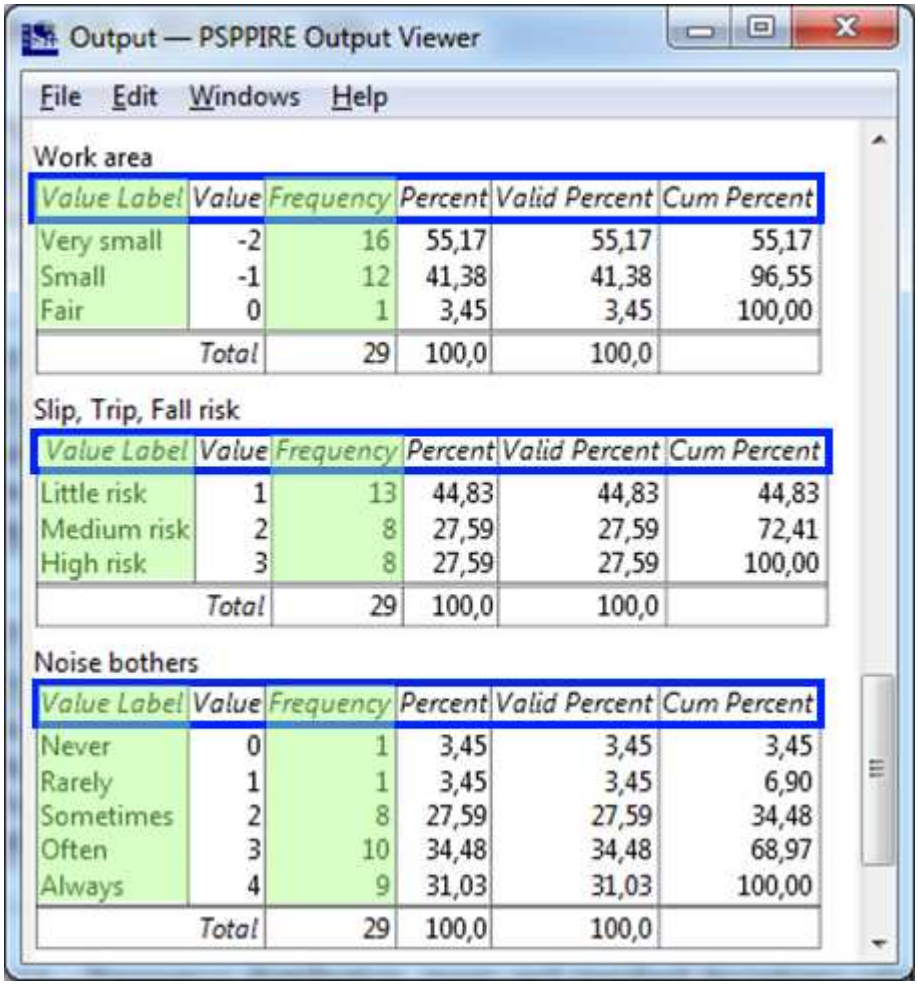


Figure 13 – Frequency distribution calculation using PSPP

3.6 Report the collected data

To properly report the collected data by the methodology, dashboards were developed seeking to follow the guidelines cited in chapter 2.11. They were created using Microsoft Excel 2010 due to its flexibility, simplicity and widespread use, and with the aim of showing the four types of data generated by the methodology: single measurements, continuous measurements, observations, and questionnaire. In order to proper format the dashboards, a way to show each one of the four types of data was also developed.

3.6.1 Single measurements

Two types of tables were created to show single measurement data. The first table has a header, the measured variables label, the minimum (Min) value for each variable, and the measured values. The latter cells were formatted to change their background color to green when the measured value is above the minimum requirements or red when the measured values are below the minimum value. An example is shown in table 6. The second table has the same fields of the first one, including a column with the maximum (Max) value for the variable. The cells showing the measured values were formatted to change their background color to green when the measured value is between the minimum and maximum values and to red if it is below the minimum value or above the maximum values. The background cells can assume light and dark shades of green or red aiming to easy the rows visualization. An example can be seen in table 7. In some situations, when the variable does not require a minimum or maximum value, the cell background color is gray.

Table 6 – Example of single measurement data table with minimum limit

Dimensions		
	Min	**Measured**
Total area (m^2)	20,0	**18,0**
Length (m)	5,00	**5,30**
Width (m)	5,00	**5,60**
Height (m)	2,80	**2,75**

Table 7 – Example of single measurement data table with minimum and maximum limit

Iluminance (lux)			
	Min	Max	Measured
General illuminance	100	200	**227**
Nurse station	150	300	**290**
Medical prescription area	300	750	**376**
Patient bed	150	300	**128**

3.6.2 Continuous measurements

Charts containing statistical information such as mean, standard deviation, minimum measured value, maximum measured value, and amplitude were created to show data regarding continuous measurement of temperature, relative humidity, CO_2 concentration, and noise. An example is shown in figure 14. The shaded area in the chart indicates the limits of the parameter, in this case 18 ^{o}C to 22 ^{o}C. The statistical values are shown on the right side of the chart to aid further analyses.

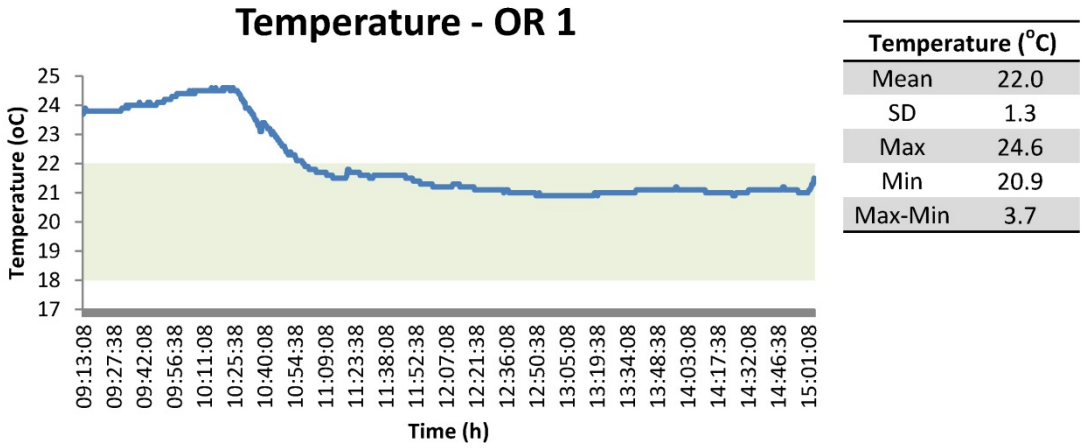
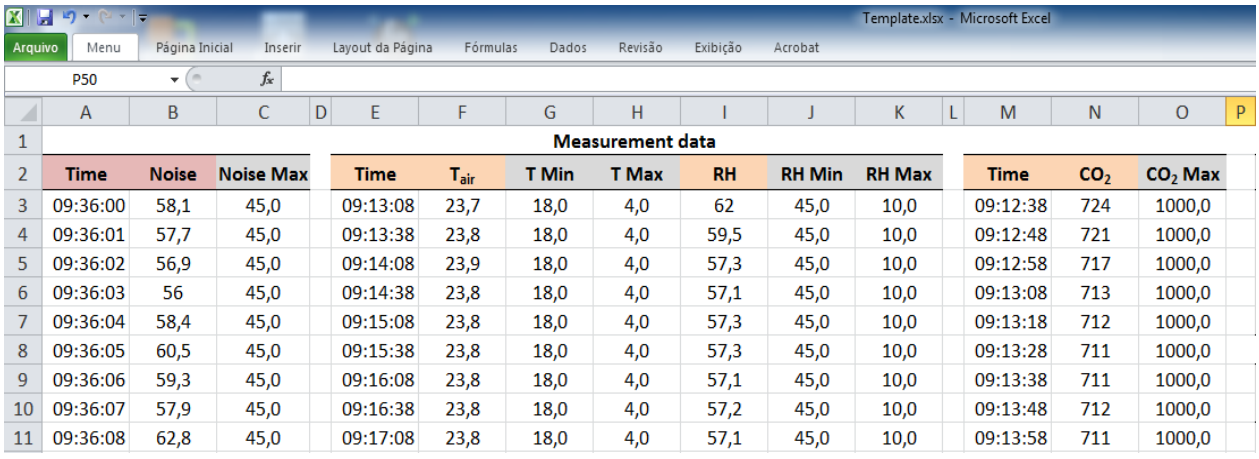


Figure 14 – Continuous measurement chart example

A spreadsheet (named 'DATA') was created to enter the data used to plot the charts as well as the statistical values. The spreadsheet is divided in two main sections: 'Measurement data' and 'Calculated data', as it can be seen in figure 15. The measured values of noise, temperature, relative humidity, and CO_2 concentration are to be pasted on the respective

cells. The parameter requirements found using the "Determine parameter requirements" form should be pasted in the proper R, S, T, and U cells (rows: Reference-Minimum and Reference-Maximum). These values are used in the columns C, G, H, J, K, and O (Tmin, Tmax, RH min, RH max, and CO_2 max). The mean, SD, Max, Min, and Max-Min values of each parameter ought to be pasted in the respective R, S, T, and U columns.



							Measurement data								
	Time	Noise	Noise Max	Time	T_{air}	T Min	T Max	RH	RH Min	RH Max	Time	CO_2	CO_2 Max		
	09:36:00	58,1	45,0	09:13:08	23,7	18,0	4,0	62	45,0	10,0	09:12:38	724	1000,0		
	09:36:01	57,7	45,0	09:13:38	23,8	18,0	4,0	59,5	45,0	10,0	09:12:48	721	1000,0		
	09:36:02	56,9	45,0	09:14:08	23,9	18,0	4,0	57,3	45,0	10,0	09:12:58	717	1000,0		
	09:36:03	56	45,0	09:14:38	23,8	18,0	4,0	57,1	45,0	10,0	09:13:08	713	1000,0		
	09:36:04	58,4	45,0	09:15:08	23,8	18,0	4,0	57,3	45,0	10,0	09:13:18	712	1000,0		
	09:36:05	60,5	45,0	09:15:38	23,8	18,0	4,0	57,3	45,0	10,0	09:13:28	711	1000,0		
	09:36:06	59,3	45,0	09:16:08	23,8	18,0	4,0	57,1	45,0	10,0	09:13:38	711	1000,0		
	09:36:07	57,9	45,0	09:16:38	23,8	18,0	4,0	57,2	45,0	10,0	09:13:48	712	1000,0		
	09:36:08	62,8	45,0	09:17:08	23,8	18,0	4,0	57,1	45,0	10,0	09:13:58	711	1000,0		

			Calculated data		
	Noise (dB)	T_{air} (°C)	RH (%)	CO_2 (ppm)	
Mean	66,2	22,0	54,8	549,5	
SD	7,5	1,3	1,4	116,6	
Max	103,1	24,6	62,0	890,0	
Min	50,1	20,9	49,8	449,0	
Δ	53,0	3,7	12,2	441,0	
Reference - Minimum		18,0	45,0		
Reference - Maximum	45,0	22,0	55,0	1000,0	

Figure 15 – DATA spreadsheet example

3.6.3 Observations

A drop-down list was created to show data regarding parameter observation. This data can assume values as YES, NO, SOMETIMES, or N/A. When the result of the observation is selected in the list, the cell changes its background color (green, red, yellow, gray) according to the meaning of the result. For example, if the floor is reflective, the cell changes its color to red,

indicating an improper condition. If the floor is non-reflective, the cell color changes to green. The cell color changes to yellow, indicating that the parameter may or may not cause improper environmental conditions. When the parameter observation does not apply (N/A) to that environment, cell background turns into gray. As in the single measurements related data, the background cells can assume light and dark shades of green or red aiming to easy the rows visualization. An example of this drop-down list is shown in table 8.

Table 8 – Example of drop-down list

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflexive	NO
There are liquids on the floor	YES / NO
There are buckets, seats, other objects in passageways	YES
There are cables and tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

3.6.4 Questionnaire data

Charts were created to show data regarding questionnaire application, since they map quantities and relationships more directly than words or numbers (ALRECK; SETTLE, 2004). While vertical bar charts were used to display data related to noise sources and noise/lighting/environmental parameters symptoms, horizontal bar charts were used to show information about the remaining questions. This way, regarding those 31 questions, four of them generated the vertical bar charts, whereas the remaining 27 created the horizontal bar charts. The development of these two types of charts is explained in the following paragraphs.

A spreadsheet named ‘Sources-symptoms’, shown in figure 16, was created to plot vertical bar charts. The number of questionnaire respondents is supposed to be entered in cell B1. The values regarding each noise source, as well as the ones related to noise, lighting, and environmental symptoms ought to be entered in the appropriate cells. All these values come from the frequency distribution previously calculated, being used to plot charts on the respective dashboards. After the values are entered in the cells, the corresponding chart is automatically plotted. An example of a lighting related symptoms chart is shown in figure 17, where it is

possible to observe the types of symptoms related by the workers as well as the number of times each respective symptom was cited (on top of the chart).

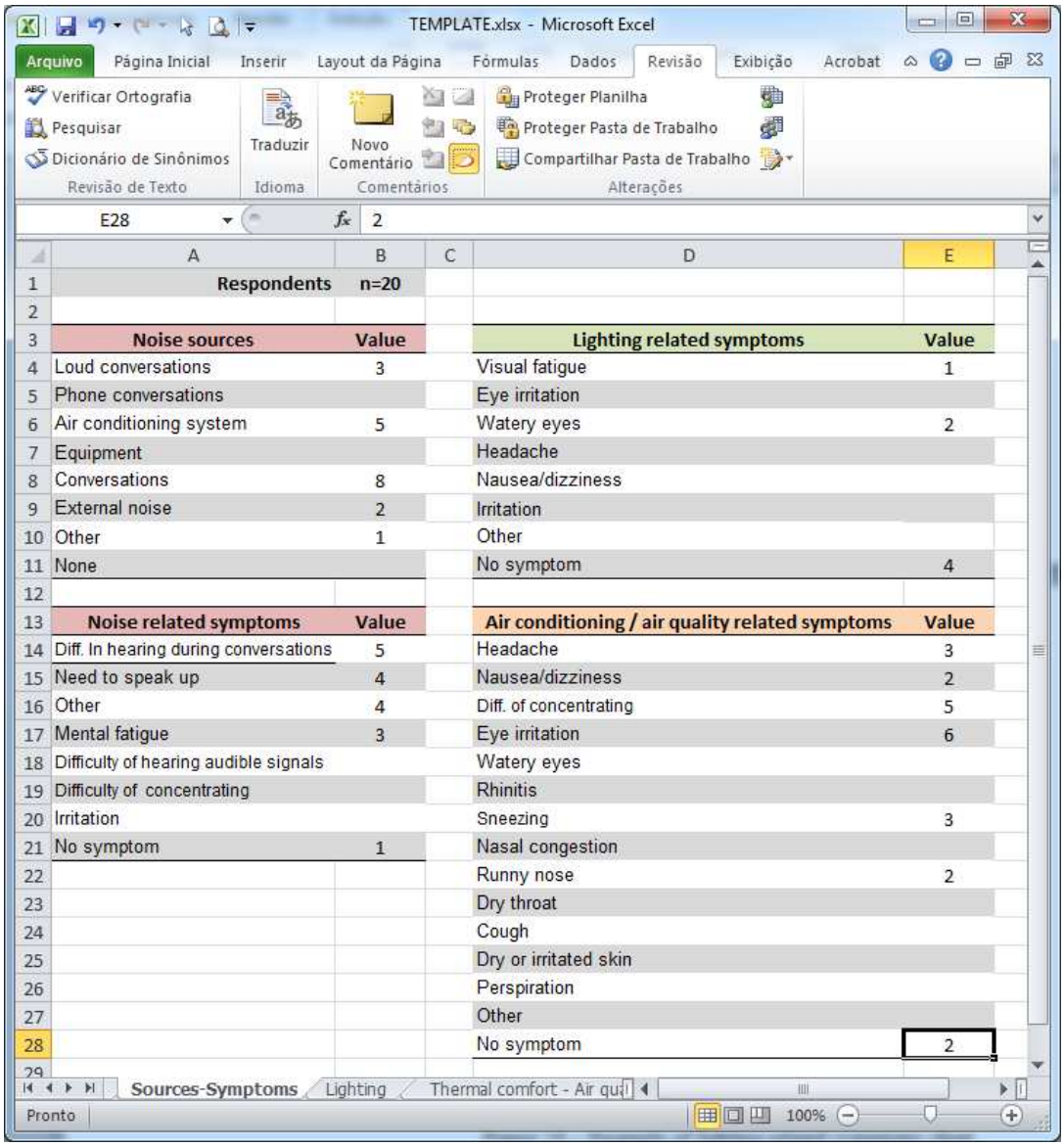


Figure 16 – Sources-symptoms spreadsheet example

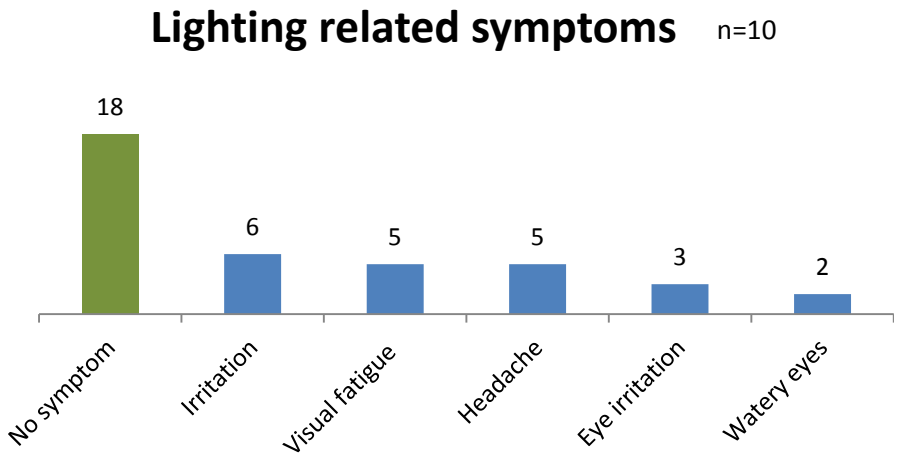


Figure 17 – Example of lighting related symptoms chart

Horizontal bar charts are to be made using Excel functions inside the cells. As mentioned before, a total of 27 charts should be created. Figure 18 shows examples of three types of charts developed in this research. Each chart has a title corresponding to the question it comes from. The values of each parameter come from the frequency distribution previously calculated and are to be typed directly in the cell, creating the chart. Charts such as number 1 below are composed of a frequency scale, usually varying from ‘never’ to ‘always’. Bar colors change according to the scale, usually from green to red, indicating how the workers are supposed to be affected by the parameter, where red affects them more negatively and green does not affect them at all. Charts that are similar to number 2 have a mid-point, varying to opposite extremities with corresponding change in bar colors. Charts such as number 3 indicate the number of events related to each variable: if there are no events, bar color is green; otherwise it is red, indicating an undesirable condition. These color scales were adopted aiming to draw attention to the information contained in the charts.

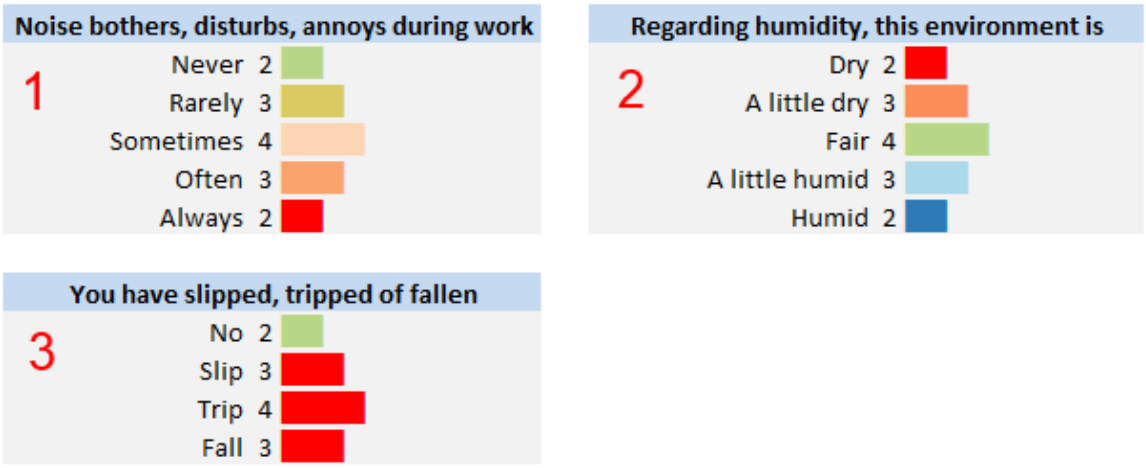


Figure 18 – Example of horizontal bar charts

3.6.5 Dashboard creation

To generate the dashboards, an Excel file was created. This file contains six spreadsheets as shown in figure 19: (1) work area - noise, (2) lighting, (3) environmental parameters, (4) power - medical gas outlets, (5) for charts related data, and (6) for noise sources and symptoms caused by the environment (both 5 and 6 spreadsheets were explained in 3.6.2 and 3.6.4, respectively).

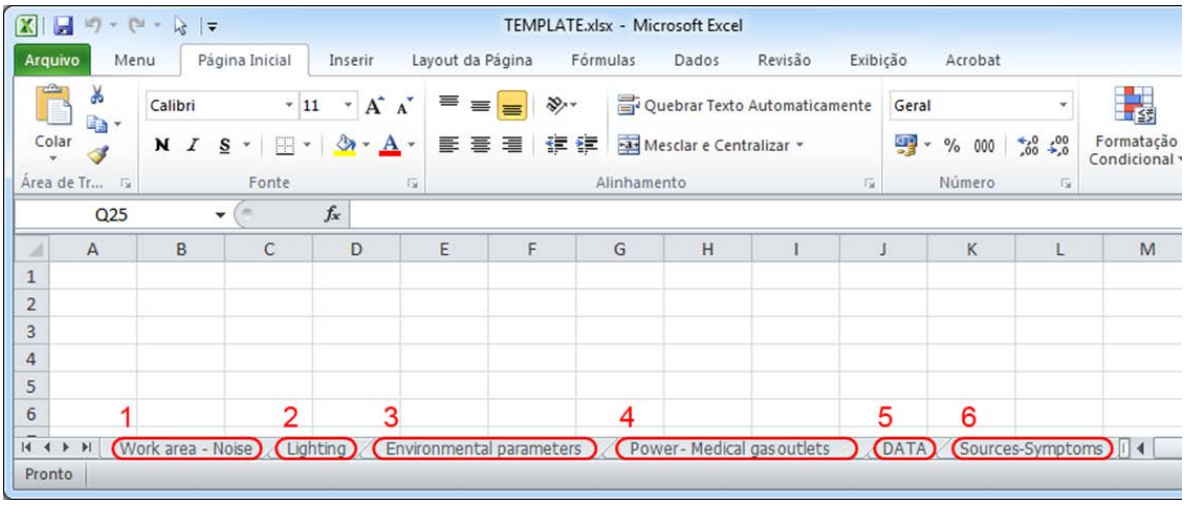


Figure 19 – Excel spreadsheet template used to design the dashboards

Each one of the six groups of parameters (work area, noise, lighting, environmental parameters, power outlets, medical gas outlets) has specific types of data associated to them (single/continuous measurement, observations, and questionnaire). The dashboard for each one of the six groups was elaborated disposing the four types of specific data for each group in the proper spreadsheet as seen in figure 19 (1– Work area – Noise, 2– Lighting, 3– Environmental parameters, 4– Power– Medical gas outlets). The four created dashboards have the same four types of data, changing only the placement of each type of data in the spreadsheet.

Figure 20 shows the work area and noise dashboard with non-real data for exemplification. It is possible to see five sections containing the four types of data previously explained. The first section comprises data related to single measurements. It shows the measured parameters, the minimum (Min) reference values for these parameters, and the measured value. The second section shows data related to observed parameters, while the third section encompasses the horizontal bar charts related to questionnaire answers. The fourth section shows vertical bar charts regarding noise sources and the worker symptoms caused by noise, and, finally, the fifth section relates to data regarding continuous measurement – charts and corresponding statistical values.

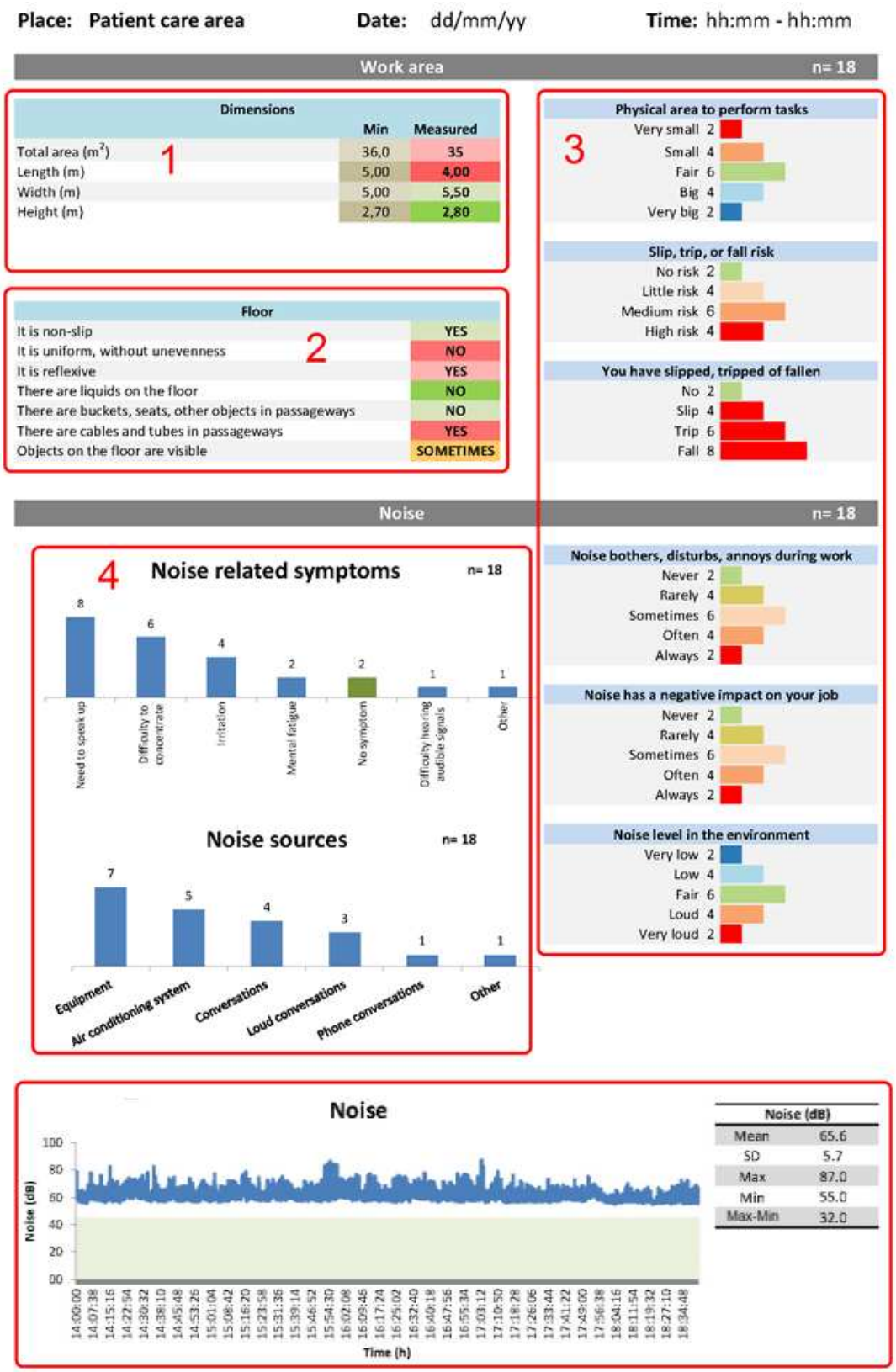


Figure 20 – Work area and Noise dashboard example

The other three dashboards have different formatting but contain the same type of sections. The complete reports with all the four dashboards are shown in chapter 4.6.

3.7 Elaborate the application guideline

The application of the methodology comprises six stages, as shown in figure 21.

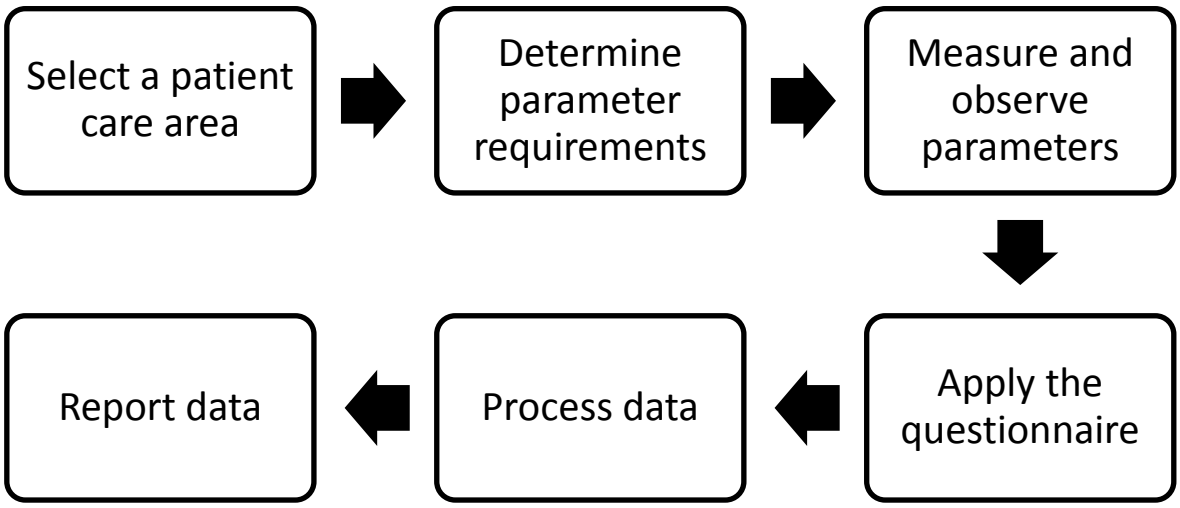


Figure 21 – Methodology application stages

The following application guideline was developed to help the applicant use the methodology. It covers the six stages presented in figure 21.

1. Define the patient care area to be evaluated, set a time period to perform the measurements and write them down in the form "Determine parameter requirements";
2. Use the same form to determine the parameter requirements in the defined patient care area, according to the references researched;
3. Follow the instructions in the "Measure and observe parameters" form in order to:
   3.1. Record the values regarding temperature, relative humidity, CO_2 concentration, and noise during the defined time period;
   3.2. Measure and observe the remaining parameters according to the form;

4. Apply the questionnaire to the workers present in the environment during the measurement/observation period. Explain the objective of the research to each worker invited to participate. Thank the worker for the collaboration after the questionnaire is returned;
5. Calculate the mean ($\bar{x}$), standard deviation (SD), maximum (max) value, minimum (min) value, and amplitude (max-min) value of the temperature, relative humidity, CO_2 concentration, and noise;
6. Use the code-sheet (Appendix 2) and the software PSPP to calculate the frequency distribution of the questionnaire answers;
7. Copy the reference values from the form "Determine parameter requirements" to the appropriate cells in the *Work area – noise*, *Lighting*, *Environmental parameters*, and *Power– Medical gas outlets* spreadsheets;
8. Enter the measured and observed parameter values from the "Measure and observe parameters" form to the appropriate cells in *Work area – noise*, *Lighting*, *Environmental parameters*, and *Power – Medical gas outlets* spreadsheets;
9. Copy the data about noise, temperature, relative humidity, and CO_2 concentration measurement to the respective cells in the *DATA* spreadsheet;
10. Calculate the mean, standard deviation, maximum, minimum, and amplitude (max-min) values of the measured parameters and type them in the respective cell in the *DATA* spreadsheet;
11. In the *DATA* spreadsheet, fill in the cells in the columns C, G, H, J, K, and O with the same number of samples of the respective measurement;
12. Adjust the data range in the noise, temperature, relative humidity, and CO_2 concentration charts to properly draw them;
13. Type the calculated frequency distribution into each respective cell in the *Work area – noise*, *Lighting*, *Environmental parameters*, and *Power – Medical gas outlets* spreadsheets;
14. Type the data regarding noise sources, and symptoms caused by noise, lighting, and environmental parameters in the *Sources-Symptoms* spreadsheet;
15. Arrange each table in this spreadsheet from the highest to lowest value in order to properly draw the charts.

4. Results

The methodology was applied in a public teaching hospital in the city of Campinas/São Paulo built in 1985 with a gross floor area of 65,000.00 m^2 it has 375 active beds and performs nearly 32,000 medical consultations monthly in 44 medical specialties. It is considered a high complexity hospital, offering both outpatient and inpatient care, urgent and emergency care, as well as simple and specialized procedures such as lab tests, cardiac catheterization, cancer treatment, organ transplantation, digital X-ray, endoscopy, ultrasonography, computed tomography, magnetic resonance imaging, etc.

This research was submitted and approved by the ethics committee (Appendix 4) and issued an informed consent (Appendix 5). The methodology was applied according to the six stages previously presented (chapter 3.7 – figure 21): select a patient care area, determine parameters value, measure and observe parameters, apply the questionnaire, process data and report.

4.1 Selecting a patient care area

In order to test the applicability of the methodology in different patient care areas, three of them, with distinct requirements regarding physical parameters such as temperature, humidity, area, lighting, and other ones, were selected: emergency department observation unit (ED-OU), intensive care unit (ICU), and operating room (OR). The characteristics of each area are briefly described below.

The emergency department provides medical care to victims of trauma, strokes, cerebral vascular accident, traumatic brain injury, psychotic break, as well as to victims of gunshot and stab wounds, burns and other serious accidents. The clinical staff is composed by professors, physicians, students, nurses, nursing assistants, and residents. About 240 patients are treated daily in the department. In this area, measurements were performed just once.

The intensive care unit was opened in 1986. There are 24 ICU beds divided into post-operative unit, general ICU, and coronary care unit. The clinical staff comprises physicians, pediatricians, intensive care nurses, nursing assistants, and physical therapists. Measurements

were taken once in the post-operative unit, named by the hospital ICU 203, and once in the general ICU, named ICU 206.

In the operating rooms, about 40 surgeries are performed daily in the 16 available rooms allocated not only to elective surgeries but also to emergency surgeries. The hospital provides services in the following surgical specialties: general surgery, head and neck surgery, cardiovascular surgery, neurosurgery, pediatric surgery, plastic surgery, orthopedic surgery, thoracic surgery, trauma surgery, urologic surgery, vascular surgery, and gastric surgery. For the purpose of this research, the surgery schedule was analyzed and the operating rooms 1, 2, 3, 5, 8, and 10 were selected. Distinct surgeries are carried out in each one of these rooms: 1 – cardiac surgery, 3 – knee arthroscopy, 5 – laparoscopic ureterolithotomy, 6 – umbilical hernia, and 10 – bariatric surgery. Measurements were performed during the surgeries in these ORs and also at three different surgeries in OR 2, since it was used by three different orthopedic surgical teams that performed the following surgeries: hip endoprosthesis, osteosynthesis of tibia fractures with intramedullary rod, and femur elongation. A total of eight measurements were made in the OR.

An authorization of each department head (ED-OU, ICU, OR) was obtained before the application of the methodology. Moreover, each department head introduced the researcher to the clinical staff, explaining the research being performed. Whenever necessary, a verbal authorization was requested to the chief surgeon before applying the methodology in each operating room.

For each area, a time period to take the measurements was established as follows: ED-OU – 09:40 – 19:15, ICU 203 – 08:00 – 21:00, ICU 206 – 8:30 – 19:30, OR – length of the surgery. These time periods were established aiming to analyze the environment regarding either the worker's shift (ED-OU, ICU) or a task performed in the environment (OR).

4.2 Determining parameter requirements

The parameter requirements for each area (ED-OU, ICU, and OR) were determined following the form 1 – "Determine parameter requirements" (chapter 3.3). Sources such as standards and resolutions were consulted and the values found were written down in the

respective fields. Table 9 shows the parameter requirements found for each area and the respective consulted reference.

Table 9 – Parameter required for each area analyzed

Place / Parameter	Emergency department observation unit		Intensive care unit		Operating room	
	Value	**Reference**	**Value**	**Reference**	**Value**	**Reference**
Total area (m^2)					36.0 / 25.0	RDC 50
Length (m)					5.0 / 4.65	RDC 50
Width (m)					5.0 / 4.65	RDC 50
Height(m)					2.70	RDC 50
Area/bed (m2)	8.5	RDC 50	9.0	RDC 50		
Distance between walls and bed (m)			1.0	RDC 50		
Distance between beds (m)			2.0	RDC 50		
Nurse station (m^2)			6.0	RDC 50		
Medical prescription area (m^2)			1.5	RDC 50		
Noise (dB)	45.0	NBR10152	45.0	NBR10152	45.0	NBR10152
Illuminance general (lux)	150-300	NBR 5413	100-200	NBR 5413	300 - 750	NBR 5413
Illuminance patient bed (lux)	350- 700	NBR 5413	350- 700	NBR 5413		
Illuminance nurse station (lux)			150-300	NBR 5413		
Illuminance medical prescription	300-750	NBR 5413	300-750	NBR 5413		
Temperature (^oC)	23-26	ANVISA RE9	21-24	NBR 7256	18-22	NBR 7256
Relative humidity (%)	40-65	ANVISA RE9	40-60	NBR 7256	45-55	NBR 7256
Number of power outlets			8	RDC 50		RDC 50

Place / Parameter	Emergency department observation unit		Intensive care unit		Operating room	
	Value	**Reference**	**Value**	**Reference**	**Value**	**Reference**
Number of oxygen outlets	1	NBR 12188	2	NBR 12188	2	NBR 12188
Number of Nitrous Oxide outlets					1	NBR 12188
Number of vacuum outlets		NBR 12188	1	NBR 12188	1	NBR 12188
Number of Medical air outlets	1	NBR 12188	2	NBR 12188	2	NBR 12188

4.3 Measuring and observing parameters

The instructions presented in the form 2 – "Measure and observe parameters" (chapter 3.3) were followed to accomplish the stage of measuring and observing the parameters for each one of the three areas.

The devices used for continuous measurement (thermo-hygrometer, CO_2 concentration meter, sound level meter) were set up at about 1.70m high, in spots indicated by the clinical staff, trying to follow form 2 recommendations. However, in some areas, the positioning of some devices could not match these recommendations. The resulting effects will be discussed in chapter 5. The sampling time of the thermo-hygrometer was set to 1 minute, since temperature and relative humidity vary slowly in time. The sampling time of the CO_2 concentration meter was set to 30 seconds. Since requirements for the sampling time were not found in the researched literature, this 30 seconds period was chosen to better characterize the gas concentration in the environment. The sound level meter was set to SLOW response and the sampling time to 1 second to record all the possible noise during the measurement period. Before starting the measurements, the sound level meter were adjusted by using a 94dB sound level calibrator.

The measurements were performed using the devices listed in table 5. All devices were new and under warranty. Moreover, the sound level meter calibrator, thermo-hygrometer,

and CO_2 concentration meter were calibrated by laboratories certified by the Brazilian Calibration Network (RBC).

The remaining parameters (length, width, height, area, and illuminance) were measured during the established time period (see 4.1 above) in the ICU and in the ED-OU. Regarding the OR, these parameters were measured after the surgery was finished, usually when the patient and the members of staff had already left the OR.

The observations regarding the floor, lighting, power and medical gas outlets were all made during the same established time period determined in 4.1.

4.4 Applying the questionnaire

The questionnaires were applied by the thesis author. The sampling was based on convenience, looking for the highest number of respondents in each staff group (e.g. physicians, nurses, assistants) for each researched area. Depending on how appropriate the moment was, the members of the staff were requested to answer the printed questionnaire, being thanked after returning it. No further action was performed when a worker denied answering the questionnaire.

When applying the questionnaire in the ORs, anesthetists and nursing assistants were required to answer it during the surgeries, but the surgeons, soon after the surgeries. For the other areas (ED-OU and ICU), the requests were usually made near the end of the shift or when one staff member was filling paperwork or even taking a break. Any doubts on how to answer the questions were clarified by the author. The table below summarizes the number of questionnaires answered in each place.

Table 10 – Number of questionnaires answered by place

Place	Questionnaires
ED-OU	**30**
ICU 203	**11**
ICU 206	**12**
OR 1	**7**
OR 2	**9**
OR 2	**5**
OR 2	**6**
OR 3	**5**
OR 5	**6**
OR 8	**4**
OR 10	**6**
Total	**101**

4.4.1 Questionnaire reliability calculation

As described in chapter 2.10.1, Cronbach's alpha coefficient is used to calculate the questionnaire here developed reliability; assuming that a value above 0.70 will indicate an acceptable result. Questions 3, 7, 8, 13, and 22 were excluded for the calculation since they provide multiple choice answers that are not used to determine the coefficient. In addition, the questions 26, 27, and 28 related to power plug adapters were also excluded due to the problems cited in chapter 5, thus remaining 23 items used to alpha calculations.

The coefficient alpha was calculated for the questionnaires applied in the ED-OU and ICU 206, since they are different areas and presented the highest number of questionnaires answered. Table 11 shows the calculated value of 0.72 for the alpha using ED-OU questionnaires. It should be noted that due to the fact that 11 questionnaires had missing answers, they were excluded from the calculation by the software.

Table 11 – Cronbach's alpha coefficient for the questionnaire applied in the ED-OU

Case Processing Summary

	N	%
Cases Valid	19	63,33
Excluded	11	36,67
Total	30	100,00

Reliability Statistics

Cronbach's Alpha	N of Items
,72	23

Table 12 shows the Cronbach's alpha for the ICU 206. It can be seen that alpha was 0.84, higher than the recommended level of 0.70. All 12 questionnaires were used in calculation since none of them presented missing answers.

Table 12 - Cronbach's alpha coefficient for the questionnaire applied in ICU 206

Case Processing Summary

	N	%
Cases Valid	12	100,00
Excluded	0	,00
Total	12	100,00

Reliability Statistics

Cronbach's Alpha	N of Items
,84	23

4.5 Processing data

The mean ($\bar{x}$), standard deviation (SD), maximum (max) value, minimum (min) value, and amplitude (max-min) regarding the measurement of temperature, relative humidity, CO_2 concentration and noise were calculated according to the instructions described in chapter 3.5.1.

The author entered questionnaire data regarding each analyzed area in the software PSPP with the help of the code-sheet as described in 3.5.2. After all data regarding one questionnaire was entered, verification was performed to avoid typing errors. However, it is recommended that while one person enters the data, another check for errors. Figure 22 shows an excerpt of the data related to the questionnaire applied in ED-OU. It is possible to observe the

values associated to each answer for a questionnaire (e.g. 17) in the upper part of the figure and the corresponding label to the same answer in the lower part of the figure.

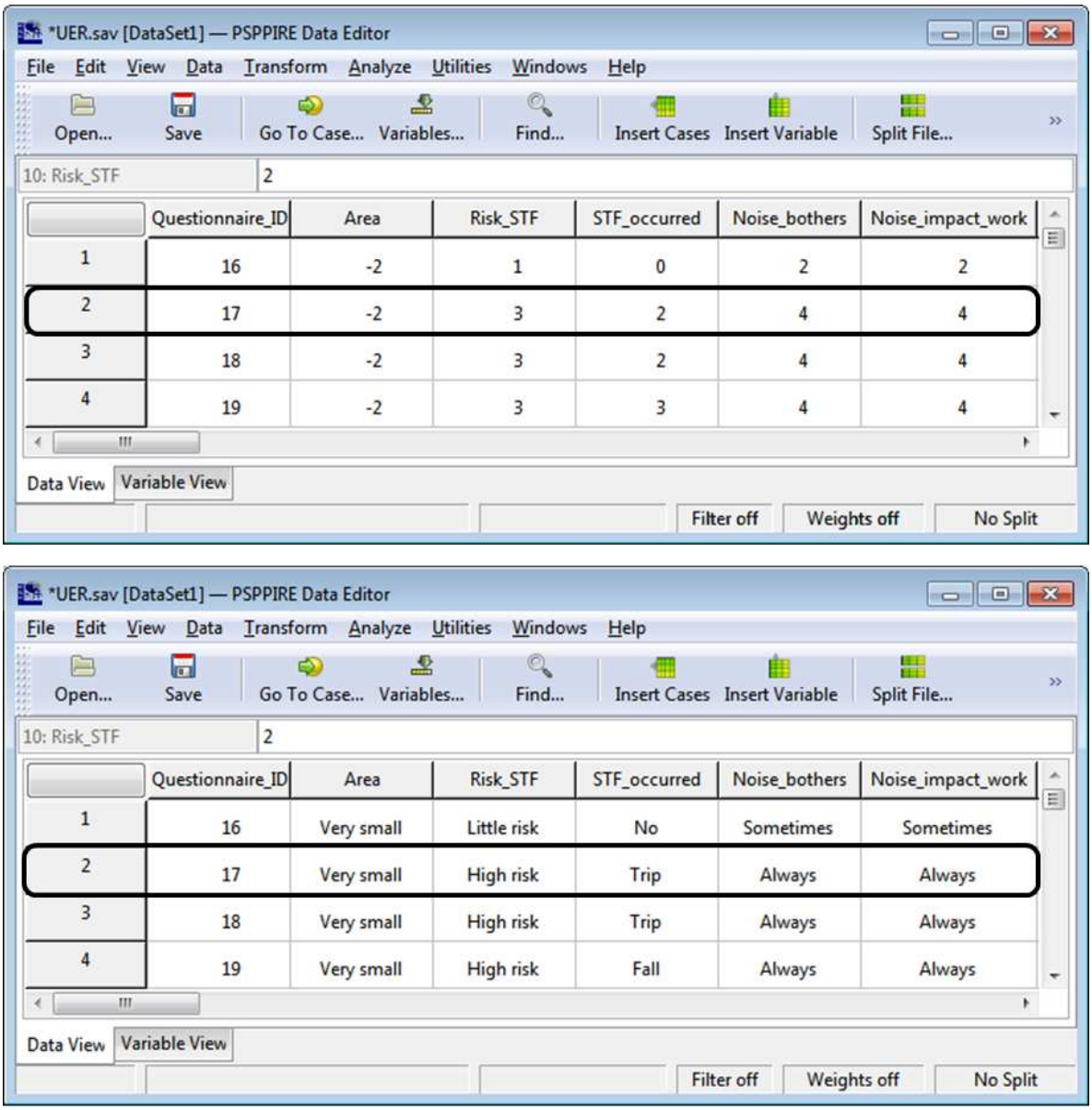


Figure 22 – Example of ED-OU questionnaire related data entered in PSPP

The option 'Analyze → Descriptive statistics → Frequencies' was used to calculate the frequency distribution for the variables. Figure 23 shows an excerpt of the generated results for these calculations. The report shows the variable labels (e.g. Physical area, STF risk, STF happened) and the respective frequency distribution calculations. The data coming from the

columns *Value Label* and *Frequency* were used to generate the reports as described in chapter 4.6.

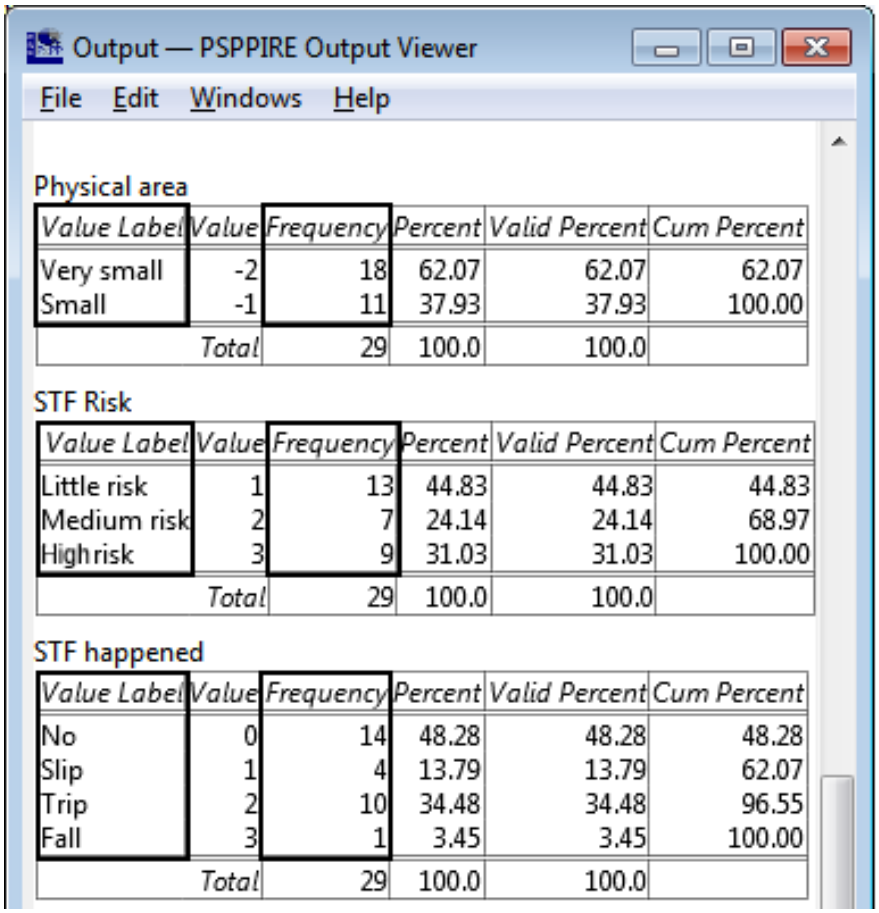


Figure 23 – Frequency distribution calculations using PSPP

4.6 Reporting

A report for each analyzed area was created according to the following steps, described in the application guideline (chapter 3.7):

- The requirements from the form “Determine parameter requirements” were copied into the appropriate cells in the spreadsheets;
- The measured and observed parameter values from the “Measure and observe parameters” form were copied into the appropriate cells in the spreadsheets;

- The data from noise, temperature, relative humidity, and CO_2 concentration measurement were copied into the respective cells in the *DATA* spreadsheet;
- The calculated values of the mean, standard deviation, maximum, minimum, and max-min were typed in the respective cell in the *DATA* spreadsheet;
- The calculated frequency distribution values were typed into each respective cell in the spreadsheets;
- Data regarding noise sources, and symptoms caused by noise, lighting, and environmental parameters were typed in the *Sources-Symptoms* spreadsheet;

The final report of the ED-OU measurements is shown in figure 24, whereas the remaining ten reports are shown in the appendix 6.

Place: ED-OU **Date: 19/04/2012** **Time: 9:40 to 19:15**

Work area n=30

Dimensions	Min	Measured
Area / bed (m^2)	8.5	3.4

Physical area to perform tasks

Very small	19
Small	11
Fair	
Big	
Very big	

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	NO
Objects on the floor are visible	SOMETIMES

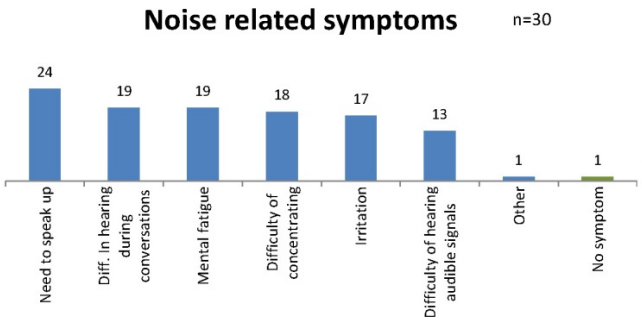
Slip, trip, or fall risk

No risk	
Little risk	13
Medium risk	7
High risk	9

You have slipped, tripped or fallen

No	15
Slip	4
Trip	10
Fall	1

Noise n=30

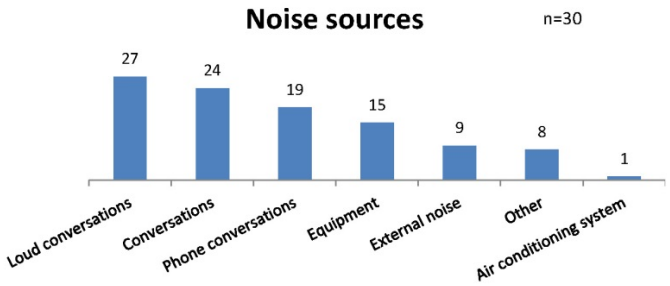


Noise bothers, disturbs, annoys during work

Never	
Rarely	
Sometimes	9
Often	9
Always	12

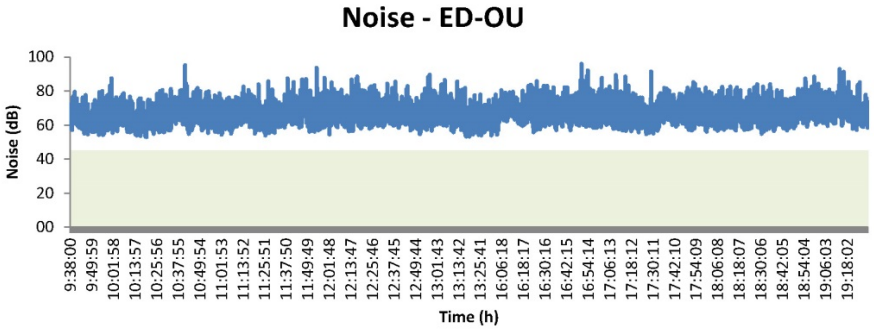
Noise has a negative impact on your job

Never	
Rarely	2
Sometimes	9
Often	5
Always	12



Noise level in the environment

Very low	0
Low	0
Fair	2
Loud	16
Very loud	11



Noise (dB)	
Mean	67.8
SD	5.0
Max	95.2
Min	53.0
Max-Min	42.2

Place: ED-OU **Date: 19/04/2012** **Time: 9:40 to 19:15**

Lighting n=30

Illuminance (lux)	Min	Max	Measured
General	150	300	249
Patient bed	300	750	180
Prescription area	300	750	187

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks

Never	7
Rarely	12
Sometimes	10
Often	1
Always	

Glare occurs during tasks

Never	9
Rarely	12
Sometimes	6
Often	2
Always	

Shadows are produced during tasks

Never	5
Rarely	6
Sometimes	11
Often	7
Always	

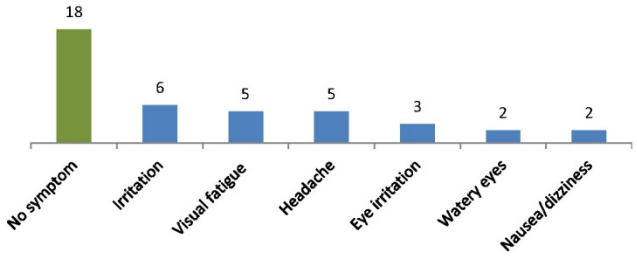
You perceive the environment as

Too dark	2
Dark	13
Fair	11
Bright	3
Too bright	

Lighting provides proper task conditions

Never	1
Rarely	2
Sometimes	12
Often	8
Always	5

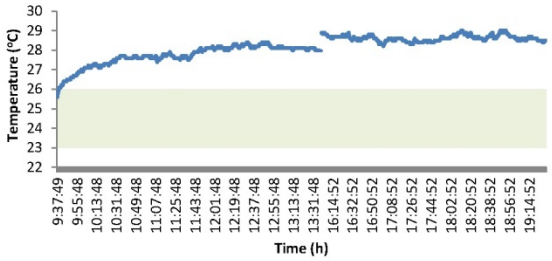
Lighting related symptoms n=30



Place: ED-OU **Date:** 19/04/2012 **Time:** 9:40 to 19:15

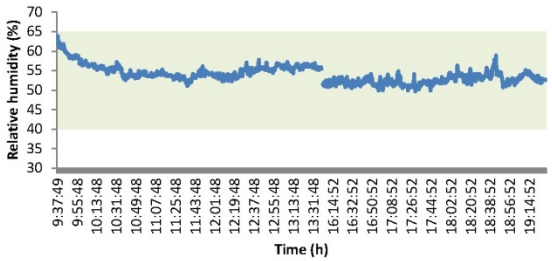
Environmental parameters — n=30

Temperature - ED-OU



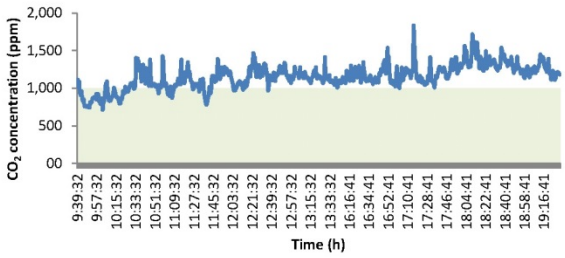
Temperature (°C)	
Mean	28.1
SD	0.6
Max	29.0
Min	25.6
Max-Min	3.4

Relative Humidity - ED-OU



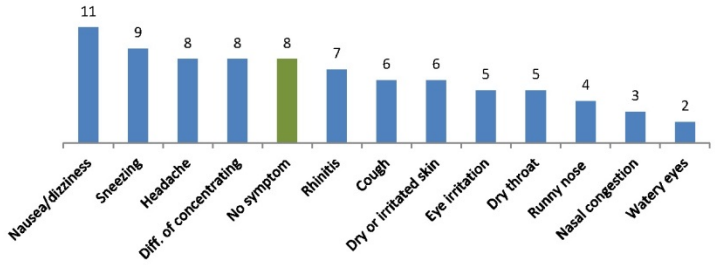
Rel. Humidity (%)	
Mean	54.0
SD	2.1
Max	63.9
Min	49.7
Max-Min	14.2

CO2 concentration - ED-OU



CO_2 conc. (ppm)	
Mean	1153.6
SD	161.0
Max	1833.0
Min	715.0
Max-Min	1118.0

Air conditioning / air quality related symptoms — n=30



Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	4
Uncomfortable	9
Very uncomfortable	16

Temperature variations bother you

Never	3
Rarely	5
Sometimes	5
Often	8
Always	7

Regarding humidity, this environment is

Dry	11
A little dry	8
Fair	6
A little humid	2
Humid	

You are bothered by annoying drafts

Never	20
Rarely	4
Sometimes	3
Often	2
Always	1

The environment seems stuffy

Never	
Rarely	
Sometimes	3
Often	4
Always	22

The environment presents unpleasant odors

Never	
Rarely	
Sometimes	
Often	8
Always	21

Air quality in the environment is

Very poor	12
Poor	10
Acceptable	3
Good	1
Very good	

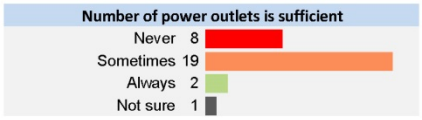
Place: ED-OU **Date:** 19/04/2012 **Time:** 9:40 to 19:15

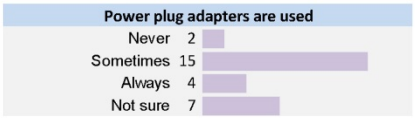
Power outlets n=30

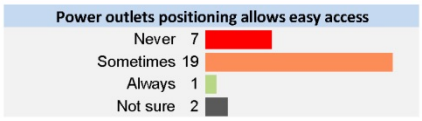
Number and height of power outlets	Min	Measured
Number of power outlets (total)	-	17
Number of 127 V power outlets		-
Number of 220 V power outlets		17
Number of X-Ray power outlets		4
Power outlets height (m)		1.50

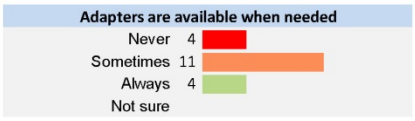
Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	YES
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

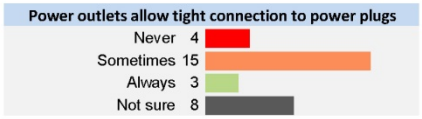
Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

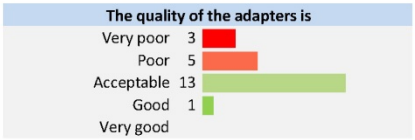






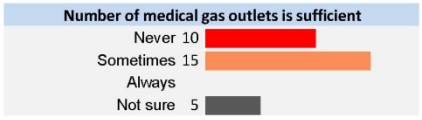


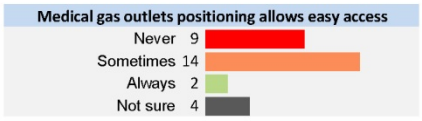




Medical gas outlets n=30

Medical gas outlets	Min	Measured
Number of Oxygen outlets/bed	1	0.2
Number of Nitrous Oxide outlets/bed		-
Number of Vacuum outlets/bed		0.2
Number of Medical air outlets/bed	1	0
Medical gas outlets height (m)	1.5	1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		N/A
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		N/A





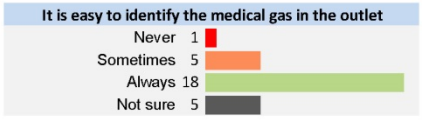


Figure 24 – Final report of the ED-OU

5. Discussion

Eleven reports were created due to the application of the methodology in 9 different areas. Since it would be tedious and repetitive to analyze each parameter in all of the 11 reports, the analyses were developed in three ways in order to avoid repetition: firstly, the ED-OU report was analyzed; secondly, the common findings for the ICUs 203 and 206 were shown, followed by the particular findings for each ICU; finally, the findings for OR 2 were discussed. The remaining ORs reports are not discussed here but can be found in appendix 6.

The analyses were done as follows:

- The number of answered questionnaires varied from four to 30 per area. Since one answer in a group of four counts as 25% and the same answer in a group of 30 counts only as 3.3%, the analyses of the questionnaire answers were made by using only the number of respondents instead of percentage;
- Questions not answered were not accounted for in the analyses. For example, if a person did not answer one particular question in a group of 15 questionnaires, the analysis of this question took into consideration the 14 answered ones;
- Words in *italics* refer to answer options in the questionnaire. For example, the phrase "all workers desired the noise level *diminished*" means that workers checked the option "*diminished*" in the questionnaire as an answer;
- When cited in the text, the required values refer to the values found by consulting the references according to the form 1 – "Determine parameter requirements" and organized in table 9;
- Only the two most cited noise sources, as well as noise, lighting, and environmental parameters related symptoms were cited. The full reports containing all answers can be found in appendix 6;
- The researcher did not express personal opinion when analyzing questionnaire answers.

In a significant number of questionnaires, many answers pointed to the use of power plug adapters, as well as their availability and quality. In fact, about 11 out of the 102

respondents affirmed that the adapters were *never* used, 63 stated that the adapters were *sometimes* used, 14 affirmed that the adapters were *always* used, while the remaining 14 were *not sure* about it. However, during the two weeks of application of the methodology, not even a single power plug adapter was seen in any of the analyzed environments. This fact generated the following hypothesis: (1) some (or even many) workers may have misinterpreted the meaning of "power plug adapters"; (2) the workers were not sure about the power plug adapters and checked the "central" option *sometimes*; (3) in fact, the adapters had been used and were not seen during this time as a matter of coincidence. Thus, since it was not possible to verify which hypothesis is the correct one at the moment of the questionnaire analysis, the answers regarding power plug adapters will not be discussed here because they may be biased or even wrong.

5.1 Emergency department observation unity

There are seven treatment spaces in this environment, which should be used by seven patients. However, since the hospital does not deny care to any patient, this environment usually becomes overcrowded. In fact, during the analysis, an average of 23 patients was being treated there. Sometimes, four patients were placed on gurneys in the same treatment space or even in the corridor, as it can be seen in figure 25 and figure 26. In addition, a family member was sometimes allowed to stay with the patient, increasing the number of people in the same environment. In figure 25, it is also possible to see the positioning of the continuous measurement devices in the blueprint.

Figure 25 – Blueprint with gurneys example

Figure 26 – ED-OU picture

Figure 27 shows a picture of such devices placed very closely to the prescription area, to a corridor, and to people in general. Although this was not the best place to set up the devices, it was the only one available.

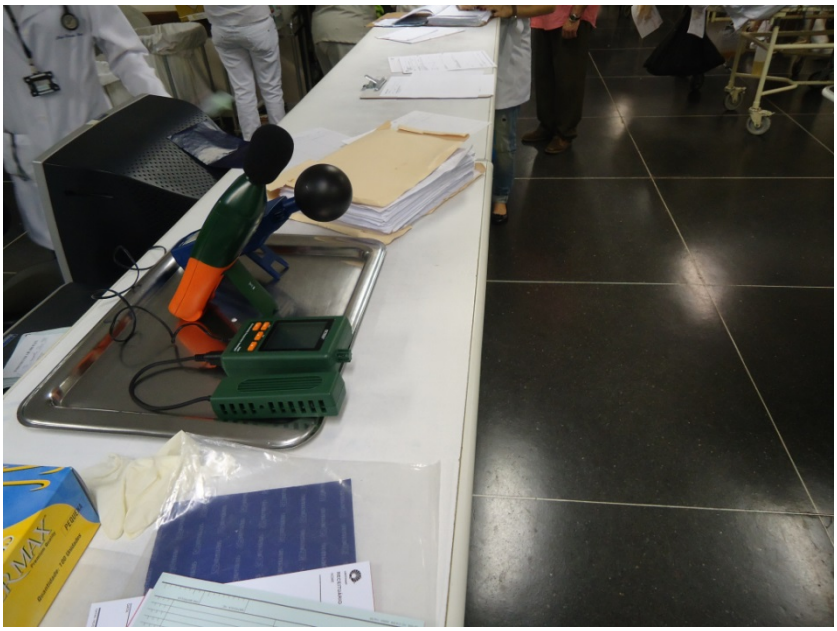


Figure 27 – Picture of the continuous measurement devices in ED-OU

The patient care area was about 60% smaller (3.4 m^2) than required (8.5 m^2) and all staff agreed that this area was *small* or *very small* to perform the tasks. The floor presented risks of slips, trips, and falls, and four slips, ten trips, and one fall occurred on the previous 15 days. Moreover, the floor was black, making it difficult to see dark or transparent objects, increasing the risk of a slip.

The average measured noise was 67.8 dB. Figure 28 shows noise measurements in ED-OU where it can be verified that the noise level was always above the maximum recommended value of 45 dB.

It can be stated that noise had a significant effect on the workers, since 26 out of 30 respondents affirmed that noise had a negative impact on the job and all workers were *sometimes*, *often*, or *always* bothered by it. Twenty seven out of 29 workers agreed that noise level in the environment was *loud* or *very loud*. Loud conversations and conversations in general were considered the main sources, whereas the need to speak up and difficulty in hearing during conversations were the main symptoms caused by noise. It was possible to perceive that the need to speak up was caused by excessive noise but, on the other hand, it contributed to increase noise levels, creating a vicious cycle.

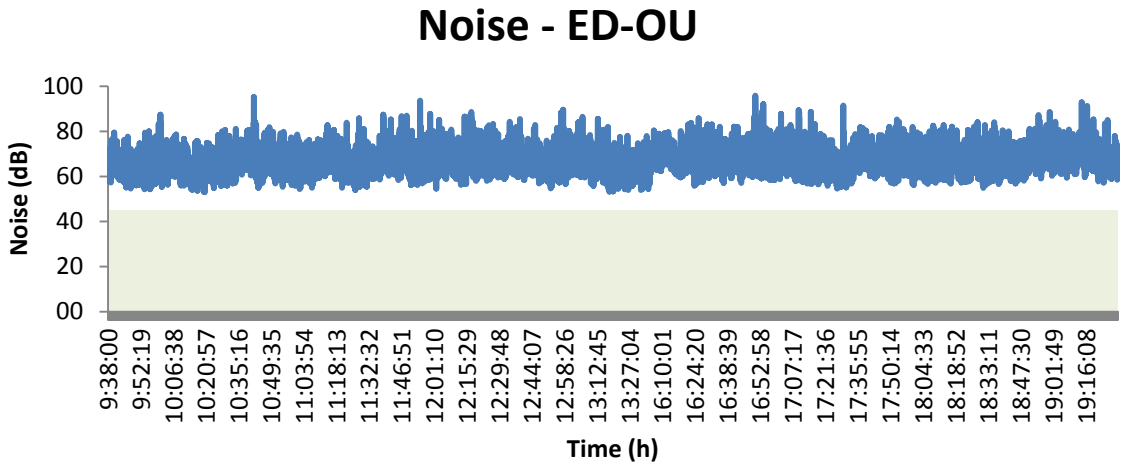


Figure 28 – Noise in the ED-OU

Table 13 shows noise measurements performed by different authors in observation units and wards. The places where the measurements were performed and the minimum, average,

and maximum noise level recorded are displayed. Respective fields in the table were left empty due to non-performed measurements. It is possible to see that very similar values were found by all authors regarding the three noise levels measured: minimum, average, and maximum. However, the average and maximum noise values found in the observation unit measured in the thesis were at least 9% higher than the measurements conducted in the wards. It can be seen in the table that all places presented minimum noise levels higher than the maximum tolerated during all the measurement period.

Table 13– Observation units and wards noise measurements comparison

		Noise Level		
	Place	Minimum (dB)	Average (dB)	Maximum (dB)
MacKenzie; Galbrun (2007)	Ward	–	59.6	86.7
McLaren, Armstrong (2008)	Ward A	56.0	62.1	86.3
	Ward B	51.0	58.7	81.0
	Ward C	50.1	59.3	78.5
Lima (2004)	Observation unit	–	59.0	–
Thesis	**Observation unit**	**53.0**	**67.8**	**95.2**

* Recommended noise level ≤ 45.0dB

Table 14 shows the measured illuminance in the ED-OU. The patient bed and prescription area illuminance was below the lower limit of 300 lux. Workers complained about lighting problems due to the occurrence of shadows, reflex, and glare. However, only six of them reported irritation, five mentioned visual fatigue, and 18 people did not present any lighting related symptoms.

Table 14 – Illuminance in the ED-OU

	Illuminance (lux)		
	Min	Max	Measured
General	150	300	**249**
Patient bed	300	750	**180**
Prescription area	300	750	**187**

The environment did not provide proper temperature conditions, since it was considered *uncomfortable* or *very uncomfortable* by 25 people. It was possible to see in figure 29 that the temperature reached 29.0 ^{o}C, about 3.0 ^{o}C above the required limit of 26 ^{o}C. At the time of measurements, the air conditioning system was not working due to maintenance. However, some members of the clinical staff said that even when the air conditioning is working properly, the temperature does not get low enough to make them feel comfortable. The sudden jump in the temperature was due to the fact the measurements were halt at 13:39. When they were resumed at 16:04, the environment temperature was 0.8 ^{o}C higher than at 13:39.

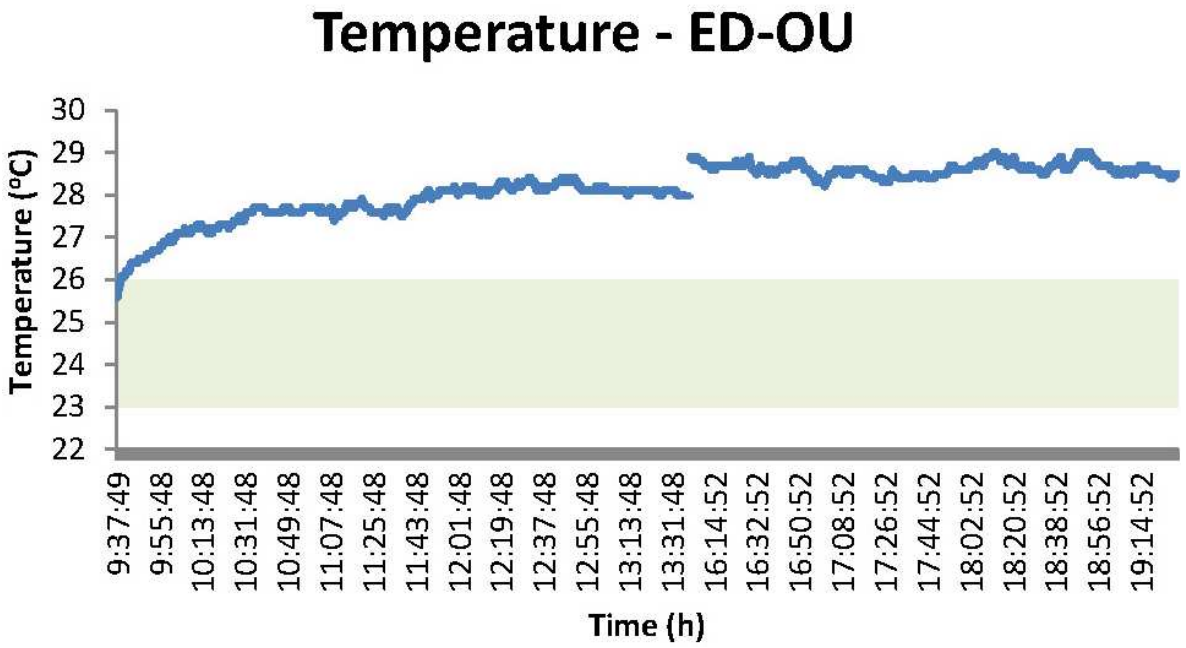


Figure 29 – Temperature in the ED-OU

Despite the fact that average relative humidity was about 54%, 19 out of 30 workers considered the environment a *little dry* or *dry*. It is possible to see in figure 30 that the RH was between the established limits. The sudden jump in the RH was due to the fact the measurements were halt at 13:39. When they were resumed at 16:04, the environment relative humidity was 4.2% lower than at 13:39.

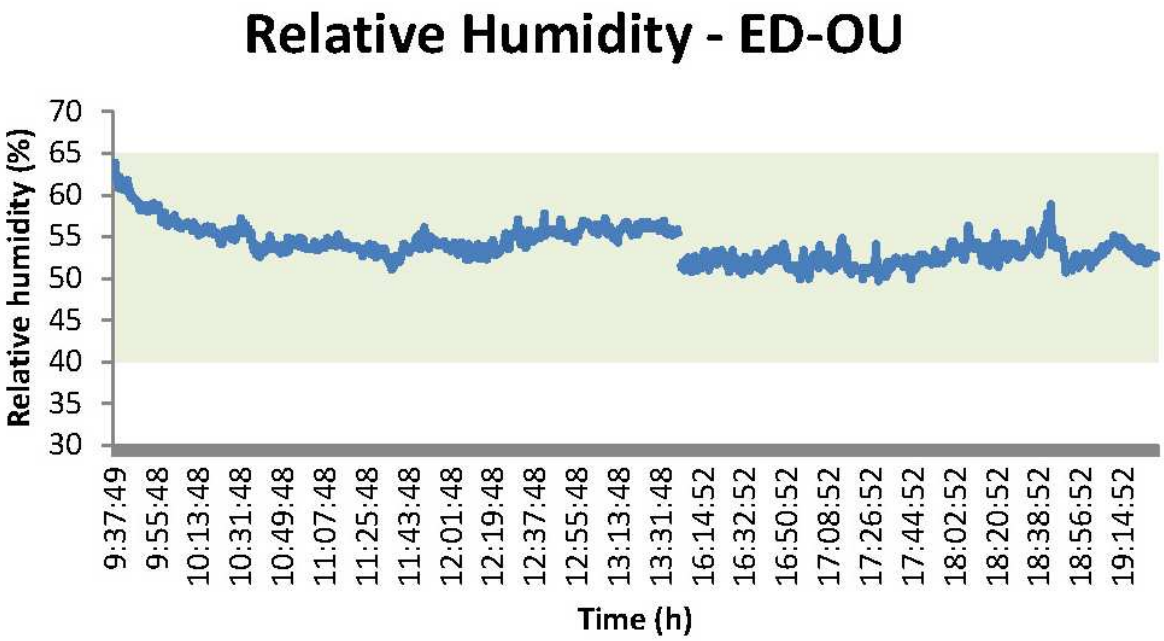


Figure 30 – Relative humidity in ED-OU

The levels of CO_2 concentration were higher than the established limit during 91% of the measurement time. Figure 31 shows significant variations in CO_2 concentrations, which may be due to the malfunctioning of the air conditioning system, the great number of people coming in and out of the environment and/or the proximity of the measurement device to people in general. The device may have measured part of people's exhaled CO_2, since it could not be positioned 2.0 m away from people, as recommended. In addition, the environment seemed stuffy, presented unpleasant odors, and had a *poor* or *very poor* air quality in the view of the vast majority of the staff. Nausea/dizziness and sneezing were the main symptoms caused by environmental parameters mentioned by the workers.

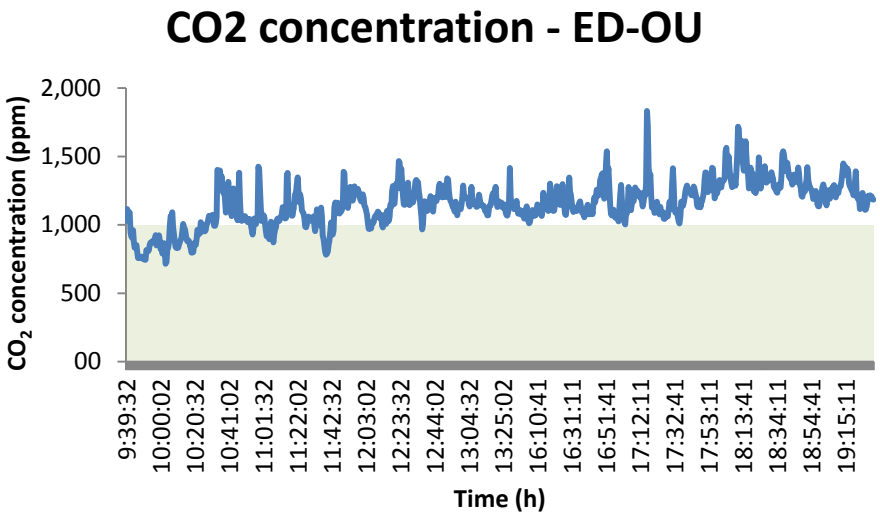


Figure 31 – CO_2 concentration in the ED-OU

In this environment, there were 13 unidentified 220V power outlets in total. It can be stated by the questionnaire answers that the number of power outlets was not sufficient to perform the tasks, their positioning did not allow easy access, and they only *sometimes* provided tight connection to power plugs. In addition, it was possible to plug 127V devices in 220V outlets, which could possibly damage them.

The problems related to medical gases were similar to the ones related to power outlets: the workers agreed that the number of medical gas outlets was not sufficient to perform their tasks, and that their positioning did not allow easy access. In fact, the environment lacked medical air outlets as demanded by NBR 12.188 (ABNT, 2012), and the number of existing Oxygen outlets/bed was only 0.2 instead of 1.

5.2 Intensive care unit

Figure 32 shows the blueprints of the ICU 203 and ICU 206, as well as the positioning of the measurement devices. In both ICUs there was only one place to set up the devices without interfering with workers' routine.

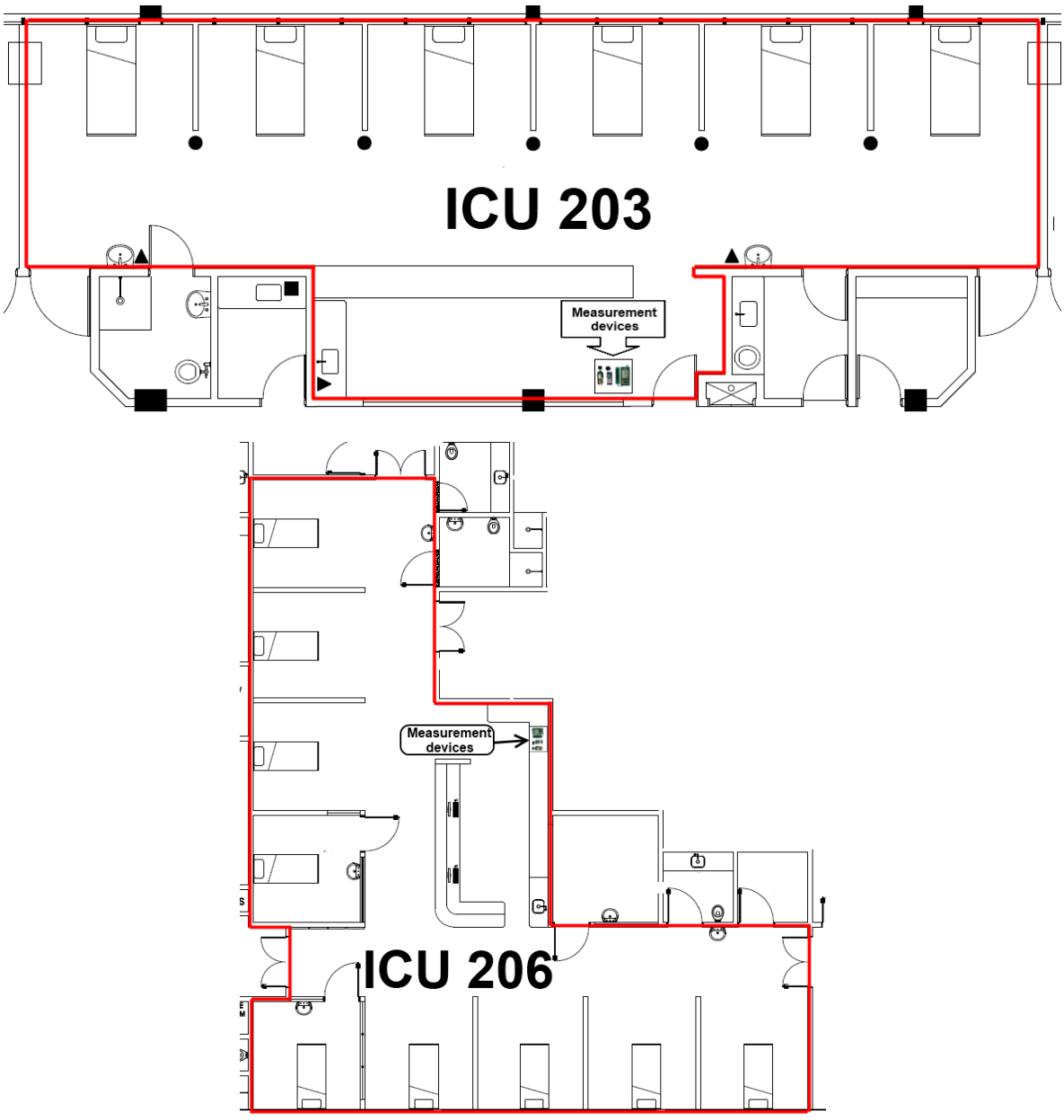


Figure 32 – Blueprints of the ICU 203 (above) and ICU 207 (below)

All respondents agreed that the size of each ICU area was *fair* or *big* to perform the tasks, despite the fact that the environment area of ICU 203 is about 9% smaller (8.15 m^2) than required (9.00 m^2). However, the area of ICU 206 is 39% bigger (12.5 m^2) than recommended. Table 12 shows all area measurements for both ICUs. A similar result was found by Piesanti (2004) where most of the ICU workers researched considered being somewhat satisfied with the work space.

Table 15 – ICU 203 and 206 dimensions

Dimensions	Min	ICU 203	ICU 206
Area/bed (m^2)	9,0	**8,15**	**12,5**
Distance between walls and bed (m)	1,00	**1,20**	**1,20**
Distance between beds (m)	2,00	**2,20**	**2,20**
Nurse station (m^2)	6,00	**7,40**	**6,00**
Medical prescription area (m^2)	1,50	**3,70**	**2,40**

The floor type was Terrazzo and it presented risks of slips, trips, and fall. In fact, six slips and one trip happened in ICU 203, whereas four slips occurred in ICU 206 on the previous 15 days. In addition, the floor material makes it difficult to see some types of objects, as shown in figure 33.

Figure 33 – Transparent object on the floor of ICU 206

The average measured noise in ICU 203 and ICU 206 was 64.4 dB and 65.2 dB, values that are 19.6 and 20.2 dB above the upper limit of 45.0 dB, respectively. However, these values may be high due to the fact that the sound level meter was positioned at the nurse station, sometimes 10 m for the farthest bed. However, noise seemed to be a major concern, since only one member of the staff in each ICU claimed *never* to be disturbed by noise, while all the other workers agreed that noise had a negative impact on their job. In ICU 203, seven out of 11 members of the staff considered the noise level in the environment *loud* or *very loud,* whereas 11 out of 12 members in the ICU 206 had the same perception. Figure 34 shows the noise measurement in both ICUs.

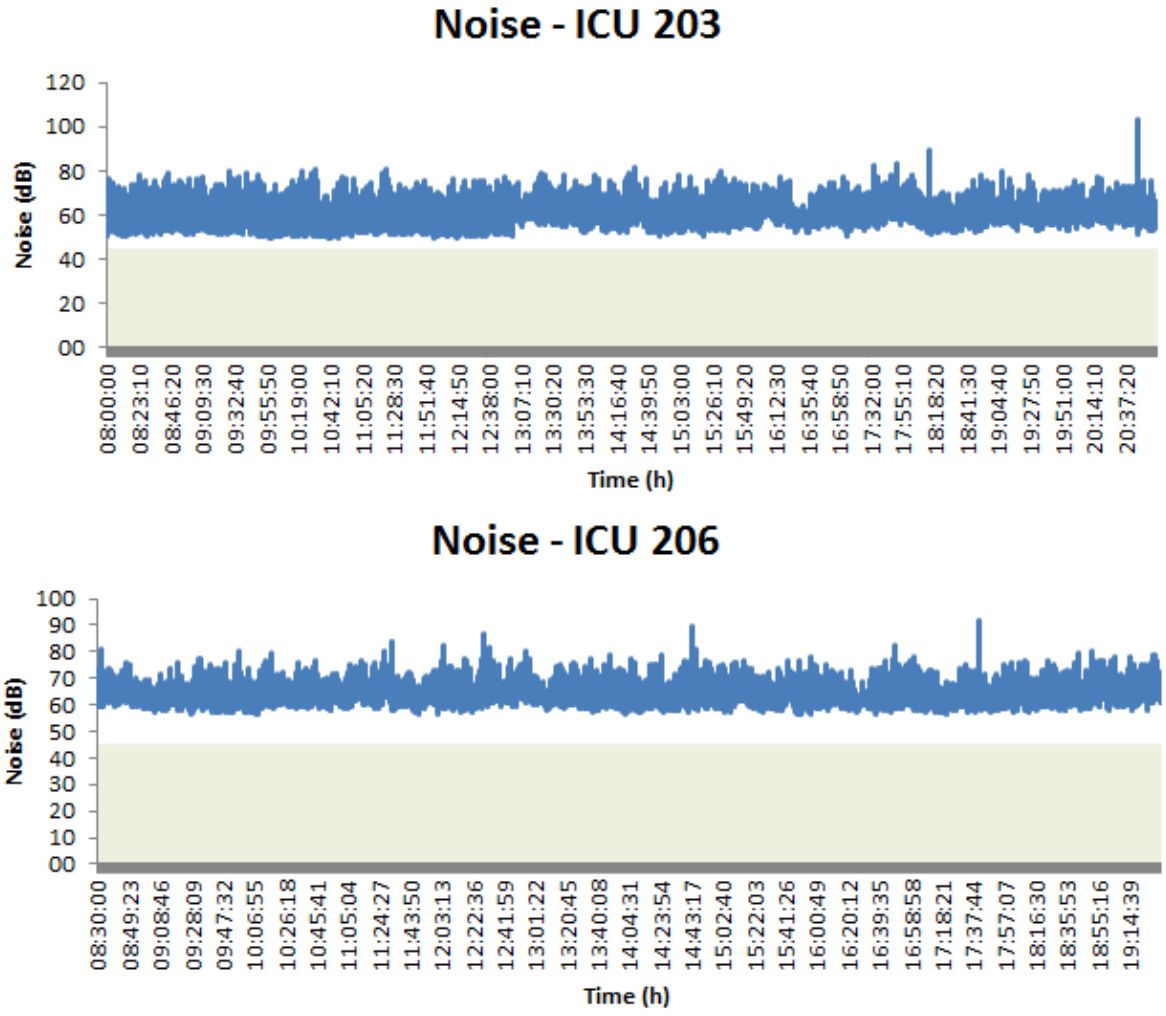


Figure 34 – Noise in the ICUs 203 and 206

While the ICU 203 staff considered equipment and conversations to be the main noise sources, and irritation and difficulty of concentrating, the main symptoms caused by noise, workers in the ICU 206 mentioned equipment and loud conversations as the main noise sources and the need to speak up and irritation as the main symptoms caused by it.

Table 16 shows ICU noise measurements performed by different authors. The structure of the table is the same the one described for Table 13. Respective fields in the table were left empty due to non-performed measurements. It is possible to see that very similar values were found by all authors regarding the three noise levels measured: minimum, average, and maximum. Moreover, the average noise levels measured were, at least, 11.0dB higher than recommended. It can be seen in the table that all studied ICUs presented noise levels higher than the maximum tolerated during all the measurement period, indicating how high noise levels were widespread in this clinical environment.

Table 16 – ICU noise measurements comparison

		Noise Level		
	Place	Minimum (dB)	Average (dB)	Maximum (dB)
Otenio; Cremer; Claro (2007)	ICU	58.0	62.7	65.0
Neto et al (2010)	ICU	–	60.9	–
Pereira et al (2003)	ICU	48.3	65.4	100.4
Macedo et al (2009)	ICU 1	57.0	64.1	80.4
	ICU 2	55.9	64.0	82.4
MacKenzie; Galbrun (2007)	ICU 1	–	56.0	89.0
	ICU 2	–	58.9	87.7
Thesis	**ICU 203**	**49.7**	**64.4**	**103.0**
	ICU 206	**59.9**	**65.2**	**70.8**

* Recommended noise level ≤ 45.0dB

The measured illuminance of both ICUs is shown in table 17. It can be seen that the general illuminance of ICU 203 was about 14% higher than the upper limit and patient bed illuminance was about 15% lower than recommended. Illuminance in the medical prescription

area was about 6% lower than required. It seems that both ICUs shared lighting problems due to the occurrence of shadows, reflex, and glare during tasks, according to the staff: the ICU 203 team complained about visual fatigue, whereas the staff members of ICU 206 equally complained about visual fatigue and eye irritation. However, most of the workers agreed that ICU lighting provided proper task conditions, since the majority of the workers in both ICUs did not complain about lighting.

Table 17 – Illuminance in ICUs 203 and 206

	Illuminance (lux)			
	Min	Max	ICU 203	ICU 206
General illuminance	100	200	**227**	**182**
Nursing station	150	300	**290**	**239**
Medical prescription	300	750	**376**	**283**
Patient bed	150	300	**128**	**270**

The illuminance levels measured by Peccin (2002) in ICUs of two different hospitals are shown in table 18. It is possible to see that illuminance levels in Hospital A were according to the standards whereas in Hospital B they were well above the maximum recommended level. According to the author, 100% of the interviewed workers in Hospital A and Hospital B considered the illuminance in the patient bad and nurse station to be good or very good, while only 3% of the workers in Hospital B complained that the illuminance in nursing station was bad.

Table 18 – Illuminance in two hospitals measured by Peccin (2002)

	Illuminance (lux)			
	Min	Max	Hospital A	Hospital B
General illuminance	100	200	**169**	**750**
Nursing station	150	300	**290**	**592**
Patient bed	150	300	**225**	**900**

It can be seen in figure 35 below that temperature levels were between the required values in both ICUs, although they continuously varied about 2.5^{o}C in ICU 206. These variations were caused by the workers constantly turning the air conditioning system on and off. The "+" marks the moment the air conditioning was turned on and the "*" the moment it was turned off.

Temperature variations in ICU 203 occurred because the air conditioning was not working due to the replacement of the HEPA filters.

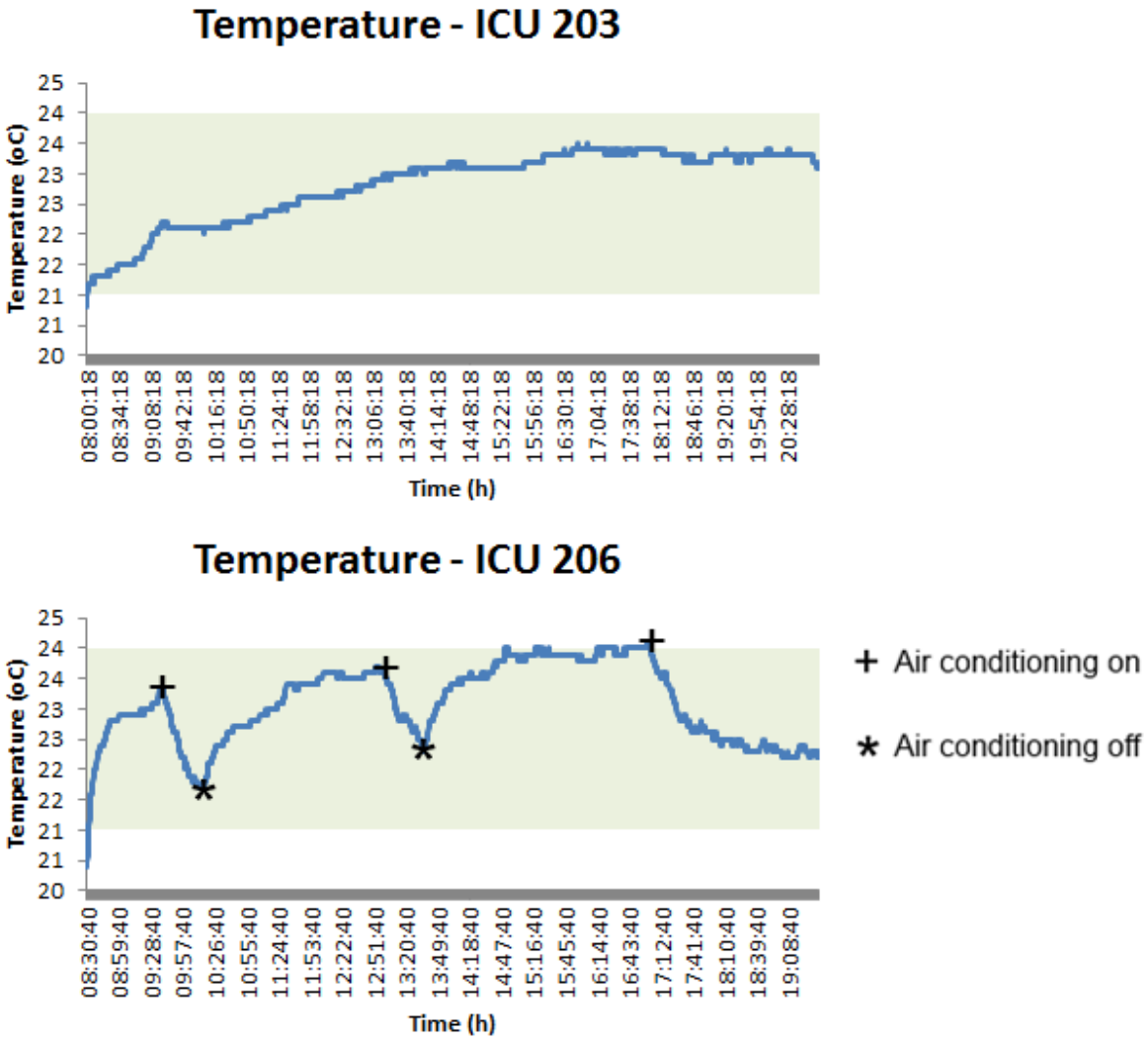


Figure 35 – Temperature in ICUs 203 and 206

Six respondents out of 11 felt comfortable in ICU 203, although 4 people were *sometimes* bothered by temperature variations. However, while only one respondent felt comfortable in the ICU 206, 11 people out of 12 felt *slightly uncomfortable* or *uncomfortable*.

Relative humidity values were also within the recommended limits in both ICUs, as shown in figure 36. The variations in relative humidity in ICU 206 were caused by the workers constantly turning the air conditioning system on and off. When the air conditioning was turned on, the humidity levels decreased. On the contrary, when the air conditioning was turned off, the

humidity levels increased. Nevertheless, four out of 11 workers in ICU 203 and seven out of 12 in ICU 206 considered the environment a *little dry* or *dry*.

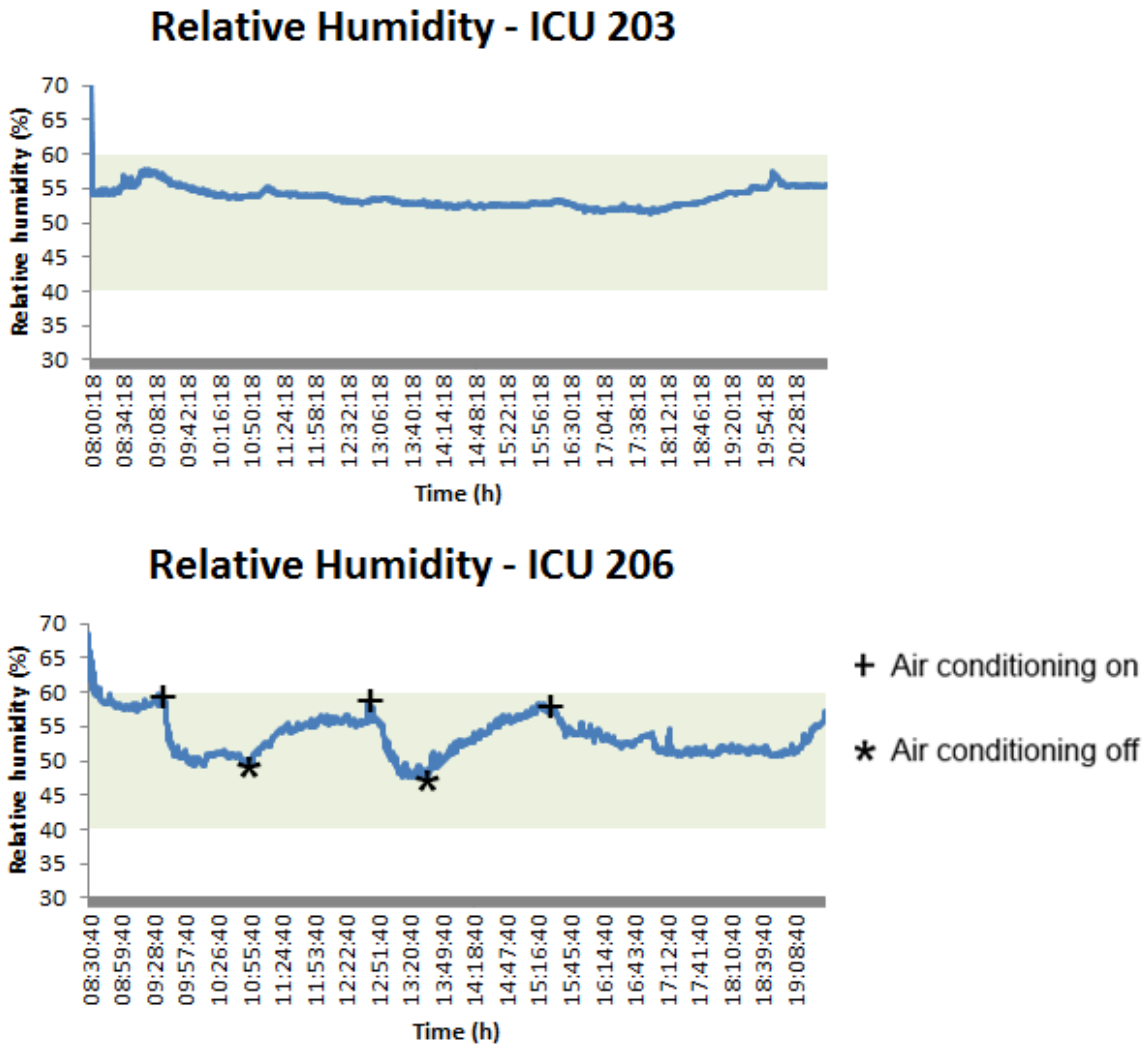


Figure 36 – Relative humidity in ICUs 203 and 206

Carbon Dioxide concentration in ICU 203 was below the limit, whereas it was higher than the limit in ICU 206 at certain moments, as shown in figure 37. Since the device was close to the clinical personnel, it may have measured worker's exhaled CO_2.

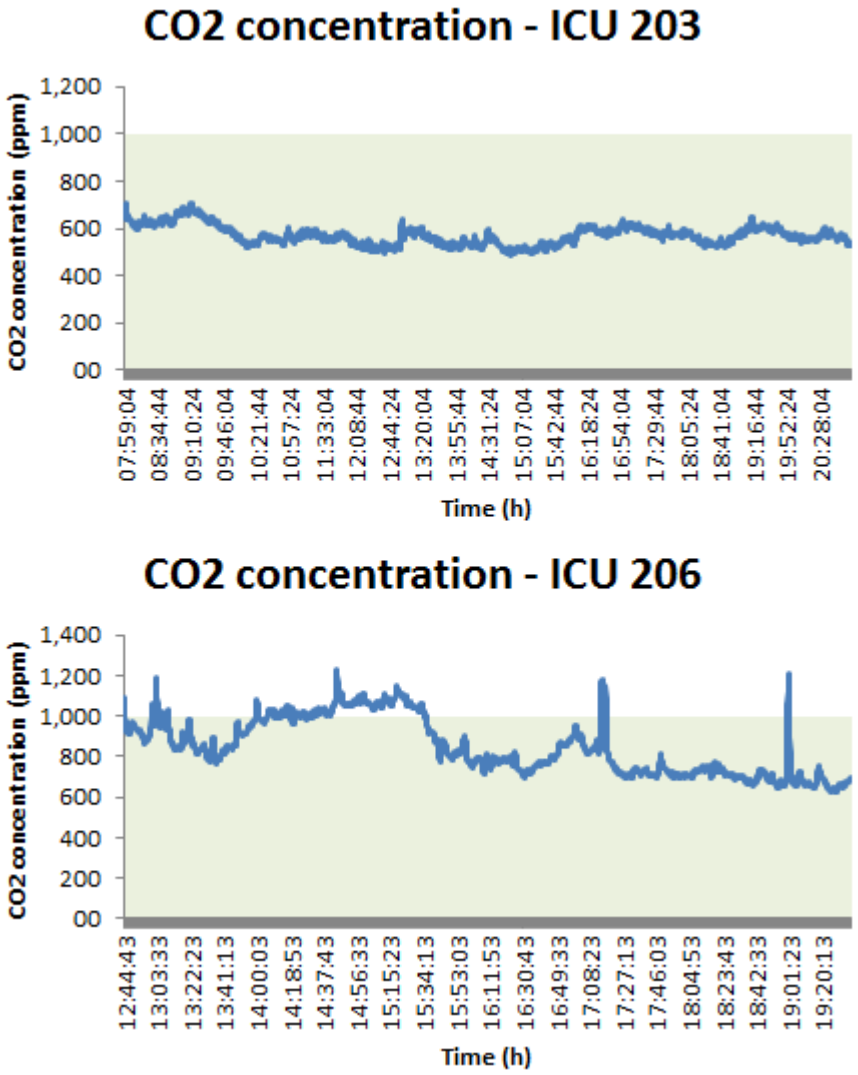


Figure 37 – CO_2 concentration in ICUs 203 and 206

Table 19 below shows ICU measurements of CO_2, temperature and RH performed in this work and by Quadros (2008). It can be seen that the CO_2 levels of both measurements were according to the references, although the standard deviation in ICU 206 (±140 ppm) is much higher than the ones found by Quadros. This is mainly caused by workers turning the air conditioning system on and off as seen above. It can be verified that the resulting measurements of temperature and relative humidity parameters were above the recommended levels in Quadros' measurements.

Table 19 – Comparison between environmental parameter measurements in ICUs

	Parameter	Carbon Dioxide (ppm)	Temperature (°C)	Relative Humidity (%)
	Limits	(0 – 1000ppm)	(21 – 24 °C)	(40 – 60%)
Thesis	ICU 203	560 ± 41	22.8 ± 0.6	53.7 ± 1.4
	ICU 206	848 ± 140	23.1 ± 0.6	53.5 ± 2.9
Quadros (2008)	ICU	567 ± 10	24.6 ± 0.1	64.6 ± 0.2
	ICU	608 ± 6	25.0 ± 0.0	64.7 ± 0.2

Despite the fact that some answers mentioned that the environment may seem stuffy and may present unpleasant odors, all the respondents considered the air quality as *good* or *acceptable* in both ICUs, although in ICU 206, three out of 12 believed the air quality was *poor* or *very poor*.

Five participants in ICU 203 did not present any symptoms caused by the environmental parameters, while four complained about sneezing, and six workers out of 12 in ICU 206 complained about nasal congestion, dry throat, and perspiration.

All power outlets delivered 220V, being non-identified in ICU 203 and identified in ICU 206. Even complying with the standard requirements (minimum of 8 power outlets/bed), ten people out of 12 in ICU 206 thought that the number of power outlets was not enough to perform the tasks, although eight out of 11 workers of ICU 203 agreed that, in fact, the number of power outlets was adequate. Moreover, four people out of nine in ICU 203 and seven out of nine people in ICU 206 thought that the positioning of the outlets did not allow easy access to them and they only *sometimes* provided tight connections with power plugs. In addition, it was possible to plug 127V devices in 220V outlets.

In general, most workers of ICU 203 were satisfied with medical gas outlets conditions. However, in ICU 206 the problems related to medical gas outlets were similar to the ones related to power outlets. Even complying with the standard requirements, seven people out of 12 declared that the medical gas outlets were not enough to perform the tasks. In addition, six people out of 12 stated that gas outlets positioning did not allow easy access to them.

5.3 Operating room 2

The findings of the OR 2 are reported and discussed below, whereas the ones regarding the measurements performed in ORs 1, 3, 5, 8, and 10 are not presented in this chapter, being available in appendix 6. Figure 38 shows the blueprint of all hospital operating rooms, highlighting the analyzed ones. Appendix 7 shows individual blueprints of each OR including the positioning of the measurement devices.

Figure 38 – Blueprint of the hospital operating rooms

The analysis of the findings in OR 2 took into consideration the data gathered at three different moments, when the measurements were made: on 23/04/2013, on 24/04/2013, and on 27/04/2013. Questionnaires were applied on these three days, collecting a total of 20 answers. Since the measurements of temperature, relative humidity, and CO_2 concentration were taken on different days, during different periods of time, the charts regarding each of these measurements were chosen to be plotted all in one axis. Instead of present the time of the day the measurements were performed, the 'x' axis shows the duration of the respective measurements. Figure 39 shows the blueprint of OR 2, including the positioning of the measurement devices, as well as the air conditioning supply and exhausting ducts.

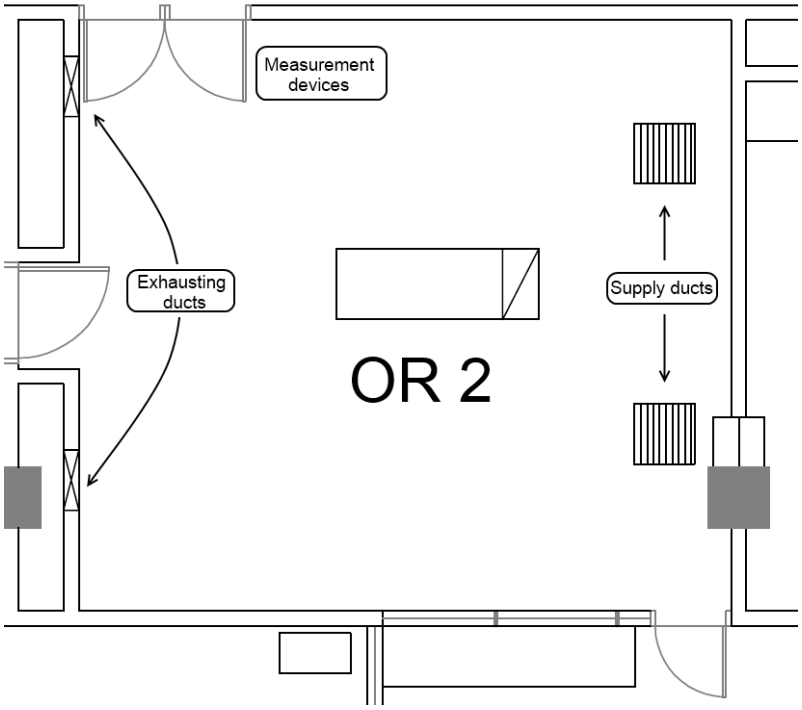


Figure 39 – Blueprint of OR 2

The environment area was about 4% smaller (34.4 m^2) than required (36.0 m^2). Thirteen out of 20 respondents agreed that the work area to perform the tasks was *fair*. Nine out of 20 workers thought the floor possessed *medium* or *high* risk of slips, trips, and falls. Table 20 shows the number of slips, trips, and falls that occurred on the 15 days prior to this research.

Table 20 – Number of slips, trips, or falls in OR 2

You have slipped, tripped of fallen	
No	15
Slip	2
Trip	3
Fall	

The average noise levels regarding the three measurements are shown in figure 40. It can be seen that they were quite similar: 65.6 dB, 63.7 dB, and 65.2 dB, a difference of only 1.9 dB between the lowest and the highest value. It seems that noise caused disturbances during work and had a negative impact on the job, according to the answers. Fourteen out of 20

respondents considered the noise level in the environment to be *loud* and only five considered it to be *fair*.

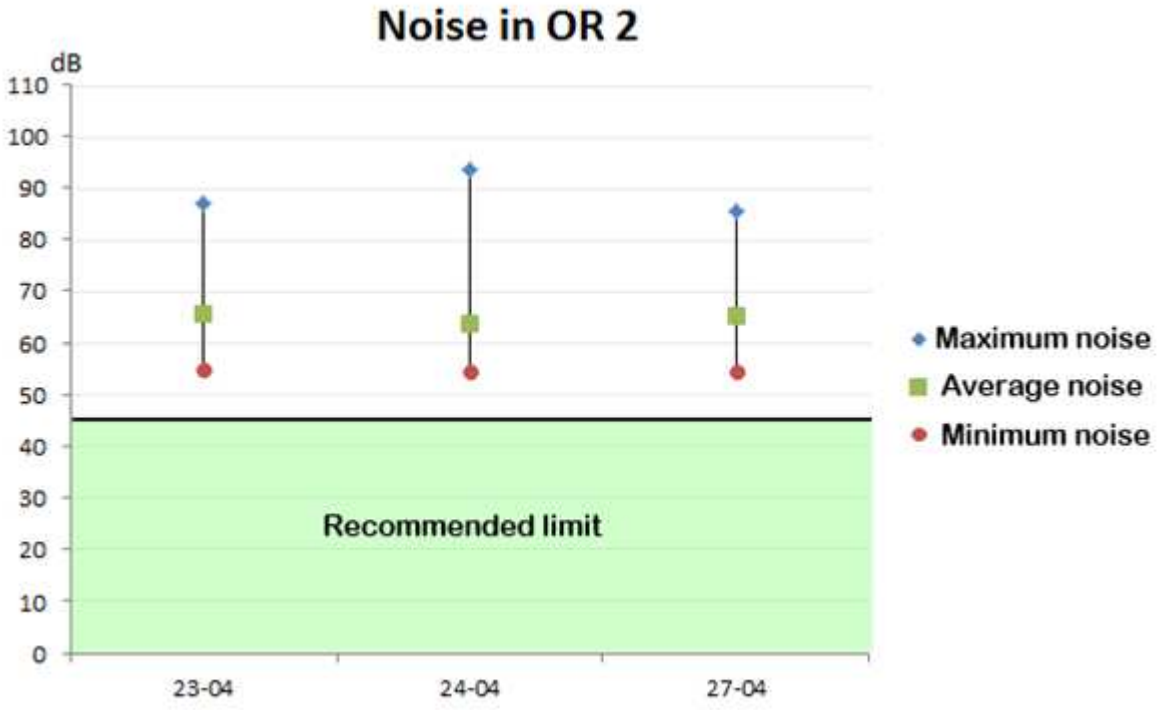


Figure 40 – Noise in OR 2 measured in three different days

While five out of 20 respondents did not present any noise related symptom, ten out of 20 complained about irritation, and seven complained about the difficulty of hearing during conversations. Equipment was voted as the highest noise source by 17 out of 20 workers while conversations were considered the second source by 16 respondents.

Otenio, Cremer and Claro (2007) found average noise level in five ORs to be 59.1 dB, while the average levels measured by Tsiou, Efthymiatos, and Katostaras(2008) varied from 57.4 to 70.1 dB and Kracht, Busch-Vishniac, and West(2007) found noise levels varying from 53.0 to 70.5 dB. In this work it was found average noise levels varying from 61.7 to 66.2 dB in ORs. It can be argued that the values found by all authors were close to each other and also higher than the maximum recommended value of 45.0 dB.

The measured environment illuminance was 675 lux, within the required limits of 300 to 700 lux. Okumoto (2006) found illuminance levels varying from 170 to 770 lux in the ORs of a hospital. In general, reflex, glare, and shadows rarely occurred. Most of the workers

were satisfied with the illuminance levels of the environment, since 14 out of 19 stated that lighting *often* or *always* provided proper task conditions. While 16 out of 20 respondents did no present lighting related symptoms, three complained about visual fatigue.

It was possible to observe in figure 41 that the temperature charts presented a similar shape due to the fact that workers turned on the air conditioning system when the surgery began and turned it off after the surgery ended. The "+" marks the moment the air conditioning was turned on and the "*" the moment it was turned off. The calculated values for the average and standard deviation after the temperature stabilized were: 22.0 ± 0.1 ^{o}C; 21.5 ± 0.1 ^{o}C; and 21.2 ± 0.3 ^{o}C (23-04-2013; 24-04-2013; 27-04-2013, respectively). When asked about the temperature in OR 2, the majority of the respondents agreed that the environment was uncomfortable or very uncomfortable.

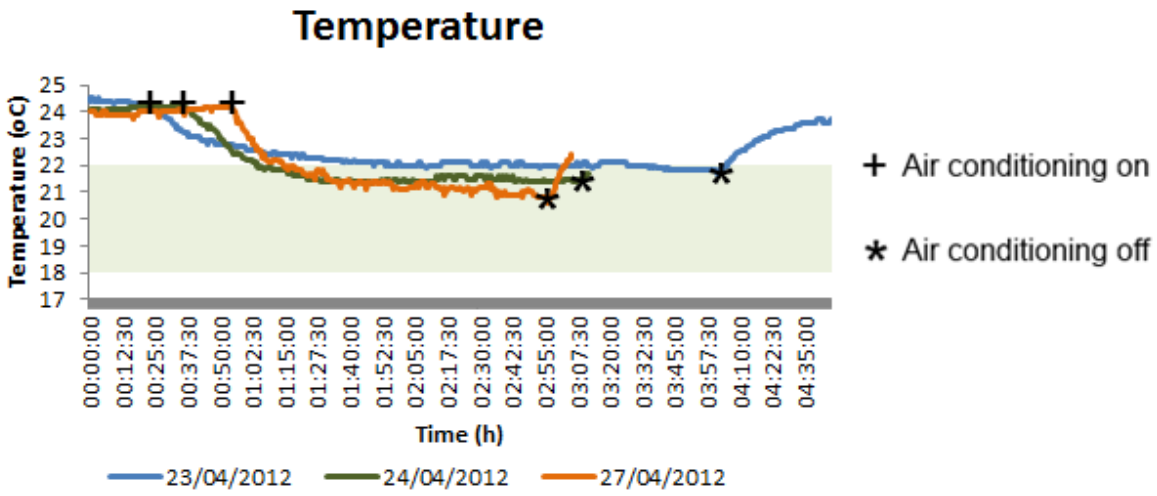


Figure 41 – Temperature in OR 2 measured in three different days

Figure 42 shows relative humidity charts in OR 2. It is possible to see that it was above the upper limit regarding the measurement taken on 23-04-2013 and within the limits regarding the measurements on 24-04-2013 and 27-04-2013. The "+" marks the moment the air conditioning was turned on and the "*" the moment it was turned off. It can be seen that relative humidity levels lowered when the air conditioning was turned on. The calculated values for the average and standard deviation after the relative humidity stabilized were: 57.6 ± 0.2 %; 54.3 ±

0.9 %; and 54.9 ± 0.6 % (23-04-2013; 24-04-2013; 27-04-2013, respectively). While nine workers considered the humidity in the environment *fair*, 11 considered it *dry* or *a little dry*.

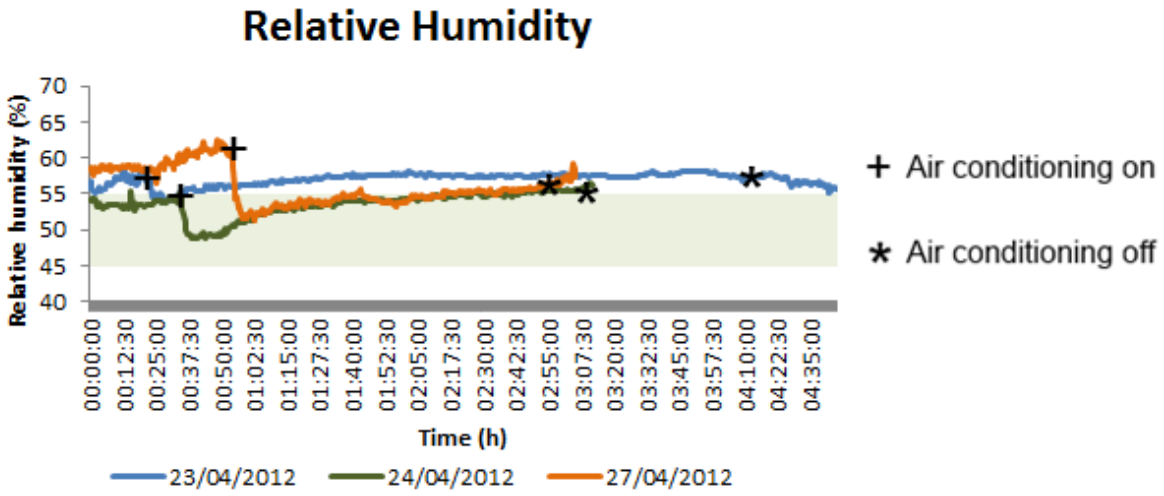


Figure 42 – Relative humidity in OR 2 measured in three different days

Carbon Dioxide levels were below the maximum recommended level, as shown in figure 43.

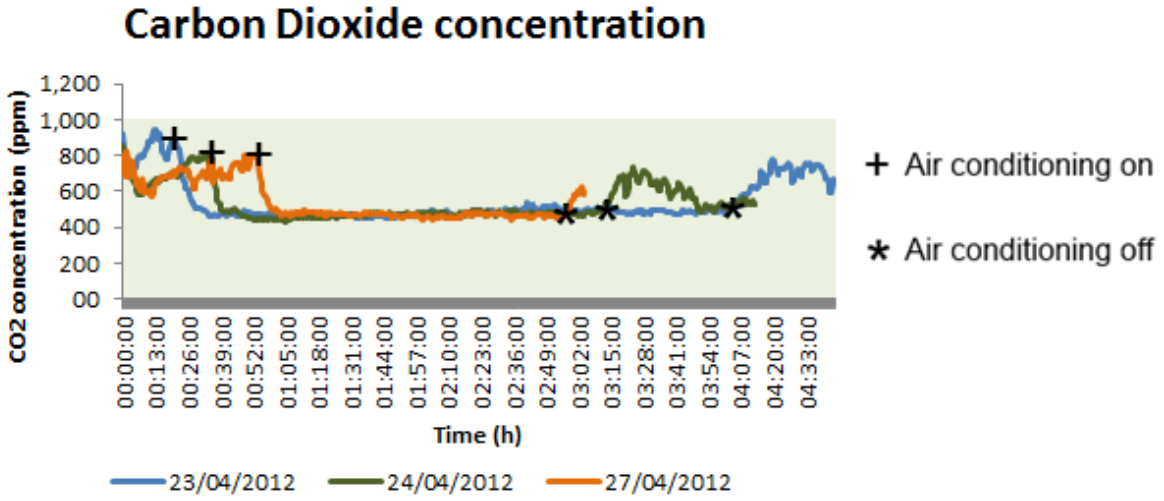


Figure 43 – CO_2 concentration in OR 2 measured in three different days

Table 21 below shows the OR measurements of CO_2, temperature and RH performed in this work and the ones performed by Quadros (2008), similar to Table 19. It can be

seen that the CO_2 and relative humidity levels of both measurements were according to the references. Variations in the standard deviation in the thesis measurements are higher than the ones found by Quadros due to the fact that workers turned the air conditioning system on and off during the measurements, as seen in the graphs above. It is possible to see that the temperature of OR – 03 was above the recommended levels in Quadros' measurements.

Table 21 – Comparison between environmental parameter measurements in the OR

	Parameter	Carbon Dioxide (ppm)	Temperature (^oC)	Relative Humidity (%)
	Limits	(0 – 1000ppm)	(21 – 24 ^oC)	(40 – 60%)
Quadros (2008)	OR – 01	321 ± 19	23.8 ± 0.1	59.1 ± 0.2
	OR – 03	618 ± 30	25.7 ± 0.1	51.7 ± 0.7
Thesis	**OR 2 (23-04)**	**540 ± 115**	**22.6 ± 0.8**	**57.1 ± 0.9**
	OR 2 (24-04)	**534 ± 96**	**22.2 ± 1.1**	**53.6 ± 1.7**
	OR 2 (27-04)	**544 ± 108**	**22.3 ± 1.3**	**56.1 ± 2.6**

Despite evaluating the implementation of the methodology in only OR 2 in this chapter, it is worth the comparison of the temperature and humidity measurements in all ORs against a paper published by Balaras, Dascalaki, and Gaglia (2007). The authors measured the temperature in 20 operating rooms in ten Hellenic hospitals built from 1930 up to 1991. Some of them were considered over-aged by the authors. The upper part of figure 44 shows temperature measurements in the 20 operating rooms of Hellenic hospitals while the lower part shows the eight measurements performed in the six ORs described in chapter 4.2. Large temperature variations between the ORs (maximum, mean, and minimum temperature) can be seen in Greek hospitals. The authors stated that it occurred due to the age built of some ORs and the not functioning of the air conditioning system in two ORs. On the other hand, there were fewer temperature variations in the ORs where this methodology was applied. The larger temperature variation in this work was 4.8 ^oC while in Hellenic hospitals it was about 15 ^oC.

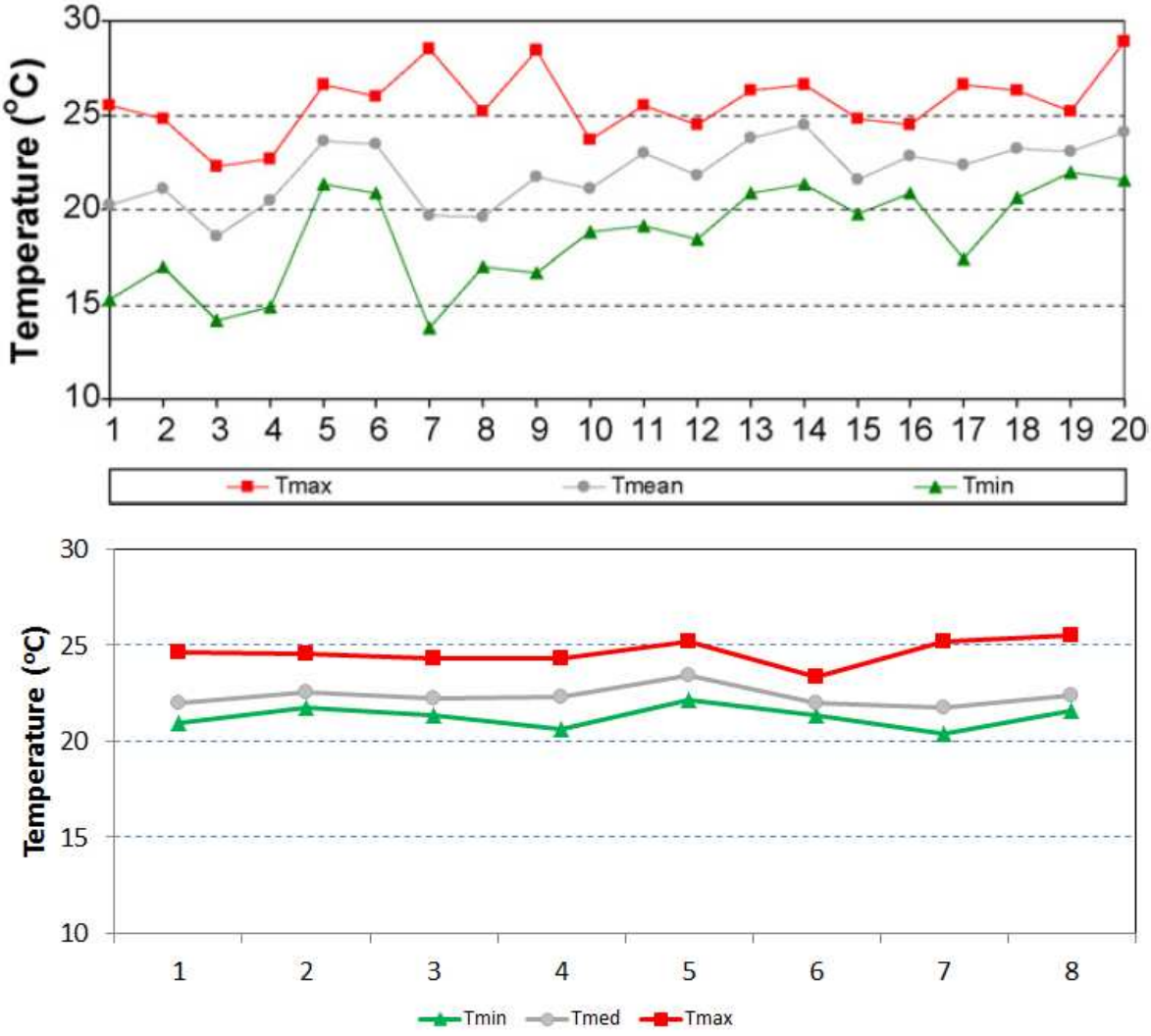


Figure 44 – Temperature measurements in operating rooms in distinct hospitals

The relative humidity measurements performed by Balaras, Dascalaki, and Gaglia (2007) also presented large variations, as can be seen in the upper part of figure 45. The authors cited that it happened mainly due to a lack of humidity control in the installations. Again, in the lower part of figure 45 it is possible to observe fewer variations in the RH measurements in the ORs where this methodology was applied. The larger relative humidity variation in this work was 15% while in Hellenic hospitals it was about 60%.

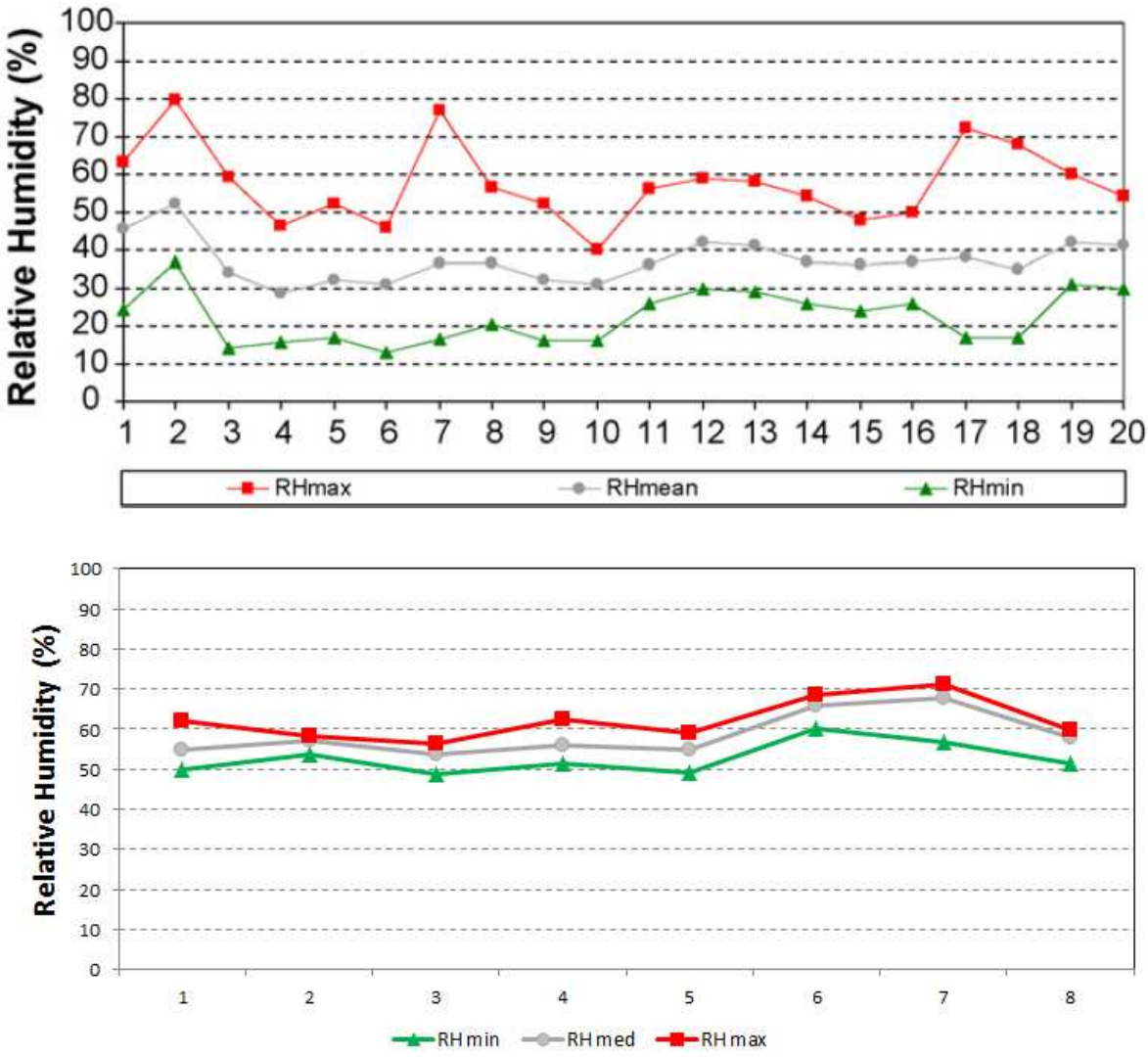


Figure 45 – Relative humidity measurements in operating rooms in distinct hospitals

There were mixed results regarding the perception of a stuffy environment and unpleasant odors. While 11 workers agreed that the environment *never* or *rarely* seemed stuffy, nine of them thought that it was *sometimes* or *often* stuffy. Eight respondents considered that the environment *never* or *rarely* presented unpleasant odors, while 11 considered that it *sometimes* or *often* presented unpleasant odors. While ten out of 20 workers complained about nasal congestion and six about perspiration and rhinitis caused by environmental parameters, four did not complain about any symptoms.

The OR 2 contained three sets of six non-identified 220V power outlets and one also non-identified X-Ray power outlet at the height of 1.42m, according to the requiresements.

The main related problem was that the number of power outlets was *sometimes* sufficient to plug the devices, the same happening with their positioning, which only *sometimes* allowed easy access, and the connection with power plugs was tight only *sometimes*. In addition, it was possible to plug 127V devices in 220V outlets and no power cord extension use was verified during the measurements. Okumoto (2006) verified that power outlets were positioned at heights lower than 1.50m and the frequent use of power cord extensions in the ORs of an analyzed hospital.

There were no problems regarding medical gas outlets. In general, the staff agreed that medical gas outlets positioning *always* allowed easy access, it was *always* easy to identify the medical gas in the outlet. However, the number of medical gas outlets was *sometimes* sufficient to perform the tasks.

5.4 Limitations

The positioning of the devices used to perform continuous measurements of temperature, relative humidity, CO_2 concentration, and noise was not adequate in some environments. Since the methodology was applied by a person who was not a member of hospital staff and was not aware of hospital routines, the devices were positioned in a way not to disturb staff routines and not to compromise staff movement in the area, even if it meant setting up the devices in not so adequate places. For example, during measurement in one OR, the devices were located in a corner, away from the workers and behind the medical devices in use. In addition, when the measurements were being performed in both ICUs, the sound level meter was far away from some beds. In both examples, the values of the measured parameters may have been different if the devices had been positioned near the staff: for instance, the noise levels could have been higher than measured, the temperature could have been lower, and so on.

The continuous measurement of the parameters in only one place also had its drawbacks. Since all the operating rooms have an asymmetrical airflow distribution, the temperature in the rooms varied according to the location of the air intakes, being cooler near the air intakes and warmer far away from them. Thus, the positioning of the devices may have influenced the results. For example, the temperature in OR 3 was measured with the devices positioned in a corner far away from the exhausting ducts and close to the return ducts, as well as

behind the medical devices. The fact that the temperature in this spot was higher than required does not necessarily indicate that the temperature near the patient was also higher than required. Figure 46 shows a picture of OR 3 including the exhausting duct in the right upper corner and the measurement devices in the left corner near the return ducts.

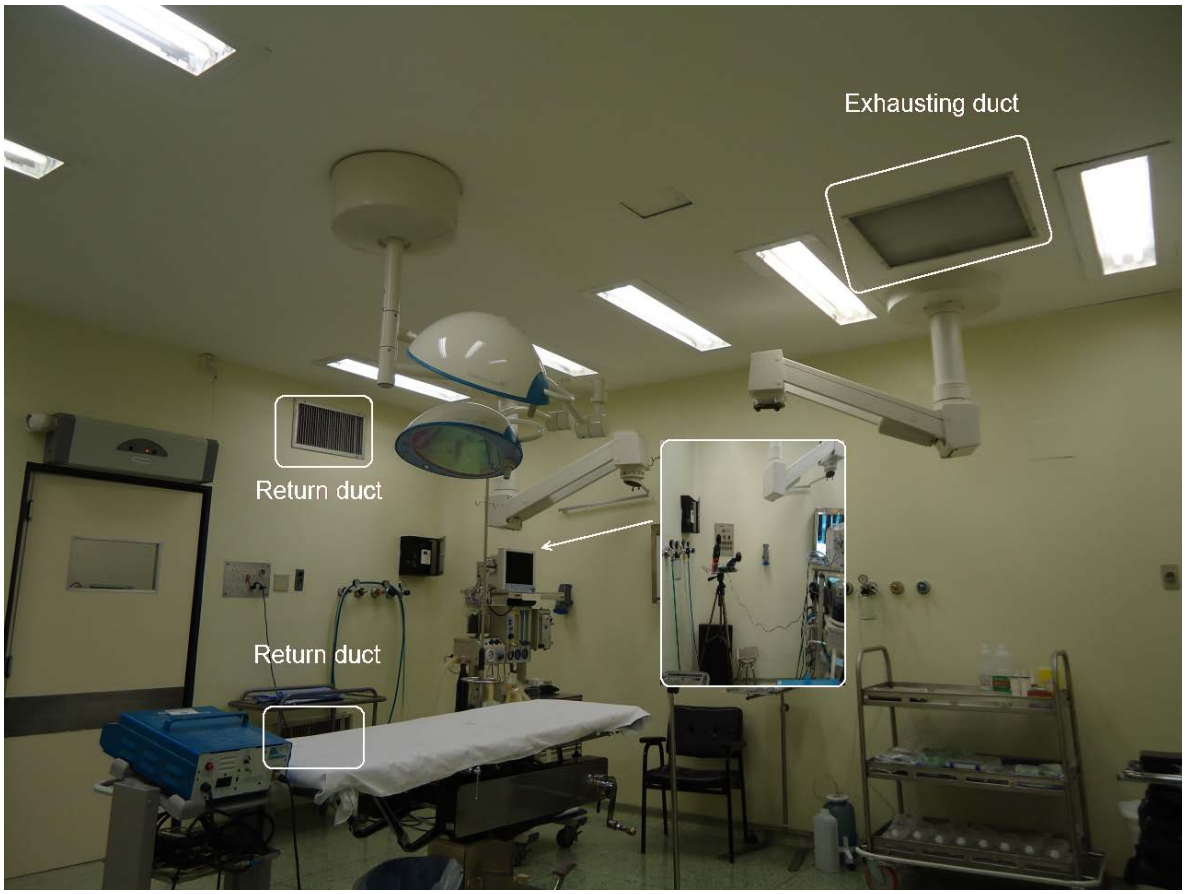


Figure 46 – Exhausting and return ducts in OR 3

In some cases, even when the devices were positioned near one group of professionals, they may have been away from the other groups. For instance, the devices could have been near anesthesiologists and away from the surgeons. The questionnaire answers of these two groups of workers may have varied: while one group might have felt cold the other group may have felt hot.

The person conducting the environment evaluation should be aware of the devices positioning issues described above. If the positioning of the equipment is not possible in the

recommended places, he or she should pay attention to the environmental conditions and look for factors that may influence the measured values. If the environmental parameters cannot be measured well by positioning the devices in only one place, an alternative solution may be found, if desired. This solution could involve the use of another device to measure the same parameter, for example, two sound level meters used in the same environment. Another example is the manual measurement of temperature in significant places of the room with a thermometer in order to compare these values with the ones obtained by the device which performs the continuous measurement to draw a temperature profile of the environment.

Another important limitation is the fact that demographic factors such as age, gender, weight, height, physical fitness, clothing, time in the same occupation, and metabolic activity were not taken into account when elaborating the report. It is known that these factors affect people's perception of noise, temperature, humidity, or lighting factors such as illuminance, occurrence of shadows, glare, and reflexes (KEARNEY, 2008; ALVARADO, 2012; WOLSKA, 2006; ABNT, 1992a; ASHRAE, 2009; ASHRAE 2004). In addition, a questionnaire about the patient's opinion regarding some environmental factors could be developed in order to fully evaluate the physical environment.

The questionnaire response rate for all studied ORs varied from 50% up to 100% of workers present at the moment of application. The lower the response rate, the more difficult it was to make generalizations about a specific environment, making it impossible to calculate the response rate regarding all workers that use the same environment. Since most measurements were performed just once in each environment, workers from different shifts or teams were not able to answer the questionnaire raising some concerns about the correlation between significance of the sample regarding the population. To get as complete a perception of the environment as possible, a higher response rate of workers from all shifts would be necessary. In addition, a study could be conducted to determine the optimal questionnaire sample size, taking into account the analyzed environment and workers classes (e.g. doctors, nurses, assistants), in order to prevent biases and to obtain better correlated answers according to the population studied.

The methodology here does not aim to develop solutions to the problems found. However, it is possible to use some of the principles of the Root Cause Analysis (RCA) method to establish the following solution development recommendations (HEUVEL et al, 2008; JCR,

2005; ANDERSEN; FAGERHAUG, 2006; WILSON; DELL; ANDERSON, 1993; AMMERMAN, 1998; GANO, 2007; OKES, 2009; LATINO, 2009; CORBETT et al, 2004), as shown in figure 47.

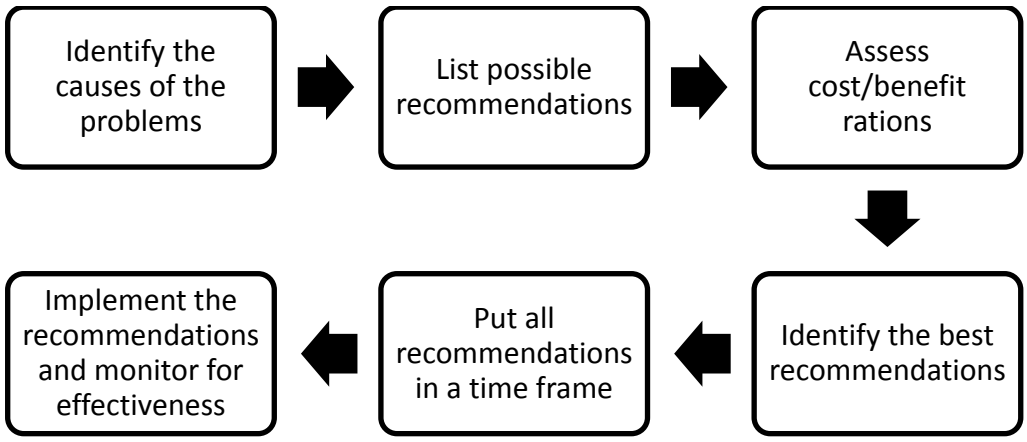


Figure 47 – Solution development recommendations

Firstly, the team must identify the causes of the problems found and make a list of possible recommendations to solve these problems. These recommendations should prevent recurrence of such problems, be cost-effective, and be practical, feasible, and achievable. Secondly, cost/benefit analyses for the listed recommendations ought to be performed, focusing on the necessary resources (financial, time, staff, management) to implement each recommendation. Thirdly, the recommendations to be implemented should be selected and put in a time-based category (short, medium, and long term). Finally, the recommendations ought to be implemented and monitored for effectiveness by using specific indicators developed for this purpose. If the recommendations do not present any improvement to the environment, new recommendations should be developed following the stages described above.

6. Conclusão

A metodologia foi sido utilizada em áreas distintas de um EAS gerando resultados que permitiram visualizar a existência de parâmetros do ambiente físico afetando negativamente os trabalhadores em determinadas áreas.

Por meio dos resultados obtidos durante o estudo de caso, percebeu-se que diferentes parâmetros ambientais são capazes de afetar os profissionais de saúde. Dos 101 questionários respondidos, foram relatadas a ocorrência de 21 escorregões, 20 tropeços e 2 quedas. Somente 16% dos entrevistados afirmaram não possuir nenhum sintoma causado pelo ruído. A necessidade de elevar a voz para conversar foi a queixa de 55% dos entrevistados, seguida pela irritação e dificuldade de ouvir durante conversas, com 52% de queixas cada. Cerca de 75 entrevistados acreditam possuir algum sintoma relacionado ao conforto térmico ou qualidade do ar do ambiente em que trabalham. Trinta e dois entrevistados afirmaram que o ambiente lhes causa espirros, ao passo que 26 afirmaram sentir congestionamento nasal e garganta seca. Além dos sintomas apresentados acima, houve queixas relativas ao tamanho da área para se realizar os procedimentos, iluminação insuficiente, odores, quantidade de tomadas disponíveis, dentre outros.

A inclusão da avaliação de parâmetros relativos a tomadas e gases medicinais no método permitiu verificar que, em alguns ambientes, estes parâmetros apresentaram não conformidades que poderiam causar danos ou problemas de conexão envolvendo equipamentos médicos levando ao atraso no diagnóstico ou terapia e criando estresse adicional na equipe médica. A existência de mangueiras de gases medicinais além de cabos de força de equipamentos no piso poderia atrapalhar o deslocamento de equipamentos e pessoas, aumentando o risco de escorregões, tropeços e quedas.

A utilização do questionário é de suma importância. Através de sua utilização, foram coletados dados significativos sobre a influência do ambiente nos trabalhadores como os sintomas causados pelo ruído, iluminação e qualidade do ar. Também foi efetuada a comparação da percepção dos entrevistados em relação a parâmetros medidos. Por exemplo, foi possível observar o que os funcionários pensaram a respeito do tamanho da área física, do ruído, da

iluminação, da temperatura e umidade, dentre outros parâmetros e comparar com os valores medidos no ambiente.

As questões 3, 8, 13 e 22 do questionário foram elaboradas com o intuito de verificar se o piso, ruído, iluminação e parâmetros ambientais causaram algum sintoma nos usuários nos últimos 15 dias. Este limite de tempo foi escolhido com o objetivo de saber sobre a ocorrência de eventos recentes e evitar esforço cognitivo desnecessário. Ao se compilar o resultado dos 101 questionários respondidos, pôde-se constatar uma queixa de 579 sintomas no total por parte dos respondentes em uma média de 5.7 sintomas por pessoa. Tal valor indica que o tempo estabelecido de 15 dias, neste estudo, foi suficiente para se verificar os efeitos do ambiente sobre os trabalhadores.

Ainda, o uso do ambiente fora dos parâmetros dimensionados possivelmente acarretará transtornos para todos os envolvidos. O fato de, por exemplo, a sala de observação da emergência, prevista para acomodar sete pacientes ser utilizada para tratar em torno de 20 a 25 pacientes, causa grande descontentamento relativo a ruído, temperatura, umidade, dentre outros parâmetros.

Os estabelecimentos assistenciais de saúde (EAS) deveriam ser projetados ou renovados utilizando-se princípios ergonômicos e tendo como foco o ser humano e não somente normas de construção. Charytonowicz (2000) afirma que os arquitetos deveriam fazer parte da equipe de ergonomistas e levar em consideração as características do ser humano no projeto de construção ou reforma de ambientes. Villeneuve e colaboradores (2007) relatam experiências bem sucedidas nas quais equipes multidisciplinares realizaram intervenções ergonômicas na arquitetura hospitalar em países como o Canadá, Holanda e Reino Unido.

A metodologia pode ser aplicada no mesmo ambiente em diferentes momentos com o objetivo de se obter uma percepção mais completa do mesmo. Três relatórios foram obtidos quando a metodologia foi aplicada na sala cirúrgica 2 em três dias diferentes. Se desejado, as respostas ao questionário podem ser adicionadas para se obter uma percepção mais precisa dos trabalhadores em relação a esta sala cirúrgica, como descrito em 5.3. Além disso, os três gráficos de temperatura, umidade relativa e concentração de CO_2 podem ser mostrados como um único gráfico cada, criando uma visualização simplificada do respectivo parâmetro, podendo levar a uma melhor análise deste.

A análise de todos os relatórios gerados com o objetivo de desenvolver e implementar soluções poderia trazer benefícios tanto para os trabalhadores quanto para os pacientes, tais como: aumento das áreas de trabalho; diminuição do risco de escorregões, tropeções e quedas; redução dos níveis de ruído , melhora da iluminação ambiente, evitando a ocorrência de reflexo, brilho, e sombras; melhora do conforto térmico e qualidade do ar; criação de condições adequadas para se conectar os dispositivos médicos em tomadas e postos de gases medicinais. Estas ações podem melhorar o bem-estar dos trabalhadores e pacientes, criando melhores condições de trabalho e, eventualmente aprimorando a qualidade dos cuidados a saúde.

Os pré-requisitos para aplicação da metodologia foram definidos no capítulo 3, onde se afirmou que o engenheiro clínico possuiría estes pré-requisitos. Caso este profissional aplique a metodologia aqui desenvolvida, haveria o aumento de seu conhecimento a respeito dos seis parâmetros do ambiente físico analisados no trabalho (área física, ruído, iluminação, parâmetros ambientais, tomadas e gases medicinais) e correspondente interação com os trabalhadores. Tal fato permitiria que este profissional participasse em projetos e resolução de problemas envolvendo estes parâmetros de maneira sistêmica, desenvolvendo soluções englobando a tecnologia, o ambiente e a interação destes com os trabalhadores. Por exemplo, ao se detectar que um equipamento médico-hospitalar gera ruído devido à grande ocorrência de alarmes, o EC poderia trabalhar em conjunto com a equipe clínica em programas de treinamento ou educação continuada visando o ajuste dos alarmes de acordo com a situação clínica do paciente. Também, ao participar de projetos e reformas, o EC pode interagir com o departamento de projetos e usuários levantando questões referentes à rotina de trabalho do corpo clínico. Essas informações permitiriam um melhor posicionamento dos pontos de tomadas e gases medicinais a fim de se evitar a presença de cabos de força de equipamentos e mangueiras de gases medicinais no piso. Além disso, poderia ser verificada com o usuário a real necessidade do número de tomadas e postos de gases medicinais para atender as demandas do serviço e não somente às normas.

Um estudo deve ser projetado para determinar a influência de fatores demográficos, como idade, sexo, peso, altura, condicionamento físico na percepção dos trabalhadores do ambiente, levando a um diagnóstico mais preciso dos problemas existentes. Um questionário para coletar a percepção dos pacientes a cerca do ambiente também podem ser desenvolvido para um maior aperfeiçoamento da avaliação.

A maneira pela qual a metodologia foi estruturada permite que se acrescentem parâmetros bem como outros grupos de parâmetros para análise, como contaminantes biológicos e compostos orgânicos voláteis, alarmes, vibração e arranjo de componentes, por exemplo. Ainda, pode se realizar uma análise mais aprofundada dos parâmetros, dependendo dos recursos físicos, humanos e financeiros disponíveis. Isso deve ser feito seguindo-se os mesmos passos descritos na figura 9 (capítulo 3): definir os parâmetros a serem avaliados, assim como a forma de avaliá-los; escrever instruções nos formulários, adicionar perguntas ao questionário, acrescentar informações sobre como processar os dados coletados e projetar dashboard para reportar os dados coletados.

6. Conclusion

The methodology proposed here was applied in different areas of healthcare facilities having generated results that allowed the visualization of the negative effects of some environmental parameters on workers in some areas.

It was also possible to confirm that environmental parameters are likely to affect health care workers. A total occurrence of 21 slips, 20 trips and two falls was reported. Only 16% of respondents did not mention any symptoms caused by noise, while 55% of the respondents complained about the need to speak up, followed by irritation and difficulty in hearing conversations. About 75 out of 101 workers believed that they had at least one symptom related to environmental parameters in the area in which they worked. Thirty-two respondents stated that the environment caused them to sneeze, while 26 said that they had nasal congestion and sore throat. In addition to the symptoms listed above, there were complaints about the size of the area to perform the procedures, insufficient lighting, and odors, among other problems.

The inclusion of power outlets and medical gas outlets in the methodology allowed significant findings. For example, in most environments, the non-identification of 220V outlets could lead to damage to medical devices which, in turn, would delay patient diagnosis and therapy, in addition to increase the level of stress on the clinical staff. The existence of power cables and gas tubes on the floor could hinder the movement of equipment and people, increasing the slip, trip, and fall risk. Moreover, even complying with the requirements, the number of power outlets in one area was reported to be insufficient to perform the clinical procedures.

The application of written survey was of paramount importance. First, it allowed the gathering of meaningful data regarding the effects of the physical environment on workers, such as symptoms caused by noise, lighting, and air quality. Second, it was possible to verify the perception of respondents regarding the measured parameters. For instance, the measured noise levels and the user's perception about these levels (low, fair, loud) could be compared. Third, it was possible to monitor the existence of parameters such as odors, air quality, shadows, glare, and other ones, parameters which would be hard for the applicant to measure.

In the questionnaire, the questions 3, 8, 13, 22 were elaborated to learn if the floor, noise, lighting, and environmental parameters have caused any symptoms on the workers in the

last 15 days. The limit of 15 days was chosen aiming to know about the occurrence of recent events and avoiding unnecessary cognitive effort. When compiling the results of the 101 answered questionnaires, it could be seen total of 579 symptoms complained by the respondents, performing an average of 5.7 symptoms per person. This value indicates that the set time period of 15 days, in this study, was sufficient to verify the effects of the environment on the workers.

An environment designed focusing only on the standards or codes can create unsatisfactory conditions to workers for a number of reasons. One of them rises from the lack of proper maintenance to factors such as lighting and air conditioning system. Another factor that may interfere with workers' performance and welfare is the inappropriate placement of outlets, medical gas stations, supply and return ducts of the air conditioning system without taking the work flow into account. For example, it could be seen that despite the fact that number of power outlets in the ICU 206 and OR 2 was according to the standards, workers complained that they were not enough to connect the devices sometimes.

Moreover, the use of an environment beyond its designed capacity can possibly cause problems. For example, the emergency unit observation room had been planned to accommodate seven patients. However, at the moment this data were collected, it was being used to treat around 20 to 25 patients, causing dissatisfaction concerning noise, temperature, humidity, among other parameters.

The healthcare facilities should be designed or renovated using ergonomic principles, being human centered, and not only relying on building code. Charytonowicz (2000) stated that architects should be part of the ergonomic group and take into consideration the characteristics of human beings during the design or renovation of facilities. Villeneuve and colleagues (2007) reported successful experiments in which multidisciplinary teams performed ergonomic interventions in hospital architecture in countries such as Canada, the Netherlands, and the UK.

The methodology can be applied in the same environment in different moments, aiming to get a more complete picture of this environment. Three reports were obtained when the methodology was applied in OR 2 in three different days. However, the questionnaire answers could be added to get a more precise perception of the workers regarding this OR, as described in 5.3. In addition, the three charts of temperature, RH, and CO_2 concentration could be drawn as

one chart each, creating a simplified visualization of the respective parameter, which, in turn, could lead to a better analysis of these parameters.

The analysis of all the generated reports with the purpose of developing and implementing solutions could bring benefits to both workers and patients, benefits such as: increasing the size of work areas; diminishing the risk of slips, trips, and falls; lowering the noise levels, improving environment illuminance; avoiding the occurrence of reflex, glare, and shadows; improving thermal comfort and air quality; creating proper conditions to plug medical devices to power and medical gas outlets. These actions could improve both workers and patients well-being, creating better work conditions, and eventually improving the quality of health care.

It was stated in chapter 3 that the clinical engineer (CE) possessed the characteristics to apply the methodology. If this professional apply the methodology here developed, there will be an increase in his or her knowledge about the physical environment regarding the six parameters analyzed (physical area, noise, lighting, environmental parameters, power outlets and medical gas outlets) and the interaction between these parameters and healthcare workers. This fact would allow CEs to participate in projects and to solve problems involving these parameters in a systematic way, developing solutions encompassing the technology, the physical environment, and the interaction among the technology, the physical environment and the workers. For example, if it was confirmed that a medical device generated noise due to the high occurrence of alarms, the CE could work together with the clinical staff in training programs aiming at setting alarm levels according to the clinical situation of the patient. In addition, by participating in healthcare facilities design and renovation, the CE could deal with the workers and design team raising questions regarding the clinical staff work routine. The gathered information would allow a better positioning of power and medical gas outlets in order to avoid the presence of power cables and medical gas hoses on the floor. Moreover, it could be verified the actual user's need about the number of power and medical gas outlets and not just relying on the design standards. By the reasons cited above, clinical engineers have an important role to play in dealing with the physical environment characteristics.

A study should be designed to determine the influence of demographic factors such as age, gender, weight, height, physical fitness in the workers perception of the environment, leading to a more precise diagnosis of the existing problems. A questionnaire to

gather patients' opinion may also be developed to further improvement of the environment evaluation.

The structure of the methodology is more important than the parameters analyzed by it. The way the methodology was developed allows the inclusion or exclusion of parameters to be analyzed as well as the inclusion of other groups of parameters such as biological contaminants and volatile organic compounds, alarms, vibration, and arrangement of components. It is still possible to perform a more thorough analysis of the parameters depending on the available physical, human and financial resources. This should be done by following the same steps described in figure 9 (chapter 3): defining the parameters to be evaluated as well as how to evaluate them; writing instructions in the forms; adding questions to the questionnaire; adding information on how to process the collected data; and designing a dashboard to report the collected data.

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Appendix 1 – Questionnaire in Portuguese

Local da análise: _____ ID:_____

Data: _____/_____/ 2012 Hora: _____:_____

Assinale a(s) reposta(s) que melhor representa(m) sua opinião com relação aos itens apresentados

Área física

1. A **área física** para realizar as tarefas é	Muito pequena ☐	Pequena ☐	Apropriada ☐	Grande ☐	Muito grande ☐
2. Em relação ao risco de escorregar, tropeçar ou cair, o **piso** apresenta	Nenhum risco ☐	Pouco risco ☐	Médio risco ☐	Muito risco ☐	
3. Você sofreu algum escorregão, tropeço ou queda nos últimos 15 dias (marque todos que se aplicam)	Não ☐	Escorregão ☐	Tropeço ☐	Queda ☐	

Ruído

	Nunca	Raramente	Algumas vezes	Frequente-mente	Sempre
4. O **ruído** do ambiente incomoda, perturba ou irrita quando você está trabalhando	☐	☐	☐	☐	☐
5. Você sente que o **ruído** nesse ambiente possui um impacto negativo no seu trabalho	☐	☐	☐	☐	☐
6. O nível de ruído no ambiente de trabalho é	Muito alto ☐	Alto ☐	Aceitável ☐	Baixo ☐	Muito baixo ☐
7. Marque todas as fontes de ruído presentes no ambiente que te incomodam	☐ Conversas ☐ Conversas telefônicas ☐ Conversas altas ☐ Equipamentos		☐ Sistema de ar-condicionado ☐ Ruído externo ☐ Outras ☐ Não há		
8. O ruído neste ambiente causou algum destes sintomas nos últimos 15 dias (marque todos que se aplicam)	☐ Dificuldade de ouvir ou entender durante conversas ☐ Ter de elevar a voz para conversar ☐ Dificuldade em escutar sinais sonoros ☐ Dificuldade em se concentrar na realização das tarefas ☐ Irritação ☐ Cansaço mental ☐ Outro ☐ Nenhum sintoma				

Iluminação

	Nunca	Raramente	Algumas vezes	Frequente-mente	Sempre
9. Com qual frequência ocorrem **reflexos** luminosos durante a execução das tarefas	☐	☐	☐	☐	☐
10. Com qual frequência ocorrem **ofuscamentos** durante a execução das tarefas	☐	☐	☐	☐	☐
11. Com qual frequência ocorrem **sombras** durante a execução das tarefas	☐	☐	☐	☐	☐
12. Em relação à **iluminação**, como percebe o ambiente	Muito Escuro ☐	Escuro ☐	Apropriado ☐	Claro ☐	Muito claro ☐
13. A iluminação causou algum destes sintomas nos últimos 15 dias (marque todos que se aplicam)	☐ Fadiga visual ☐ Irritação dos olhos ☐ Lacrimejamento		☐ Dor de cabeça ☐ Náusea/tontura ☐ Irritação mental	☐ Outro ☐ Nenhum sintoma	
14. A iluminação do ambiente garante condições satisfatórias para execução das tarefas	Nunca ☐	Raramente ☐	Algumas vezes ☐	Frequente-mente ☐	Sempre ☐

Parâmetros ambientais

15. Em relação à **sensação térmica**, você se sente	Confortável ☐	Levemente desconfortável ☐	Desconfortável ☐		Muito desconfortável ☐
16. A **variação de temperatura** do ambiente te incomoda	Nunca ou não há ☐	Raramente ☐	Algumas vezes ☐	Frequente-mente ☐	Sempre ☐
17. Com relação à **umidade**, você acha que esse ambiente é	Nunca ou não há ☐	Raramente ☐	Algumas vezes ☐	Frequente-mente ☐	Sempre ☐
18. Com qual frequência você sente **correntes de ar** incômodas	Seco ☐	Um pouco seco ☐	Apropriado ☐	Um pouco úmido ☐	Úmido ☐
19. Há a sensação de ambiente **abafado**	Nunca ☐	Raramente ☐	Algumas vezes ☐	Frequente-mente ☐	Sempre ☐
20. O ambiente apresenta **odores** desagradáveis	Nunca ☐	Raramente ☐	Algumas vezes ☐	Frequente-mente ☐	Sempre ☐
21. A **qualidade do ar** no ambiente é	Péssima ☐	Ruim ☐	Aceitável ☐	Boa ☐	Excelente ☐
22. Você apresentou algum desses sintomas que podem estar relacionado com a climatização do **ambiente** nos últimos 15 dias (marque todos que se aplicam)	☐ Dor de cabeça ☐ Náusea/tontura ☐ Dificuldades de concentração ☐ Irritação dos olhos ☐ Lacrimejamento ☐ Rinite ☐ Espirros ☐ Congestionamento nasal		☐ Coriza ☐ Garganta seca ☐ Tosse ☐ Pele seca ou irritada ☐ Transpiração ☐ Outro ☐ Nenhum sintoma		

Tomadas

	Nunca	Algumas vezes	Sempre	Não tenho certeza
23. A quantidade de **tomadas** é suficiente para se ligar os equipamentos	☐	☐	☐	☐
24. O posicionamento das **tomadas** permite acessá-las facilmente	☐	☐	☐	☐
25. A tomada permite conectar um plugue de um equipamento firmemente	☐	☐	☐	☐
26. Existe a necessidade de se utilizar **adaptadores** para ligar os equipamentos às tomadas	☐	☐	☐	☐
Se marcou **Nunca** na questão acima, ir para questão 29				
27. Estes **adaptadores** estão sempre disponíveis quando se necessita	☐	☐	☐	☐

28. A qualidade dos adaptadores é	Péssima ☐	Ruim ☐	Aceitável ☐	Boa ☐	Excelente ☐

Gases medicinais

	Nunca	Algumas vezes	Sempre	Não tenho certeza
29. O número de pontos de **gases** medicinais é suficiente para realizar as tarefas	☐	☐	☐	☐
30. O posicionamento dos pontos de **gases** medicinais permite acessá-los facilmente	☐	☐	☐	☐
31. É fácil identificar o tipo de gás (Oxigênio, ar medicinal, óxido nitroso, vácuo) no ponto de conexão	☐	☐	☐	☐

Appendix 2 – Code-sheet

Place: _____ ID:_____

Date: _____/_____/_____ Time: _____:_____

Check the answers that best represent your opinion about **this environment** regarding the following items:

Work area

1. The physical area to perform the task is	Very small (-2)	Small (-1)	Fair (0)	Big (1)	Very big (2)
2. Regarding the risk of slipping, tripping or falling, the **floor** has	No risk (0)	Little risk (1)	Medium risk (2)		High risk (3)
3. You have slipped, tripped or fallen in the last 15 days (check all that apply)	No (0)	Slip (1)	Trip (2)		Fall (3)

Noise

	Never	Rarely	Sometimes	Often	Always
4. Environmental **noise** bothers, disturbs, or annoy you during work.	(0)	(1)	(2)	(3)	(4)
5. You feel that **noise** in this environment has a negative impact on your job	(0)	(1)	(2)	(3)	(4)
6. The **noise** level in this environment is	Very low (-2)	Low (-1)	Fair (0)	Loud (1)	Very loud (2)

7. Check all the **noise** sources that bother you in this environment	(1) Conversations (2) Phone conversations (3) Loud conversations (4) Equipment	(5) Air conditioning system (6) External noise (7) Other (0) None
8. The noise in this environment has caused any of these symptoms in the last 15 days (check all that apply)	(1) Difficulty in hearing or understanding during conversations (2) Need to increase your speech during conversations (3) Difficulty of hearing audible signals (4) Difficulty of concentrating during tasks (5) Irritation (6) Mental fatigue (7) Other (0) No symptom	

Lighting

	Never	Rarely	Sometimes	Often	Always
9. **Reflex** occurs during tasks	(0)	(1)	(2)	(3)	(4)
10. **Glare** occurs during tasks	(0)	(1)	(2)	(3)	(4)
11. **Shadows** are produced during tasks	(0)	(1)	(2)	(3)	(4)
12. Regarding **lighting**, you perceive the environment as	Too dark (-2)	Dark (-1)	Fair (0)	Bright (1)	Too bright (2)

13. **Lighting** has caused any of these symptoms in the last 15 days (check all that apply)	(1) Visual fatigue (2) Eye irritation (3) Watery eyes	(4) Headache (5) Nausea/dizziness (6) Irritation	(7) Other (0) No symptom

14. The environment lighting provides proper conditions to perform the tasks	Never (0)	Rarely (1)	Sometimes (2)	Often (3)	Always (4)

Environmental parameters

15. Regarding **thermal** sensation, you feel	Comfortable (0)	Slightly uncomfortable (1)	Uncomfortable (2)		Very uncomfortable (3)
16. **Temperature** variations in the environment bother you	Never (0)	Rarely (1)	Sometimes (2)	Often (3)	Always (4)
17. Regarding **humidity**, this environment is	Dry (-2)	A little dry (-1)	Fair (0)	A little humid (1)	Humid (2)
18. You are bothered by annoying **drafts**	Never (0)	Rarely (1)	Sometimes (2)	Often (3)	Always (4)
19. The environment seems **stuffy**	Never (0)	Rarely (1)	Sometimes (2)	Often (3)	Always (4)
20. The environment presents unpleasant odors	Never (0)	Rarely (1)	Sometimes (2)	Often (3)	Always (4)
21. Air quality in the environment is	Very poor (-2)	Poor (-1)	Fair (0)	Good (1)	Very good (2)
22. **Air conditioning** or **air quality** may have been the cause of any of these symptoms in the last 15 days (check all that apply)	(1) Headache (2) Nausea/dizziness (3) Difficulty in concentration (4) Eye irritation (5) Watery eyes (6) Rhinitis (7) Sneezing (8) Nasal congestion		(9) Runny nose (10) Dry throat (11) Cough (12) Dry or irritated skin (13) Perspiration (14) Other (0) No symptom		

Power outlets

	Never	Sometimes	Always	Not sure
23. The number of **power outlets** is sufficient to connect the devices	(0)	(1)	(2)	(9)
24. The positioning of **power outlets** allows easy access to them	(0)	(1)	(2)	(9)
25. Power outlets allow tight connection to power plugs	(0)	(1)	(2)	(9)
26. You need to use power plug **adapters** to connect devices to the power outlets	(0)	(1)	(2)	(9)
If you checked never in the question 26, go to question 29				
27. The **adapters** are available when needed	(0)	(1)	(2)	(9)

28. The quality of the adapters is	Very poor (-2)	Poor (-1)	Fair (0)	Good (1)	Very good (2)

Medical gas outlets

	Never	Sometimes	Always	Not sure
29. The number of **medical gas outlets** is sufficient to accomplish the tasks	(0)	(1)	(2)	(9)
30. The positioning of **Medical gas outlets** allows easy access to them	(0)	(1)	(2)	(9)
31. It is easy to identify the medical gas (Oxygen, medical air, nitrous oxide, vacuum) in the outlet	(0)	(1)	(2)	(9)

Appendix 3 – Variable definition in PSPP

In order to proper process data, the software PSPP requires that variables be properly defined. Once done, questionnaire data can be entered in proper fields to further processing. The variables were defined according to the description below and are shown in figure 48:

- Name – short names related to each question. This variable should be unique and entered without using 'space' or reserved characters;
- Type – the type of the variable, in this case a numeric value;
- Width – the width of the numeric value, including decimals. It was left on the default value of 8;
- Decimals – the number of decimals of the numeric variable. It was left on the default value of 0 since only integers numbers were used;
- Label – a descriptive variable label up to 256 characters in which spaces and reserved characters are allowed. Longer names close related to each question were used;
- Values – descriptive value labels. They were assigned to each value of the variables according to the code-sheet in appendix 2. For example, the following values were assigned to the "Noise_level" variable: (-2) Very low, (-1) low, (0) fair, (1) loud, (2) very loud;
- Measure – definition of the variables as either nominal (categories with no intrinsic ranking) or ordinal (categories with some intrinsic ranking).

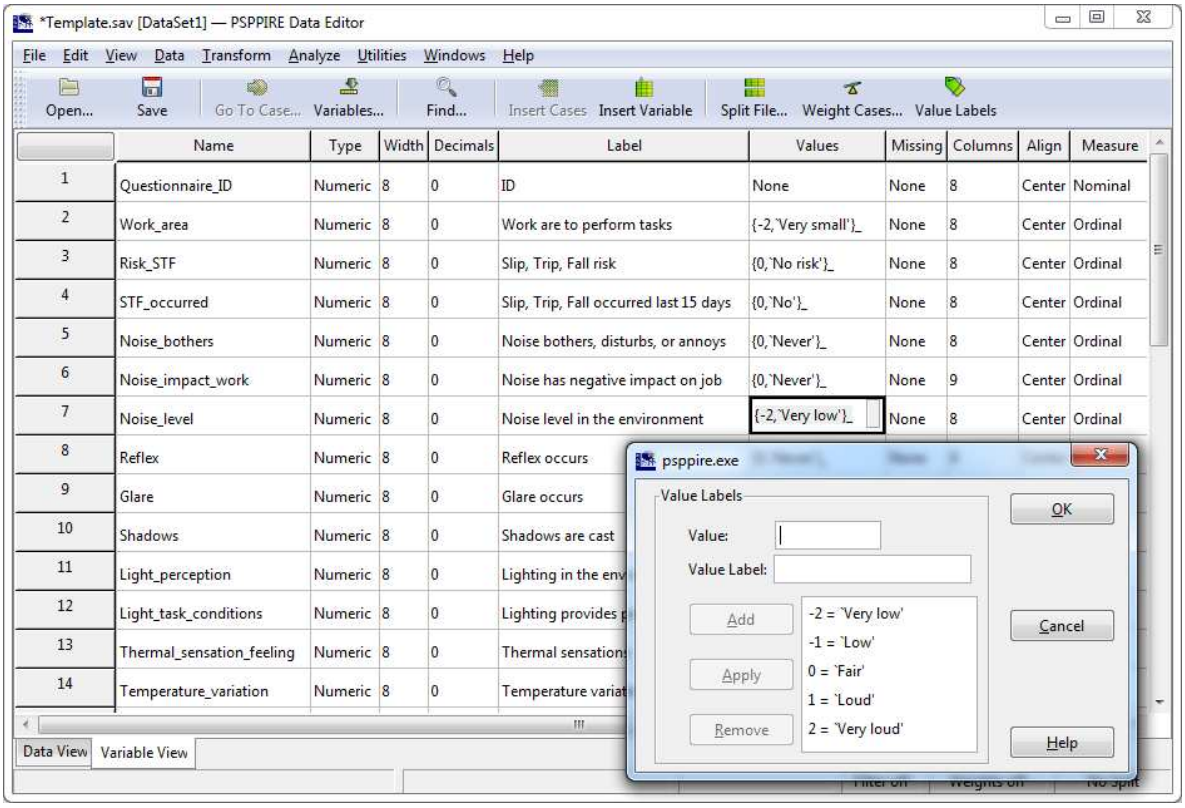


Figure 48 – Variables definition screen in PSPP

Appendix 4 – Ethics committee research approval

FACULDADE DE CIÊNCIAS MÉDICAS
COMITÊ DE ÉTICA EM PESQUISA

www.fcm.unicamp.br/fcm/pesquisa

CEP, 26/03/12
(Grupo III)

PARECER CEP: N° 1280/2011 (Este n° deve ser citado nas correspondências referente a este projeto).
CAAE: 1183.0.146.000-11

I - IDENTIFICAÇÃO:

PROJETO: **"ANÁLISE DE AMBIENTES FÍSICOS DE ESTABELECIMENTOS ASSISTENCIAIS DE SAÚDE BASEADA EM ERGONOMIA E FATORES HUMANOS".**
PESQUISADOR RESPONSÁVEL: Gustavo Alcantra Elias
INSTITUIÇÃO: Hospital de Clínicas/UNICAMP
APRESENTAÇÃO AO CEP: 07/12/2011
APRESENTAR RELATÓRIO EM: 26/03/13 (O formulário encontra-se no *site* acima).

II – OBJETIVOS.

Realizar análises de parâmetros físico-ambientais de estabelecimentos assistenciais de saúde (EAS) baseadas em ergonomia e fatores humanos. Verificar se o ambiente físico de um EAS está dentro das normas e se apresenta condições de conforto para os trabalhadores.

III – SUMÁRIO.

Parte de pesquisa para tese de doutorado. Profissionais da saúde que trabalham nos ambientes onde será realizada a pesquisa deverão responder um questionário.

IV - COMENTÁRIOS DOS RELATORES.

Após respostas às pendências, o projeto encontra-se adequadamente redigido e de acordo com a Resolução CNS/MS 196/96 e suas complementares, bem como o Termo de Consentimento Livre e Esclarecido.

V - PARECER DO CEP.

O Comitê de Ética em Pesquisa da Faculdade de Ciências Médicas da UNICAMP, após acatar os pareceres dos membros-relatores previamente designados para o presente caso e atendendo todos os dispositivos das Resoluções 196/96 e complementares, resolve aprovar sem restrições o Protocolo de Pesquisa, bem como ter aprovado o Termo do Consentimento Livre e Esclarecido, assim como todos os anexos incluídos na Pesquisa supracitada.

O conteúdo e as conclusões aqui apresentados são de responsabilidade exclusiva do CEP/FCM/UNICAMP e não representam a opinião da Universidade Estadual de Campinas nem a comprometem.

VI - INFORMAÇÕES COMPLEMENTARES.

Comitê de Ética em Pesquisa - UNICAMP
Rua: Tessália Vieira de Camargo, 126
Caixa Postal 6111
13083-887 Campinas – SP

FONE (019) 3521-8936
FAX (019) 3521-7187
cep@fcm.unicamp.br

O sujeito da pesquisa tem a liberdade de recusar-se a participar ou de retirar seu consentimento em qualquer fase da pesquisa, sem penalização alguma e sem prejuízo ao seu cuidado (Res. CNS 196/96 – Item IV.1.f) e deve receber uma cópia do Termo de Consentimento Livre e Esclarecido, na íntegra, por ele assinado (Item IV.2.d).

Pesquisador deve desenvolver a pesquisa conforme delineada no protocolo aprovado e descontinuar o estudo somente após análise das razões da descontinuidade pelo CEP que o aprovou (Res. CNS Item III.1.z), exceto quando perceber risco ou dano não previsto ao sujeito participante ou quando constatar a superioridade do regime oferecido a um dos grupos de pesquisa (Item V.3.).

O CEP deve ser informado de todos os efeitos adversos ou fatos relevantes que alterem o curso normal do estudo (Res. CNS Item V.4.). É papel do pesquisador assegurar medidas imediatas adequadas frente a evento adverso grave ocorrido (mesmo que tenha sido em outro centro) e enviar notificação ao CEP e à Agência Nacional de Vigilância Sanitária – ANVISA – junto com seu posicionamento.

Eventuais modificações ou emendas ao protocolo devem ser apresentadas ao CEP de forma clara e sucinta, identificando a parte do protocolo a ser modificada e suas justificativas. Em caso de projeto do Grupo I ou II apresentados anteriormente à ANVISA, o pesquisador ou patrocinador deve enviá-las também à mesma junto com o parecer aprovatório do CEP, para serem juntadas ao protocolo inicial (Res. 251/97, Item III.2.e)

Relatórios parciais e final devem ser apresentados ao CEP, de acordo com os prazos estabelecidos na Resolução CNS-MS 196/96.

VII- DATA DA REUNIÃO.

Homologado na XII Reunião Ordinária do CEP/FCM, em 20 de dezembro de 2011.

Prof. Dr. Carlos Eduardo Steiner
PRESIDENTE do COMITÊ DE ÉTICA EM PESQUISA
FCM / UNICAMP

Appendix 5 – Informed consent

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO
Resolução nº 196/96 – Conselho Nacional de Saúde

O(A) Sr(a) foi selecionado(a) e está sendo convidado(a) para participar da pesquisa intitulada *Análise de Ambientes Físicos de Estabelecimentos Assistenciais de Saúde Baseada em Ergonomia e Fatores Humanos*. Eu, Gustavo Alcântara Elias, sou o responsável pela pesquisa e apresentação e obtenção deste termo de consentimento.

Esta pesquisa faz parte do meu estudo de doutorado e pretende analisar tanto os parâmetros físico-ambientais do ambiente de trabalho quanto a percepção do profissional que nele exerce suas atividades.

A pesquisa terá duração prevista de ___ dia(s) e tem como objetivos a coleta de informações relativas a parâmetros ambientais do local de trabalho dos profissionais de saúde. Serão realizadas medições e observações efetuadas com instrumentos e métodos apropriados sob responsabilidade do pesquisador. Um questionário será aplicado a V.S.ª.

Não haverá riscos de qualquer natureza relacionada a sua participação. O benefício relacionado à sua participação será o de contribuir com informações que farão parte do diagnóstico realizado. Por serem pessoais, a obtenção das informações necessárias só podem advir de sua colaboração.

Suas respostas serão tratadas de forma anônima e confidencial, isto é, em nenhum momento será divulgado o seu nome em qualquer fase do estudo. O questionário aplicado não possui o campo nome ou qualquer outro que possa identificá-lo. Quando for necessário exemplificar determinada situação, sua privacidade será assegurada. Os dados coletados serão utilizados apenas nesta pesquisa e os resultados divulgados em eventos e/ou revistas científicas, mantendo-se o sigilo necessário.

Sua participação é voluntária, isto é, a qualquer momento o(a) Sr(a) pode recusar-se a responder qualquer pergunta ou desistir de participar e retirar seu consentimento. Sua recusa não trará nenhum prejuízo em sua relação com o pesquisador ou com a instituição que forneceu os seus dados, como também na que trabalha. O(A) Sr(a) não terá nenhum custo ou quaisquer compensações financeiras.

Sua participação nesta pesquisa consistirá em responder as perguntas a serem realizadas sob a forma de questionário. O pesquisador estará presente durante todo o momento podendo prestar a assistência que se fizer necessária.

O(A) Sr(a) receberá uma cópia deste termo onde consta o celular/e-mail do pesquisador responsável, podendo esclarecer as suas dúvidas sobre o projeto e sua participação, agora ou a qualquer momento.

Desde já agradecemos!

_____
Gustavo Alcântara Elias
Pesquisador - Unicamp
Cel: 31-9949-3838
e-mail: gelias@ceb.unicamp.br

Campinas, ____ de _____ de 2012.

Declaro estar ciente do inteiro teor deste TERMO DE CONSENTIMENTO e estou de acordo em participar do estudo proposto, sabendo que dele poderei desistir a qualquer momento, sem sofrer qualquer punição ou constrangimento.

Voluntário - Nome legível: _____

_____
Assinatura

Para eventuais denúncias e/ou reclamações referentes aos aspectos éticos da pesquisa, favor contatar:
Comitê de Ética em Pesquisa/FCM/UNICAMP.
Rua: Tessália Vieira de Camargo, 126 – CEP 13083-887 Campinas – SP
Fone (019) 3521-8936 ou 3521-7187 e-mail: cep@fcm.unicamp.br

Appendix 6 – Reports

Place: Intensive care unit 203 **Date:** 02/05/2012 **Time:** 08:00 - 21:00

Work area n=11

Dimensions	Min	Measured
Area/bed (m^2)	9.0	**8.15**
Distance between walls and bed (m)	1.00	**1.20**
Distance between beds (m)	2.00	**2.20**
Nursing station (m^2)	6.00	**7.40**
Medical prescription area (m^2)	1.50	**3.70**

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	NO
There are cables or tubes in passageways	NO
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	
Small	
Fair	9
Big	1
Very big	

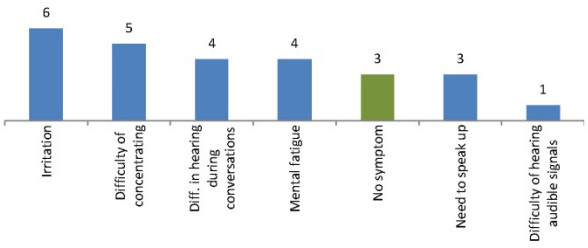
Slip, trip, or fall risk

No risk	
Little risk	5
Medium risk	5
High risk	

You have slipped, tripped of fallen

No	4
Slip	6
Trip	1
Fall	

Noise n=11

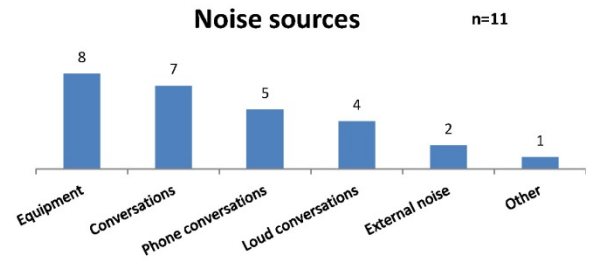


Noise bothers, disturbs, annoys during work

Never	1
Rarely	
Sometimes	6
Often	3
Always	1

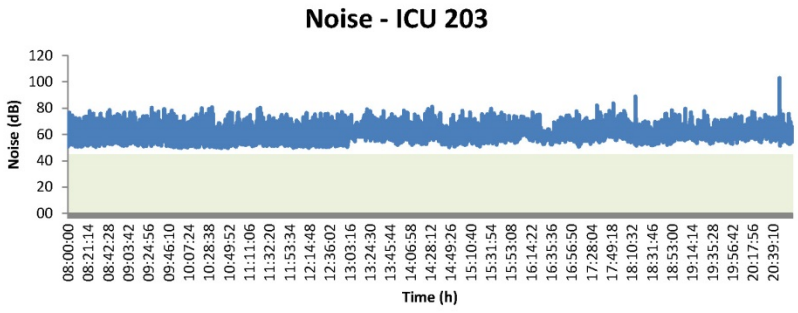
Noise has a negative impact on your job

Never	1
Rarely	3
Sometimes	5
Often	2
Always	1



Noise level in the environment

Very low	
Low	
Fair	4
Loud	6
Very loud	1



Noise (dB)	
Mean	64.4
SD	6.5
Max	103.0
Min	49.7
Max-Min	53.3

Place: ICU 203 **Date: 02/05/2012** **Time: 08:00 - 21:00**

Lighting n=11

Illuminance (lux)	Min	Max	Measured
General illuminance	100	200	**227**
Nursing station	150	300	**290**
Medical prescription	300	750	**376**
Patient bed	150	300	**128**

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks

Never	2
Rarely	6
Sometimes	3
Often	
Always	

Glare occurs during tasks

Never	5
Rarely	5
Sometimes	1
Often	
Always	

Shadows are produced during tasks

Never	4
Rarely	3
Sometimes	4
Often	
Always	

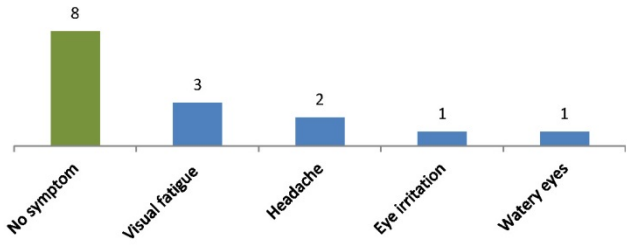
You perceive the environment as

Too dark	1
Dark	3
Fair	6
Bright	1
Too bright	

Lighting provides proper task conditions

Never	
Rarely	1
Sometimes	2
Often	6
Always	2

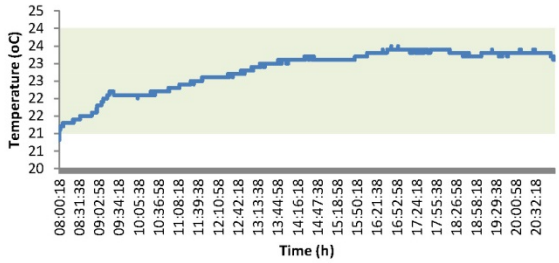
Lighting related symptoms n=11



Place: ICU 203 **Date:** 02/05/2012 **Time:** 08:00 - 21:00

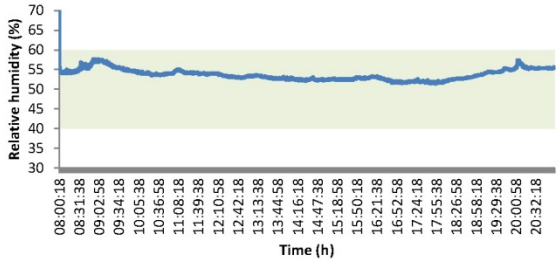
Environmental parameters n=11

Temperature - ICU 203



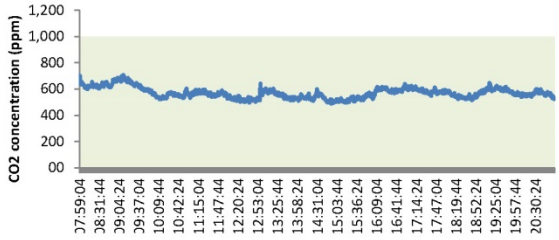
Temperature (°C)	
Mean	22.8
SD	0.6
Max	23.5
Min	20.8
Max-Min	2.7

Relative Humidity - ICU 203



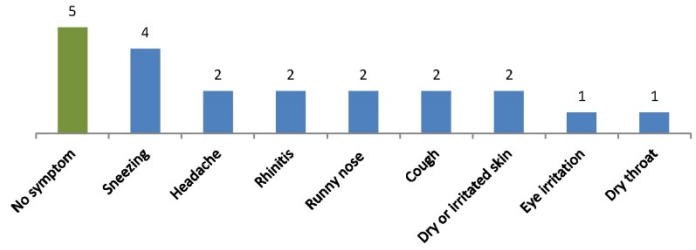
Rel. Humidity (%)	
Mean	53.7
SD	1.4
Max	71.6
Min	51.4
Max-Min	20.2

CO2 concentration - ICU 203



CO_2 conc. (ppm)	
Mean	570.0
SD	40.6
Max	708.0
Min	490.0
Max-Min	218.0

Air conditioning / air quality related symptoms n=11



Regarding temperature, you feel

Comfortable	6
Slightly uncomfortable	4
Uncomfortable	1
Very uncomfortable	

Temperature variations bother you

Never	1
Rarely	6
Sometimes	4
Often	
Always	

Regarding humidity, this environment is

Dry	1
A little dry	3
Fair	6
A little humid	1
Humid	

You are bothered by annoying drafts

Never	5
Rarely	5
Sometimes	1
Often	
Always	

The environment seems stuffy

Never	4
Rarely	4
Sometimes	3
Often	
Always	

The environment presents unpleasant odors

Never	1
Rarely	2
Sometimes	6
Often	2
Always	

Air quality in the environment is

Very poor	
Poor	1
Acceptable	7
Good	2
Very good	1

Place: ICU 203 **Date:** 02/05/2012 **Time:** 0.3346528

Power outlets n=11

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	12
Number of X-Ray power outlets	2	2
Number of 127 V power outlets		0
Number of 220 V power outlets		12
Power outlets height (m)		1.20

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never	
Sometimes	3
Always	8
Not sure	

Power plug adapters are used

Never	4
Sometimes	4
Always	2
Not sure	1

Power outlets positioning allows easy access

Never	
Sometimes	4
Always	5
Not sure	1

Adapters are available when needed

Never	
Sometimes	5
Always	1
Not sure	1

Power outlets allow tight connection to plugs

Never	
Sometimes	4
Always	6
Not sure	1

The quality of the adapters is

Very poor	
Poor	
Acceptable	5
Good	1
Very good	

Medical gas outlets n=11

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	2
Number of Nitrous Oxide outlets	-	-
Number of Vacuum outlets	1	2
Number of Medical air outlets	2	2
Medical gas outlets height (m)	1.5	1.52
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		N/A
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never	
Sometimes	2
Always	9
Not sure	

Medical gas outlets positioning allows easy access

Never	
Sometimes	1
Always	10
Not sure	

It is easy to identify the medical gas in the outlet

Never	
Sometimes	
Always	11
Not sure	

Place: ICU 206 **Date: 03/05/2012** **Time: 08:30 - 19:34**

Work area n=12

Dimensions	Min	Measured
Area/bed (m^2)	9.0	**12.5**
Distance between walls and bed (m)	1.00	**1.20**
Distance between beds (m)	2.00	**2.20**
Nursing station (m^2)	6.00	**6.00**
Medical prescription area (m^2)	1.50	**2.40**

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflexive	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	NO
There are cables or tubes in passageways	NO
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	
Small	
Fair	10
Big	2
Very big	

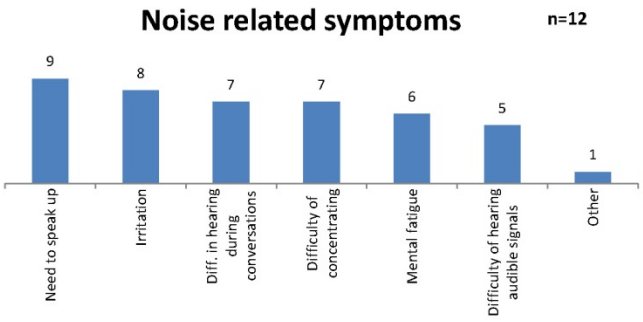
Slip, trip, or fall risk

No risk	1
Little risk	3
Medium risk	7
High risk	1

You have slipped, tripped of fallen

No	8
Slip	4
Trip	
Fall	

Noise n=12

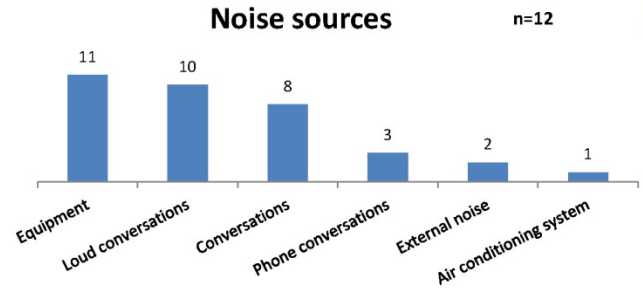


Noise bothers, disturbs, annoys during work

Never	1
Rarely	
Sometimes	4
Often	5
Always	2

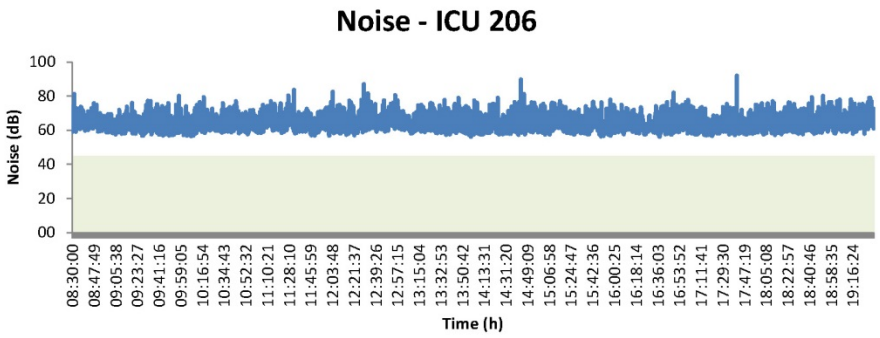
Noise has a negative impact on your job

Never	
Rarely	1
Sometimes	5
Often	5
Always	1



Noise level in the environment

Very low	
Low	
Fair	1
Loud	9
Very loud	2



Noise (dB)	
Mean	65.2
SD	3.7
Max	70.8
Min	59.9
Max-Min	10.9

Place: ICU 206 **Date: 03/05/2012** **Time: 08:30 - 19:34**

Lighting n=12

Illuminance (lux)	Min	Max	Measured
General illuminance	100	200	182
Nursing station	150	300	239
Medical prescription	300	750	283
Patient bed	150	300	270

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	YES

Reflex occurs during tasks	
Never	2
Rarely	3
Sometimes	3
Often	3
Always	1

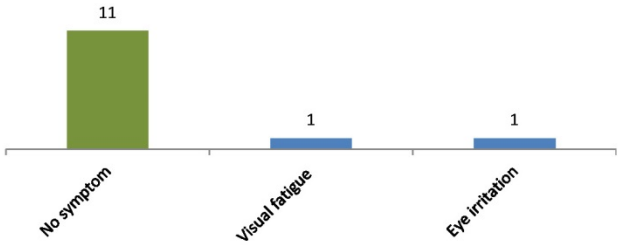
Glare occurs during tasks	
Never	5
Rarely	3
Sometimes	3
Often	1
Always	

Shadows are produced during tasks	
Never	3
Rarely	3
Sometimes	4
Often	2
Always	

You perceive the environment as	
Too dark	
Dark	3
Fair	7
Bright	2
Too bright	

Lighting provides proper task conditions	
Never	
Rarely	3
Sometimes	2
Often	4
Always	3

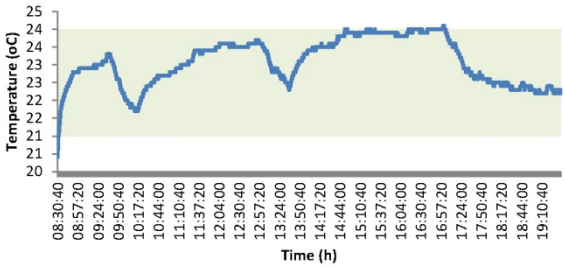
Lighting related symptoms n=12



Place: ICU 206 **Date:** 03/05/2012 **Time:** 08:30 - 19:34

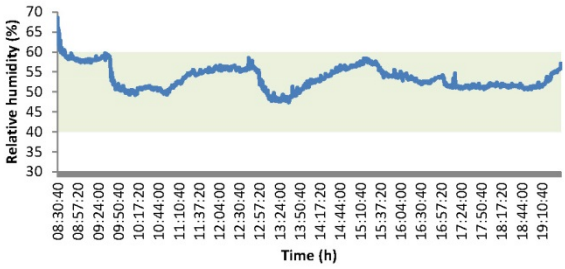
Environmental parameters n=12

Temperature - ICU 206



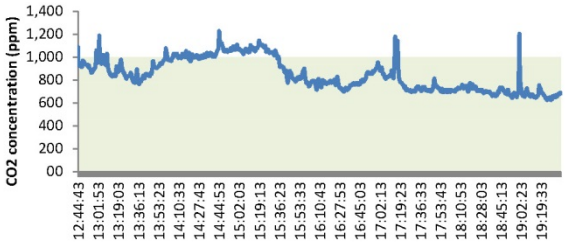
Temperature (°C)	
Mean	23.1
SD	0.6
Max	24.1
Min	20.4
Max-Min	3.7

Relative Humidity - ICU 206



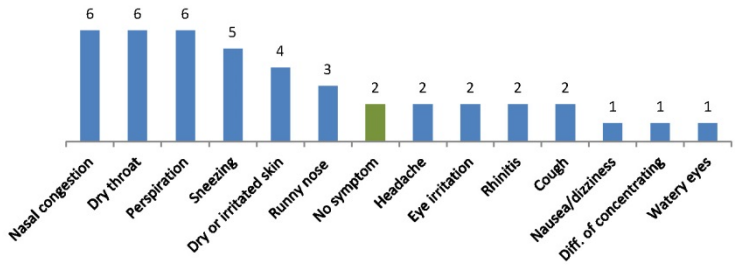
Rel. Humidity (%)	
Mean	53.5
SD	2.9
Max	68.6
Min	47.4
Max-Min	21.2

CO2 concentration - ICU 206



CO_2 conc. (ppm)	
Mean	847.7
SD	139.8
Max	1229.0
Min	627.0
Max-Min	602.0

Air conditioning / air quality related symptoms n=12



Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	6
Uncomfortable	5
Very uncomfortable	

Temperature variations bother you

Never	
Rarely	2
Sometimes	5
Often	5
Always	

Regarding humidity, this environment is

Dry	2
A little dry	5
Fair	5
A little humid	
Humid	

You are bothered by annoying drafts

Never	5
Rarely	3
Sometimes	4
Often	
Always	

The environment seems stuffy

Never	3
Rarely	4
Sometimes	4
Often	1
Always	

The environment presents unpleasant odors

Never	1
Rarely	1
Sometimes	5
Often	4
Always	1

Air quality in the environment is

Very poor	1
Poor	2
Acceptable	8
Good	1
Very good	

Place: ICU 206 **Date:** 03/05/2012 **Time:** 08:30 - 19:34

Power outlets n=12

Number and height of power outlets	Min	Measured
Number of power outlets /bed	8	10
Number of X-Ray power outlets	1	1
Number of 127 V power outlets		0
Number of 220 V power outlets		10
Power outlets height (m)		1.42

Parameters related to power outlets	
All 220 V power outlets are identified	YES
All X-Ray power outlets are identified	N/A
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never 2
Sometimes 8
Always 2
Not sure

Power plug adapters are used

Never
Sometimes 7
Always 4
Not sure 1

Power outlets positioning allows easy access

Never 2
Sometimes 5
Always 5
Not sure

Adapters are available when needed

Never 1
Sometimes 9
Always 1
Not sure

Power outlets allow tight connection to plugs

Never 3
Sometimes 3
Always 5
Not sure

The quality of the adapters is

Very poor
Poor 5
Acceptable 5
Good 1
Very good

Medical gas outlets n=12

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	2
Number of Nitrous Oxide outlets	-	-
Number of Vacuum outlets	1	2
Number of Medical air outlets	2	2
Medical gas outlets height (m)		1.52
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		N/A
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes 7
Always 5
Not sure

Medical gas outlets positioning allows easy access

Never
Sometimes 6
Always 6
Not sure

It is easy to identify the medical gas in the outlet

Never
Sometimes 4
Always 7
Not sure

Place: Operating room 1 **Date: 24/04/2012** **Time: 09:15 - 15:04**

Work area n= 7

Dimensions	Min	Measured
Total area (m^2)	36.0	**30.62**
Length (m)	5.00	**5.42**
Width (m)	5.00	**5.62**
Height (m)	2.70	**2.80**

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	1
Small	3
Fair	2
Big	1
Very big	

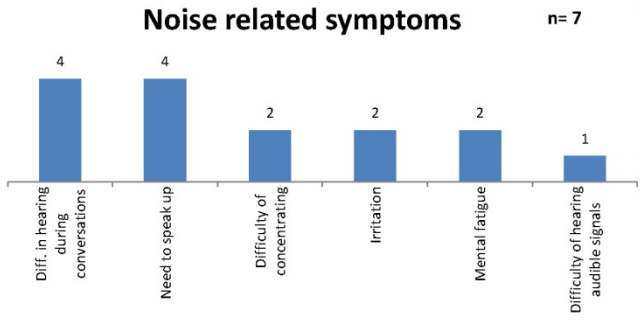
Slip, trip, or fall risk

No risk	1
Little risk	3
Medium risk	3
High risk	

You have slipped, tripped of fallen

No	4
Slip	2
Trip	1
Fall	

Noise n= 7

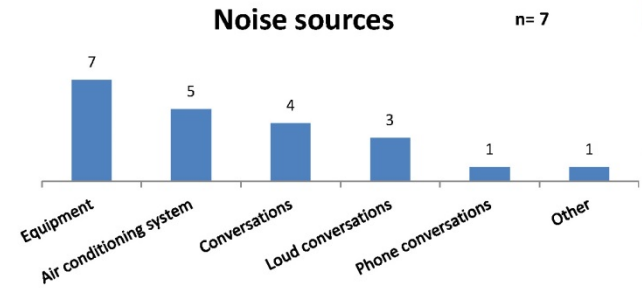


Noise bothers, disturbs, annoys during work

Never	1
Rarely	5
Sometimes	1
Often	
Always	

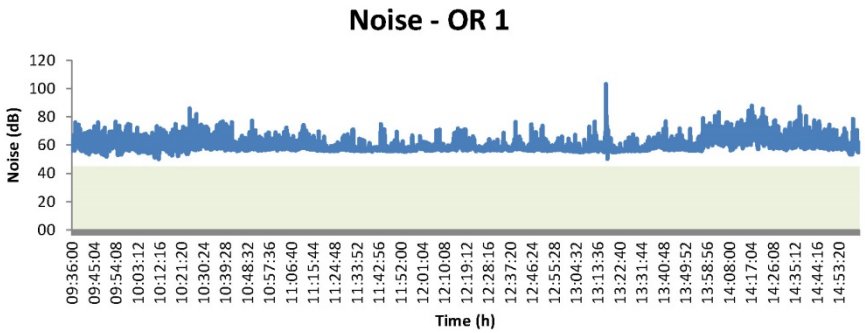
Noise has a negative impact on your job

Never	2
Rarely	2
Sometimes	1
Often	
Always	



Noise level in the environment

Very low	
Low	1
Fair	3
Loud	2
Very loud	1



Noise (dB)	
Mean	66.2
SD	7.5
Max	103.1
Min	50.1
Max-Min	53.0

Place: Operating room 1 **Date: 24/04/2012** **Time: 09:15 - 15:04**

Lighting n= 7

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	672

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks

Never	3
Rarely	2
Sometimes	2
Often	
Always	

Glare occurs during tasks

Never	3
Rarely	4
Sometimes	
Often	
Always	

Shadows are produced during tasks

Never	3
Rarely	3
Sometimes	
Often	1
Always	

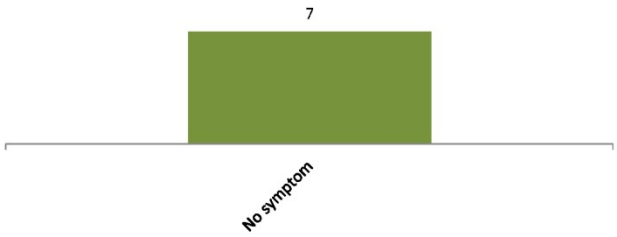
You perceive the environment as

Too dark	
Dark	1
Fair	6
Bright	
Too bright	

Lighting provides proper task conditions

Never	
Rarely	
Sometimes	1
Often	5
Always	1

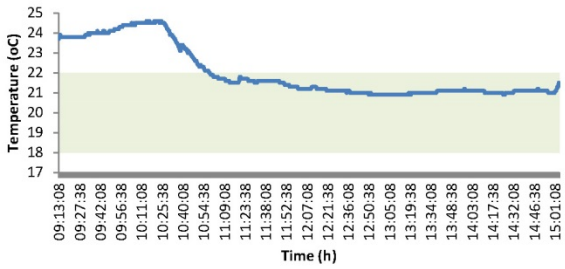
Lighting related symptoms n= 7



Place: Operating room 1 **Date:** 24/04/2012 **Time:** 09:15 - 15:04

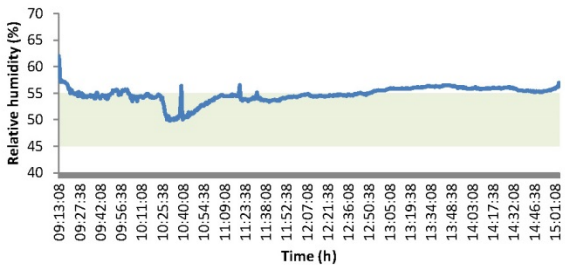
Environmental parameters n= 7

Temperature - OR 1



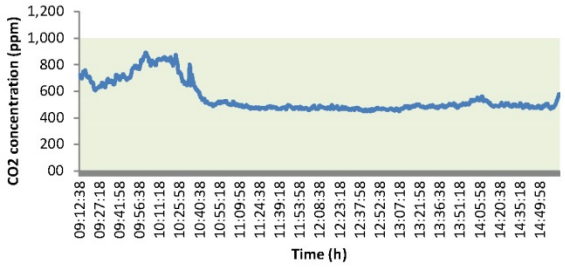
Temperature (°C)	
Mean	22.0
SD	1.3
Max	24.6
Min	20.9
Max-Min	3.7

Relative Humidity - OR 1



Rel. Humidity (%)	
Mean	54.8
SD	1.4
Max	62.0
Min	49.8
Max-Min	12.2

CO2 concentration - OR 1



CO_2 conc. (ppm)	
Mean	549.5
SD	116.6
Max	890.0
Min	449.0
Max-Min	441.0

Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	3
Uncomfortable	2
Very uncomfortable	1

Temperature variations bother you

Never	1
Rarely	1
Sometimes	1
Often	3
Always	1

Regarding humidity, this environment is

Dry	1
A little dry	1
Fair	5
A little humid	
Humid	

You are bothered by annoying drafts

Never	2
Rarely	2
Sometimes	3
Often	
Always	

The environment seems stuffy

Never	2
Rarely	3
Sometimes	
Often	2
Always	

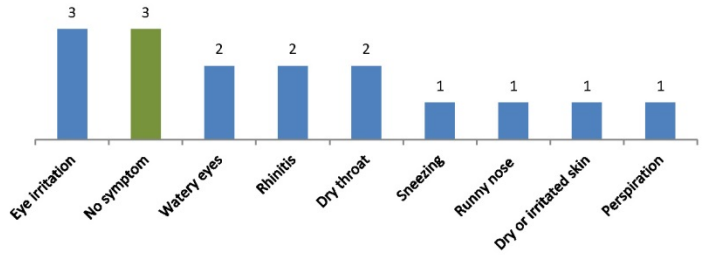
The environment presents unpleasant odors

Never	2
Rarely	4
Sometimes	1
Often	
Always	

Air quality in the environment is

Very poor	
Poor	1
Acceptable	3
Good	3
Very good	

Environmental parameters related symptoms n= 7



Place: Operating room 1 **Date:** 24/04/2012 **Time:** 09:15 - 15:04

Power outlets n= 7

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never
Sometimes 4
Always 3
Not sure

Power plug adapters are used

Never
Sometimes 5
Always 1
Not sure 1

Power outlets positioning allows easy access

Never
Sometimes 4
Always 3
Not sure

Adapters are available when needed

Never
Sometimes 3
Always 3
Not sure

Power outlets allow tight connection to plugs

Never
Sometimes 3
Always 3
Not sure 1

The quality of the adapters is

Very poor
Poor 1
Acceptable 5
Good
Very good

Medical gas outlets n= 7

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes
Always 6
Not sure

Medical gas outlets positioning allows easy access

Never
Sometimes
Always 6
Not sure

It is easy to identify the medical gas in the outlet

Never
Sometimes 1
Always 5
Not sure

Place: Operating room 2 **Date: 23/04/2012** **Time: 14:00 - 18:43**

Work area n=9

Dimensions	Min	Measured
Total area (m^2)	36.0	**34.41**
Length (m)	5.00	**6.58**
Width (m)	5.00	**5.23**
Height	2.70	**2.80**

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	1
Small	2
Fair	6
Big	
Very big	

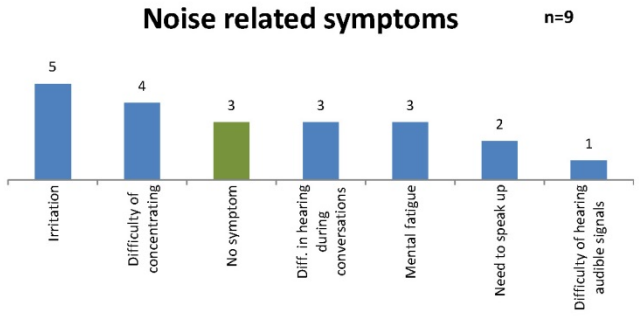
Slip, trip, or fall risk

No risk	
Little risk	5
Medium risk	3
High risk	1

You have slipped, tripped of fallen

No	7
Slip	1
Trip	1
Fall	

Noise n=9

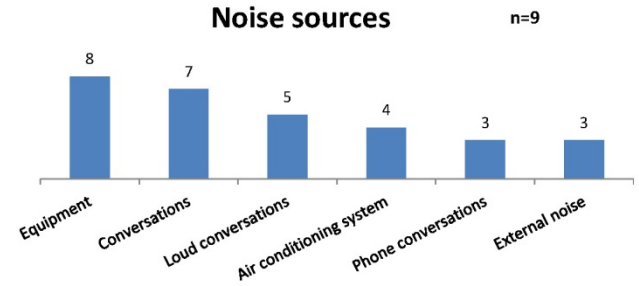


Noise bothers, disturbs, annoys during work

Never	
Rarely	3
Sometimes	4
Often	1
Always	1

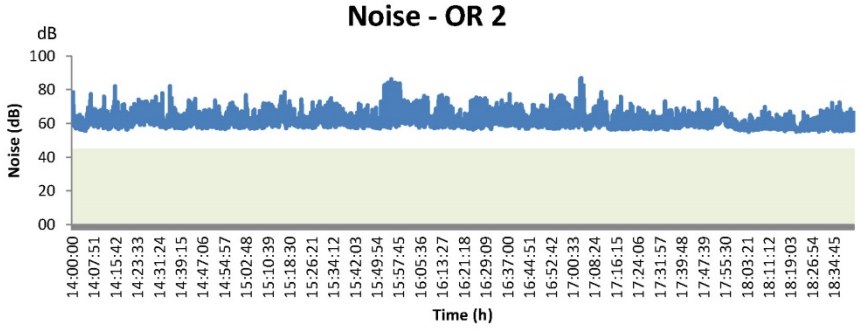
Noise has a negative impact on your job

Never	
Rarely	3
Sometimes	4
Often	1
Always	1



Noise level in the environment

Very low	
Low	1
Fair	2
Loud	6
Very loud	



Noise (dB)	
Mean	65.6
SD	5.7
Max	87.0
Min	55.0
Max-Min	32.0

Place: Operating room 2 **Date: 23/04/2012** **Time: 14:00 - 18:43**

Lighting n=9

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	675

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks

Never	
Rarely	7
Sometimes	2
Often	
Always	

Glare occurs during tasks

Never	1
Rarely	6
Sometimes	2
Often	
Always	

Shadows are produced during tasks

Never	1
Rarely	4
Sometimes	1
Often	3
Always	

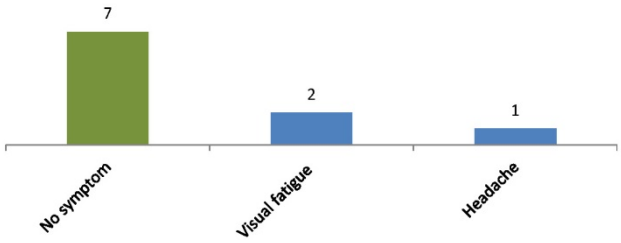
You perceive the environment as

Too dark	
Dark	1
Fair	6
Bright	1
Too bright	

Lighting provides proper task conditions

Never	
Rarely	
Sometimes	2
Often	5
Always	2

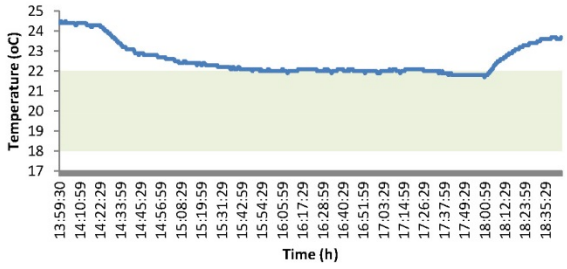
Lighting related symptoms n=9



Place: Operating room 2 **Date:** 23/04/2012 **Time:** 14:00 - 18:43

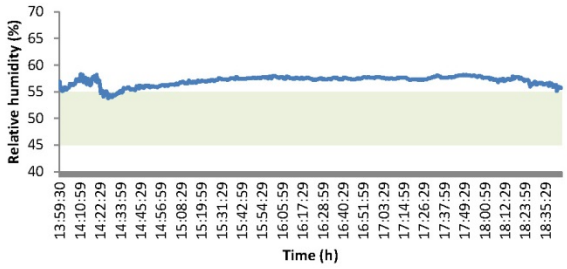
Environmental parameters n=9

Temperature - OR 2



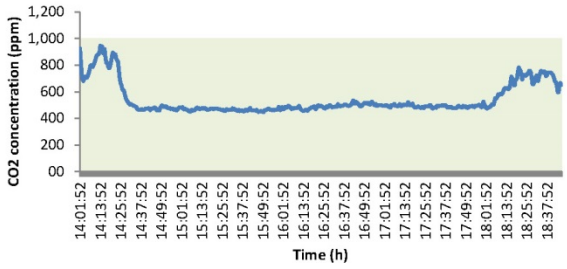
Temperature (°C)	
Mean	22.6
SD	0.8
Max	24.5
Min	21.7
Max-Min	2.8

Relative Humidity - OR 2



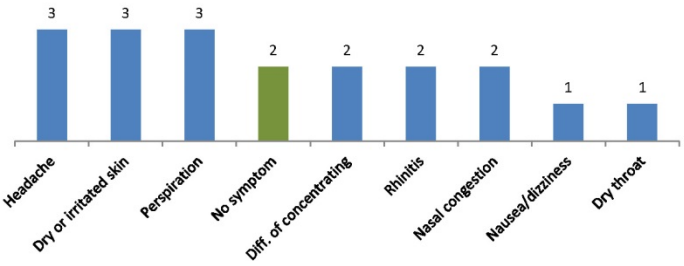
Rel. Humidity (%)	
Mean	57.1
SD	0.9
Max	58.3
Min	53.8
Max-Min	4.5

CO2 concentration - OR 2



CO_2 conc. (ppm)	
Mean	540.2
SD	114.8
Max	944.0
Min	447.0
Max-Min	497.0

Air conditioning / air quality related symptoms n=9



Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	2
Uncomfortable	3
Very uncomfortable	3

Temperature variations bother you

Never	
Rarely	
Sometimes	2
Often	5
Always	2

Regarding humidity, this environment is

Dry	3
A little dry	2
Fair	4
A little humid	
Humid	

You are bothered by annoying drafts

Never	1
Rarely	3
Sometimes	2
Often	2
Always	1

The environment seems stuffy

Never	1
Rarely	2
Sometimes	3
Often	3
Always	

The environment presents unpleasant odors

Never	1
Rarely	1
Sometimes	4
Often	3
Always	

Air quality in the environment is

Very poor	
Poor	4
Acceptable	3
Good	2
Very good	

Place: Operating room 2 **Date:** 23/04/2012 **Time:** 14:00 - 18:43

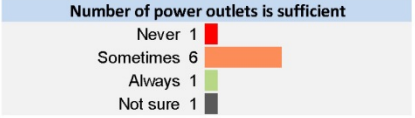
Power outlets n=9

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

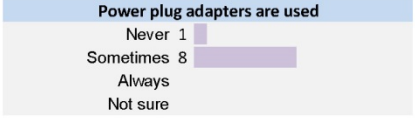
Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

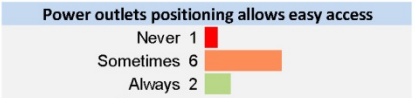
Number of power outlets is sufficient



Power plug adapters are used

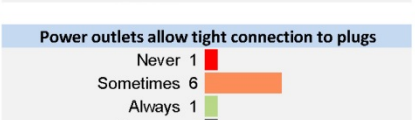


Power outlets positioning allows easy access



Adapters are available when needed

Power outlets allow tight connection to plugs

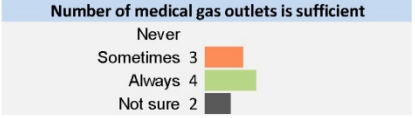


The quality of the adapters is

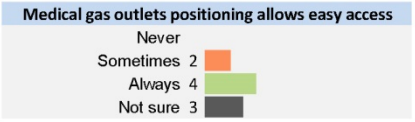
Medical gas outlets n=9

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient



Medical gas outlets positioning allows easy access



It is easy to identify the medical gas in the outlet

Place: Operating room 2 **Date: 24/04/2012** **Time: 15:58 - 20:12**

Work area n=5

Dimensions	Min	Measured
Total area (m^2)	36.0	**34.41**
Length (m)	5.00	**6.58**
Width (m)	5.00	**5.23**
Height	2.70	**2.80**

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	
Small	2
Fair	2
Big	1
Very big	

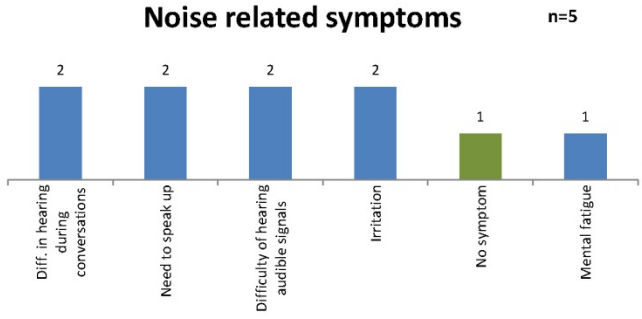
Slip, trip, or fall risk

No risk	
Little risk	4
Medium risk	1
High risk	

You have slipped, tripped of fallen

No	5
Slip	
Trip	
Fall	

Noise n=5

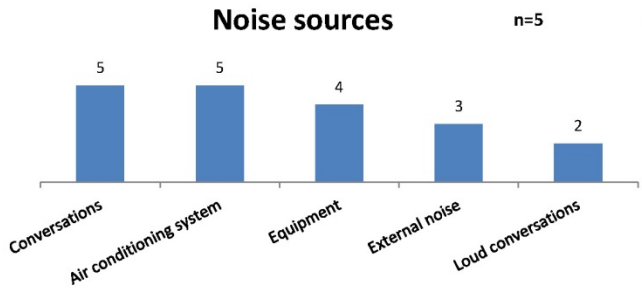


Noise bothers, disturbs, annoys during work

Never	1
Rarely	
Sometimes	1
Often	3
Always	

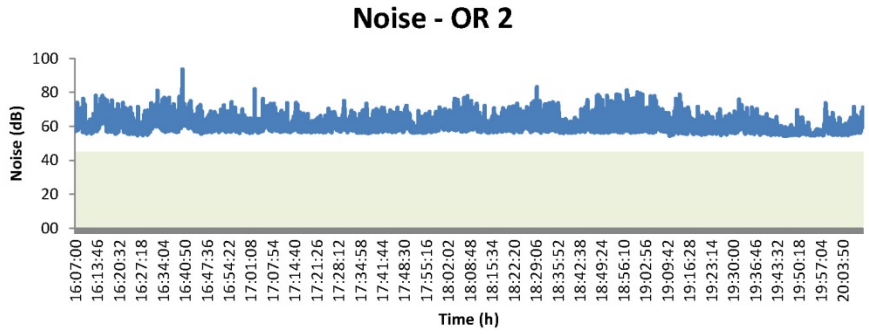
Noise has a negative impact on your job

Never	1
Rarely	
Sometimes	4
Often	
Always	



Noise level in the environment

Very low	
Low	
Fair	1
Loud	4
Very loud	



Noise (dB)	
Mean	63.7
SD	5.0
Max	93.5
Min	54.3
Max-Min	39.2

Place: Operating room 2 **Date: 24/04/2012** **Time: 15:58 - 20:12**

Lighting n=5

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	675

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks

Never	
Rarely	5
Sometimes	
Often	
Always	

Glare occurs during tasks

Never	
Rarely	5
Sometimes	
Often	
Always	

Shadows are produced during tasks

Never	
Rarely	3
Sometimes	2
Often	
Always	

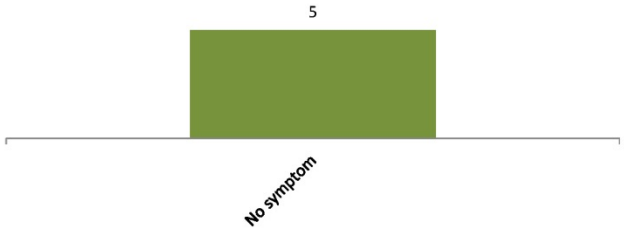
You perceive the environment as

Too dark	
Dark	
Fair	4
Bright	1
Too bright	

Lighting provides proper task conditions

Never	
Rarely	
Sometimes	
Often	3
Always	2

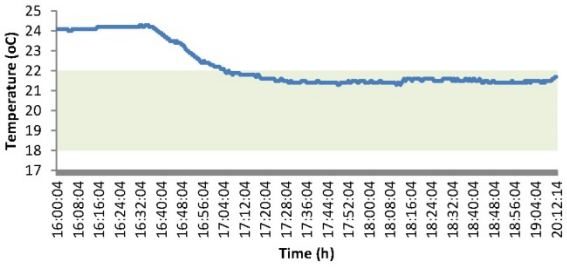
Lighting related symptoms n=5



Place: Operating room 2 **Date:** 24/04/2012 **Time:** 15:58 - 20:12

Environmental parameters n=5

Temperature - OR 2



Temperature (°C)	
Mean	22.2
SD	1.1
Max	24.3
Min	21.3
Max-Min	3.0

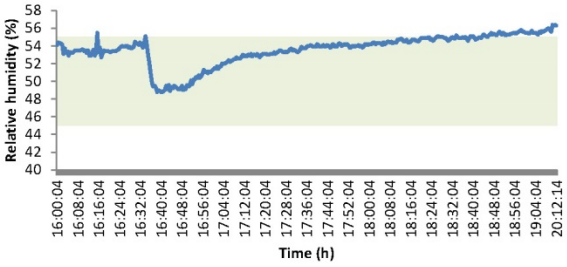
Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	
Uncomfortable	2
Very uncomfortable	1

Temperature variations bother you

Never	
Rarely	2
Sometimes	
Often	3
Always	

Relative Humidity - OR 2



Rel. Humidity (%)	
Mean	53.6
SD	1.7
Max	56.4
Min	48.8
Max-Min	7.6

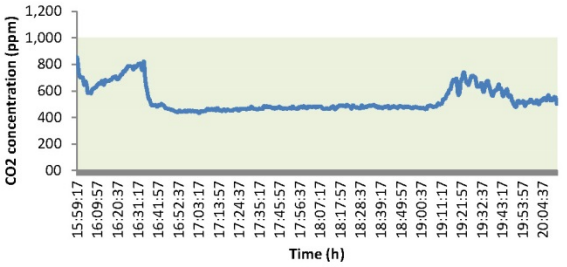
Regarding humidity, this environment is

Dry	
A little dry	3
Fair	2
A little humid	
Humid	

You are bothered by annoying drafts

Never	3
Rarely	1
Sometimes	1
Often	
Always	

CO2 concentration - OR 2



CO_2 conc. (ppm)	
Mean	533.6
SD	95.5
Max	855.0
Min	432.0
Max-Min	423.0

The environment seems stuffy

Never	
Rarely	4
Sometimes	
Often	1
Always	

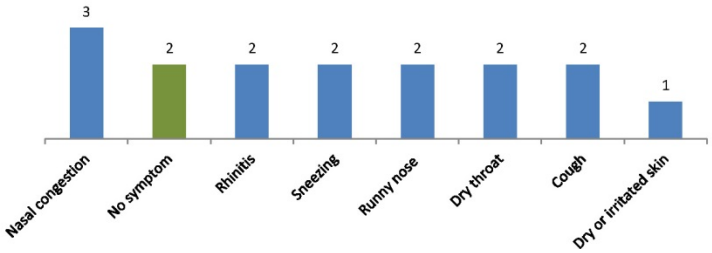
The environment presents unpleasant odors

Never	
Rarely	4
Sometimes	1
Often	
Always	

Air quality in the environment is

Very poor	
Poor	
Acceptable	3
Good	2
Very good	

Environmental parameters related symptoms n=5



Place: Operating room 2 **Date:** 24/04/2012 **Time:** 15:58 - 20:12

Power outlets n=5

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never
Sometimes 2
Always 2
Not sure 1

Power plug adapters are used

Never 1
Sometimes 4
Always
Not sure

Power outlets positioning allows easy access

Never 1
Sometimes 1
Always 3
Not sure

Adapters are available when needed

Never 1
Sometimes 1
Always 2
Not sure

Power outlets allow tight connection to plugs

Never
Sometimes 1
Always 3
Not sure 1

The quality of the adapters is

Very poor
Poor 1
Acceptable 2
Good 1
Very good

Medical gas outlets n=5

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes
Always 4
Not sure 1

Medical gas outlets positioning allows easy access

Never
Sometimes
Always 4
Not sure 1

It is easy to identify the medical gas in the outlet

Never
Sometimes
Always 4
Not sure 1

Place: Operating room 2 **Date: 27/04/2012** **Time: 07:58-11:04**

Work area n=6

Dimensions	Min	Measured
Total area (m^2)	36.0	**34.41**
Length (m)	5.00	**6.58**
Width (m)	5.00	**5.23**
Height	2.70	**2.80**

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	
Small	1
Fair	5
Big	
Very big	

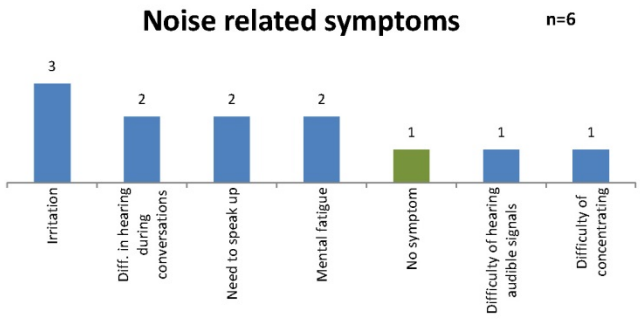
Slip, trip, or fall risk

No risk	
Little risk	2
Medium risk	3
High risk	1

You have slipped, tripped of fallen

No	3
Slip	1
Trip	2
Fall	

Noise n=6

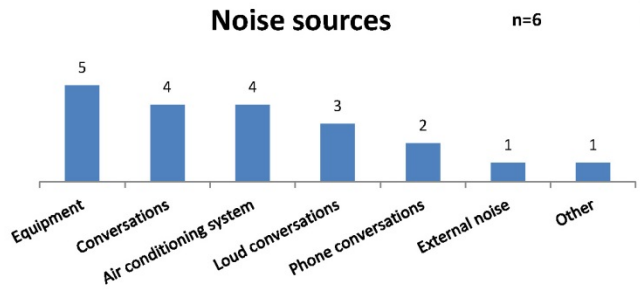


Noise bothers, disturbs, annoys during work

Never	
Rarely	1
Sometimes	3
Often	2
Always	

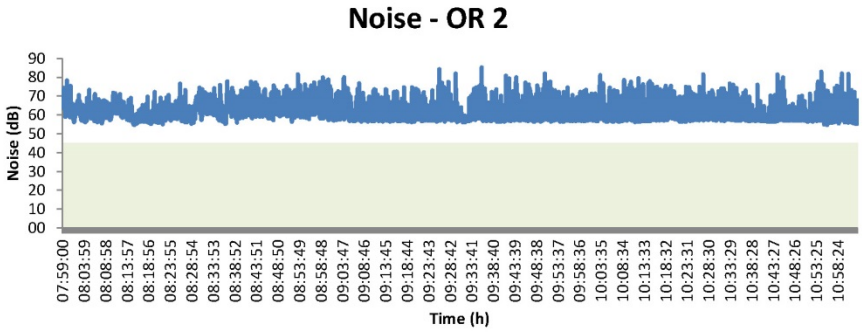
Noise has a negative impact on your job

Never	
Rarely	2
Sometimes	3
Often	1
Always	



Noise level in the environment

Very low	
Low	
Fair	2
Loud	4
Very loud	



Noise (dB)	
Mean	65.2
SD	5.6
Max	85.3
Min	54.6
Max-Min	30.7

Place: Operating room 2 **Date: 27/04/2012** **Time: 07:58 - 11:04**

Lighting n=6

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	675

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks	
Never	
Rarely	4
Sometimes	2
Often	
Always	

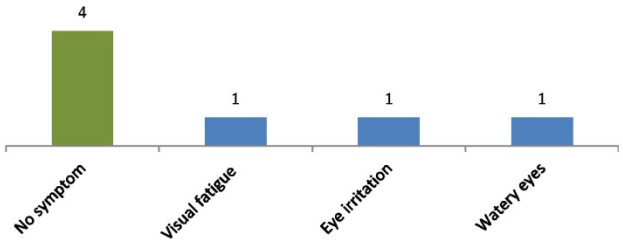
Glare occurs during tasks	
Never	1
Rarely	4
Sometimes	1
Often	
Always	

Shadows are produced during tasks	
Never	1
Rarely	2
Sometimes	2
Often	1
Always	

You perceive the environment as	
Too dark	
Dark	1
Fair	4
Bright	1
Too bright	

Lighting provides proper task conditions	
Never	
Rarely	1
Sometimes	3
Often	2
Always	

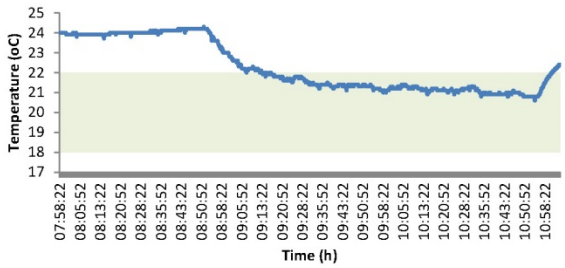
Lighting related symptoms n=6



Place: Operating room 2 **Date:** 27/04/2012 **Time:** 07:58 - 11:04

Environmental parameters n=6

Temperature - OR 2



Temperature (°C)	
Mean	22.3
SD	1.3
Max	24.3
Min	20.6
Max-Min	3.7

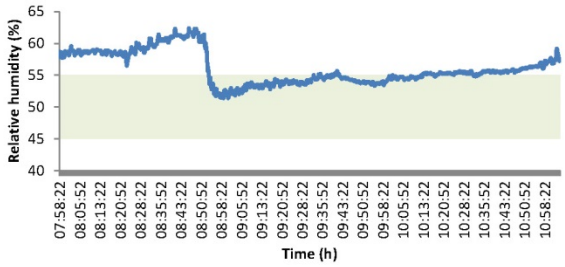
Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	2
Uncomfortable	3
Very uncomfortable	

Temperature variations bother you

Never	
Rarely	
Sometimes	3
Often	2
Always	1

Relative Humidity - OR 2



Rel. Humidity (%)	
Mean	56.1
SD	2.6
Max	62.4
Min	51.4
Max-Min	11.0

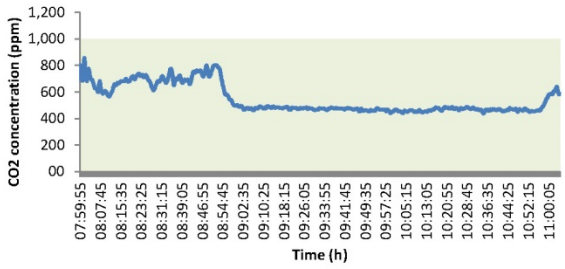
Regarding humidity, this environment is

Dry	
A little dry	3
Fair	3
A little humid	
Humid	

You are bothered by annoying drafts

Never	2
Rarely	3
Sometimes	
Often	1
Always	

CO2 concentration - OR 2



CO_2 conc. (ppm)	
Mean	544.0
SD	108.0
Max	857.0
Min	438.0
Max-Min	419.0

The environment seems stuffy

Never	3
Rarely	1
Sometimes	2
Often	
Always	

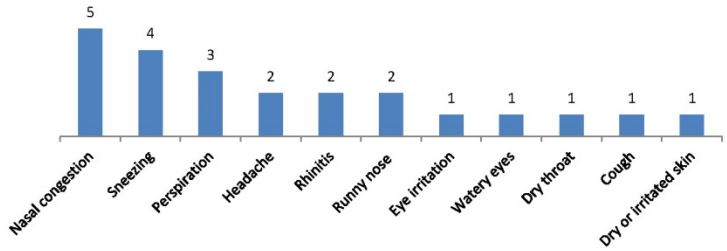
The environment presents unpleasant odors

Never	1
Rarely	1
Sometimes	2
Often	1
Always	

Air quality in the environment is

Very poor	
Poor	1
Acceptable	3
Good	2
Very good	

Environmental parameters related symptoms n=6



Place: Operating room 2 **Date:** 27/04/2012 **Time:** 07:58 - 11:04

Power outlets n=6

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never 1
Sometimes 5
Always
Not sure

Power plug adapters are used

Never 1
Sometimes 4
Always
Not sure

Power outlets positioning allows easy access

Never 2
Sometimes 4
Always
Not sure

Adapters are available when needed

Never
Sometimes 3
Always
Not sure

Power outlets allow tight connection to plugs

Never 1
Sometimes 4
Always 1
Not sure

The quality of the adapters is

Very poor
Poor 1
Acceptable 2
Good
Very good

Medical gas outlets n=6

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes 2
Always 3
Not sure

Medical gas outlets positioning allows easy access

Never
Sometimes 3
Always 2
Not sure

It is easy to identify the medical gas in the outlet

Never
Sometimes 1
Always 4
Not sure 1

Place: Operating room 3 **Date: 23/04/2012** **Time: 08:30 - 10:25**

Work area n=5

Dimensions	Min	Measured
Total area (m^2)	36.0	31.23
Length (m)	5.00	5.44
Width (m)	5.00	5.74
Height	2.70	2.80

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	1
Small	3
Fair	1
Big	
Very big	

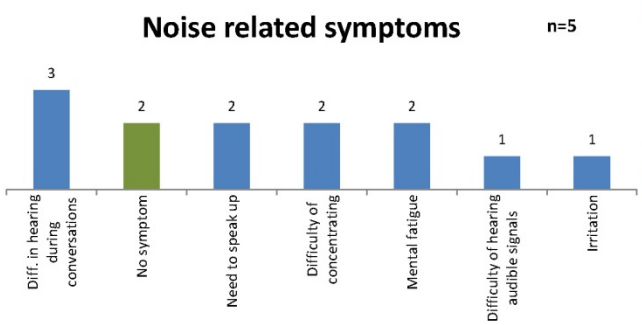
Slip, trip, or fall risk

No risk	
Little risk	1
Medium risk	4
High risk	

You have slipped, tripped of fallen

No	2
Slip	
Trip	2
Fall	1

Noise n=5

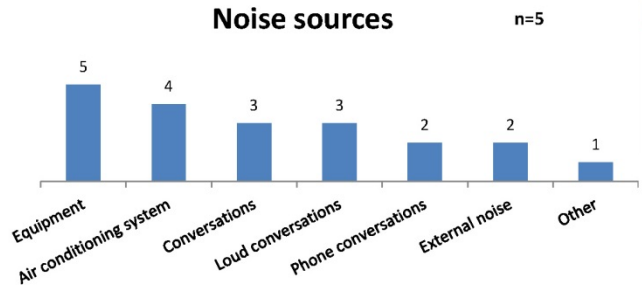


Noise bothers, disturbs, annoys during work

Never	
Rarely	2
Sometimes	3
Often	
Always	

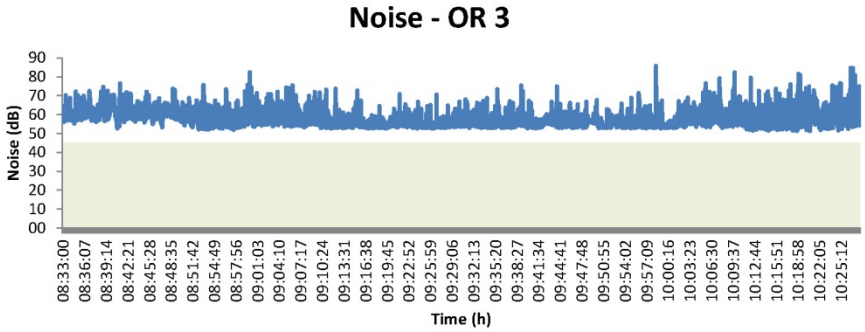
Noise has a negative impact on your job

Never	
Rarely	1
Sometimes	4
Often	
Always	



Noise level in the environment

Very low	
Low	
Fair	3
Loud	1
Very loud	1



Noise (dB)	
Mean	61.7
SD	5.8
Max	85.7
Min	51.4
Max-Min	34.3

Place: Operating room 3 **Date: 23/04/2012** **Time: 08:30 - 10:25**

Lighting n=5

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	693

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks	
Never	
Rarely	2
Sometimes	2
Often	1
Always	

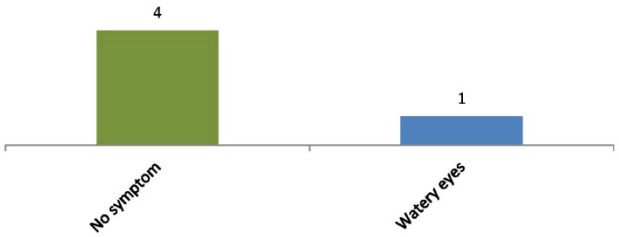
Glare occurs during tasks	
Never	
Rarely	3
Sometimes	2
Often	
Always	

Shadows are produced during tasks	
Never	
Rarely	1
Sometimes	3
Often	1
Always	

You perceive the environment as	
Too dark	
Dark	1
Fair	2
Bright	1
Too bright	1

Lighting provides proper task conditions	
Never	
Rarely	
Sometimes	1
Often	3
Always	1

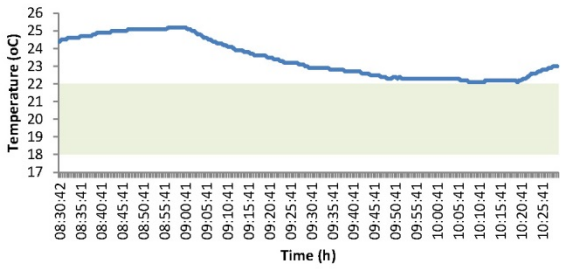
Lighting related symptoms n=5



Place: Operating room 3 **Date:** 23/04/2012 **Time:** 08:30 - 10:25

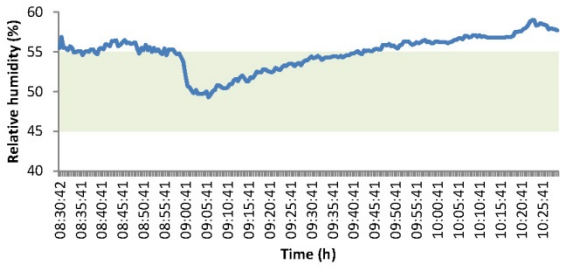
Environmental parameters n=5

Temperature - OR 3



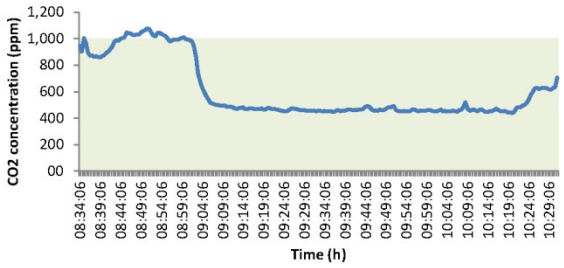
Temperature (°C)	
Mean	23.4
SD	1.1
Max	25.2
Min	22.1
Max-Min	3.1

Relative Humidity



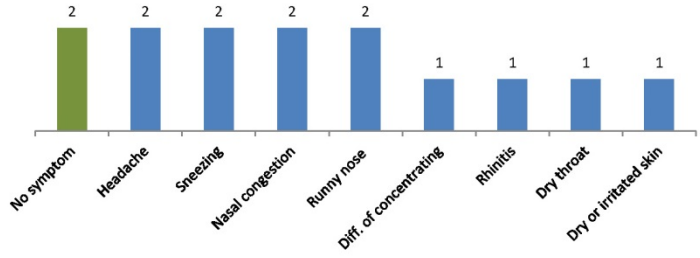
Rel. Humidity (%)	
Mean	54.9
SD	2.2
Max	59.0
Min	49.3
Max-Min	9.7

CO2 concentration - OR 3



CO_2 conc. (ppm)	
Mean	607.0
SD	221.5
Max	1078.0
Min	439.0
Max-Min	639.0

Environmental parameters related symptoms n=5



Regarding temperature, you feel

Comfortable	
Slightly uncomfortable	2
Uncomfortable	3
Very uncomfortable	

Temperature variations bother you

Never	
Rarely	
Sometimes	3
Often	2
Always	

Regarding humidity, this environment is

Dry	1
A little dry	2
Fair	2
A little humid	
Humid	

You are bothered by annoying drafts

Never	1
Rarely	1
Sometimes	2
Often	1
Always	

The environment seems stuffy

Never	
Rarely	1
Sometimes	2
Often	2
Always	

The environment presents unpleasant odors

Never	
Rarely	1
Sometimes	4
Often	
Always	

Air quality in the environment is

Very poor	
Poor	
Acceptable	5
Good	
Very good	

Place: Operating room 3 **Date:** 23/04/2012 **Time:** 08:30 - 10:25

Power outlets n=5

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never 2
Sometimes 3
Always
Not sure

Power plug adapters are used

Never
Sometimes 4
Always 1
Not sure

Power outlets positioning allows easy access

Never 3
Sometimes 2
Always
Not sure

Adapters are available when needed

Never
Sometimes 5
Always
Not sure

Power outlets allow tight connection to plugs

Never
Sometimes 4
Always 1
Not sure

The quality of the adapters is

Very poor
Poor 3
Acceptable 2
Good
Very good

Medical gas outlets n=5

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes 2
Always 2
Not sure 1

Medical gas outlets positioning allows easy access

Never
Sometimes 3
Always 1
Not sure 1

It is easy to identify the medical gas in the outlet

Never
Sometimes
Always 4
Not sure 1

Place: Operating room 5 **Date: 26/04/2012** **Time: 08:05 - 11:03**

Work area n=6

Dimensions	Min	Measured
Total area (m^2)	36.0	**28.93**
Length (m)	5.00	**5.28**
Width (m)	5.00	**5.48**
Height	2.70	**2.80**

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

Physical area to perform tasks

Very small	
Small	2
Fair	4
Big	
Very big	

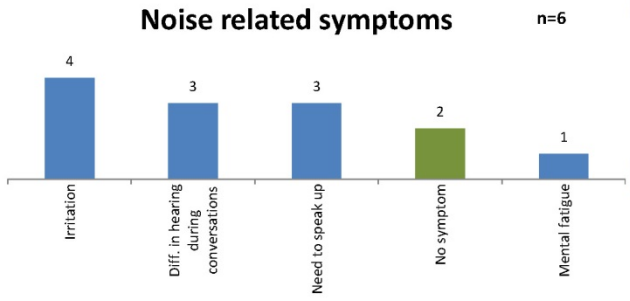
Slip, trip, or fall risk

No risk	
Little risk	2
Medium risk	4
High risk	

You have slipped, tripped of fallen

No	4
Slip	1
Trip	1
Fall	

Noise n=6

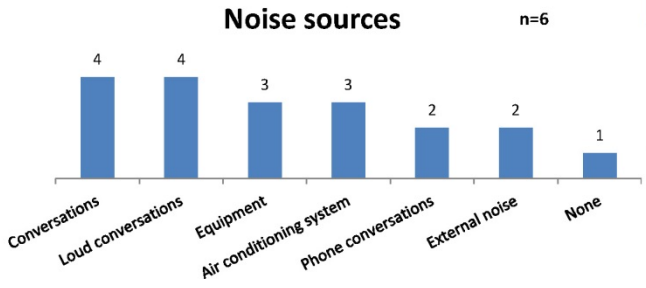


Noise bothers, disturbs, annoys during work

Never	
Rarely	
Sometimes	3
Often	3
Always	

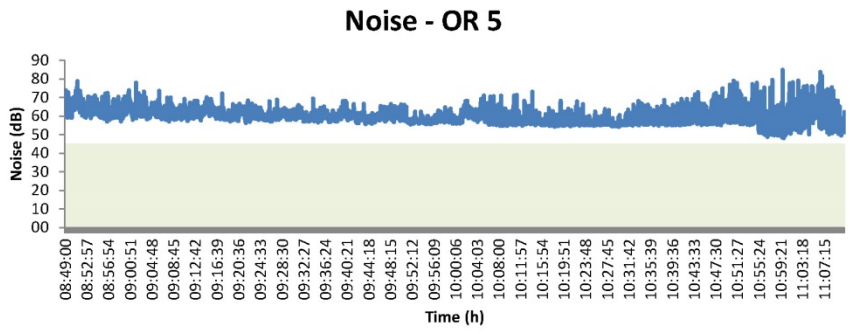
Noise has a negative impact on your job

Never	
Rarely	1
Sometimes	3
Often	2
Always	



Noise level in the environment

Very low	
Low	1
Fair	3
Loud	2
Very loud	



Noise (dB)	
Mean	62.6
SD	4.6
Max	84.9
Min	48.3
Max-Min	36.6

Place: Operating room 5 **Date: 26/04/2012** **Time: 08:05 - 11:03**

Lighting n=6

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	759

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks	
Never	1
Rarely	2
Sometimes	2
Often	1
Always	

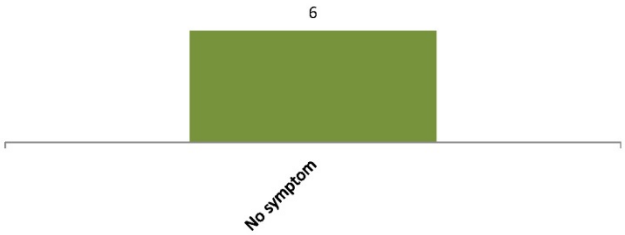
Glare occurs during tasks	
Never	1
Rarely	3
Sometimes	2
Often	
Always	

Shadows are produced during tasks	
Never	
Rarely	3
Sometimes	3
Often	
Always	

You perceive the environment as	
Too dark	
Dark	
Fair	6
Bright	
Too bright	

Lighting provides proper task conditions	
Never	
Rarely	1
Sometimes	
Often	4
Always	1

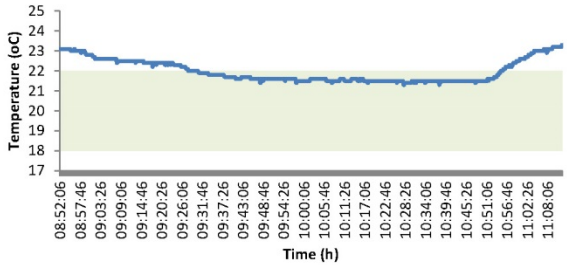
Lighting related symptoms n=6



Place: Operating room 5 **Date:** 26/04/2012 **Time:** 08:05 - 11:03

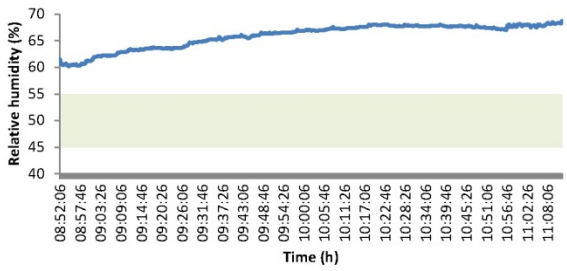
Environmental parameters n=6

Temperature - OR 5



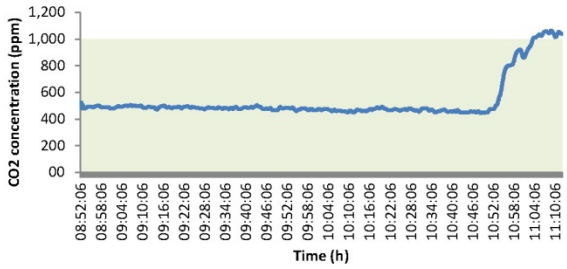
Temperature (°C)	
Mean	22.0
SD	0.6
Max	23.3
Min	21.3
Max-Min	2.0

Relative Humidity - OR 5



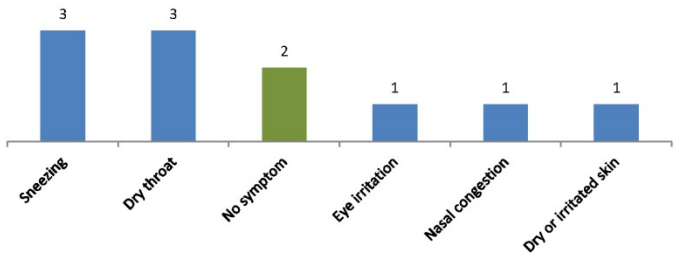
Rel. Humidity (%)	
Mean	65.9
SD	2.3
Max	68.7
Min	60.2
Max-Min	8.5

CO2 concentration - OR 5



CO_2 conc. (ppm)	
Mean	536.2
SD	159.8
Max	1064.0
Min	444.0
Max-Min	620.0

Environmental parameters related symptoms n=6



Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	3
Uncomfortable	2
Very uncomfortable	

Temperature variations bother you

Never	
Rarely	1
Sometimes	4
Often	1
Always	

Regarding humidity, this environment is

Dry	
A little dry	3
Fair	3
A little humid	
Humid	

You are bothered by annoying drafts

Never	
Rarely	4
Sometimes	2
Often	
Always	

The environment seems stuffy

Never	
Rarely	2
Sometimes	4
Often	
Always	

The environment presents unpleasant odors

Never	2
Rarely	
Sometimes	4
Often	
Always	

Air quality in the environment is

Very poor	
Poor	
Acceptable	5
Good	1
Very good	

Place: Operating room 5 **Date:** 26/04/2012 **Time:** 08:05 - 11:03

Power outlets n=6

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never 2
Sometimes 3
Always 1
Not sure

Power plug adapters are used

Never 1
Sometimes 4
Always 1
Not sure

Power outlets positioning allows easy access

Never 1
Sometimes 4
Always 1
Not sure

Adapters are available when needed

Never 1
Sometimes 4
Always
Not sure

Power outlets allow tight connection to plugs

Never 1
Sometimes 2
Always 1
Not sure

The quality of the adapters is

Very poor
Poor 2
Acceptable 3
Good
Very good

Medical gas outlets n=6

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes 2
Always 4
Not sure

Medical gas outlets positioning allows easy access

Never
Sometimes 3
Always 3
Not sure

It is easy to identify the medical gas in the outlet

Never
Sometimes
Always 6
Not sure

Place: Operating room 8 **Date: 26/04/2012** **Time: 13:43 - 14:32**

Work area n=4

Dimensions	Min	Measured
Total area (m^2)	36.0	**34.22**
Length (m)	5.00	**6.53**
Width (m)	5.00	**5.24**
Height	2.70	**2.80**

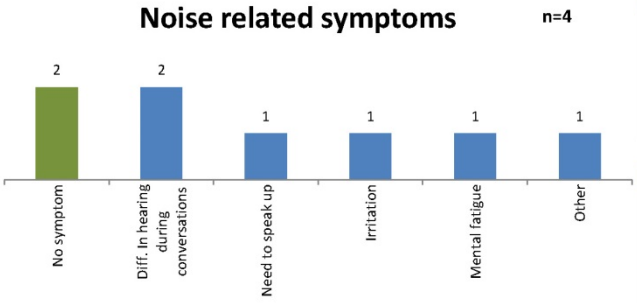
Physical area to perform tasks	
Very small	
Small	
Fair	4
Big	
Very big	

Floor	
It is non-slip	NO
It is uniform, without unevenness	YES
It is reflective	YES
There are liquids on the floor	NO
There are buckets, seats, other objects in passageways	YES
There are cables or tubes in passageways	YES
Objects on the floor are visible	SOMETIMES

Slip, trip, or fall risk	
No risk	
Little risk	3
Medium risk	1
High risk	

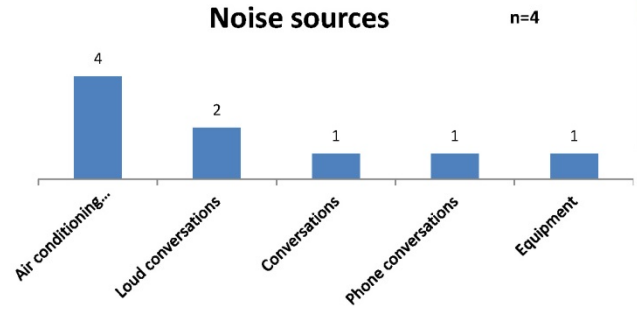
You have slipped, tripped of fallen	
No	1
Slip	2
Trip	1
Fall	

Noise n=4

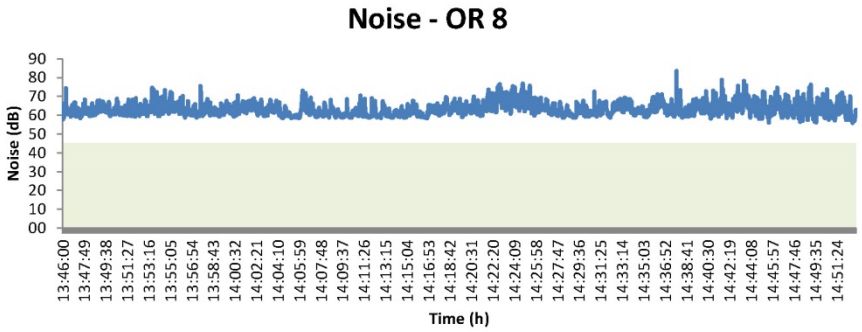


Noise bothers, disturbs, annoys during work	
Never	
Rarely	1
Sometimes	2
Often	
Always	1

Noise has a negative impact on your job	
Never	
Rarely	1
Sometimes	3
Often	
Always	



Noise level in the environment	
Very low	
Low	1
Fair	2
Loud	1
Very loud	



Noise (dB)	
Mean	64.7
SD	3.6
Max	83.5
Min	55.9
Max-Min	27.6

Place: Operating room 8 **Date: 26/04/2012** **Time: 13:43 - 14:32**

Lighting n=4

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	607

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks	
Never	1
Rarely	2
Sometimes	
Often	1
Always	

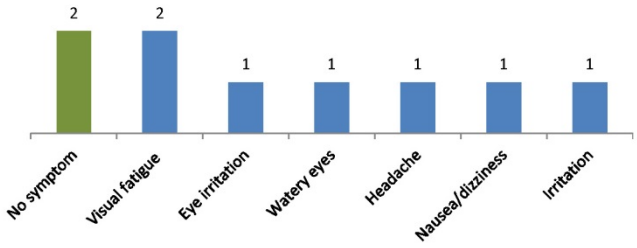
Glare occurs during tasks	
Never	1
Rarely	1
Sometimes	1
Often	
Always	1

Shadows are produced during tasks	
Never	1
Rarely	1
Sometimes	1
Often	
Always	1

You perceive the environment as	
Too dark	1
Dark	1
Fair	1
Bright	1
Too bright	

Lighting provides proper task conditions	
Never	
Rarely	
Sometimes	1
Often	
Always	3

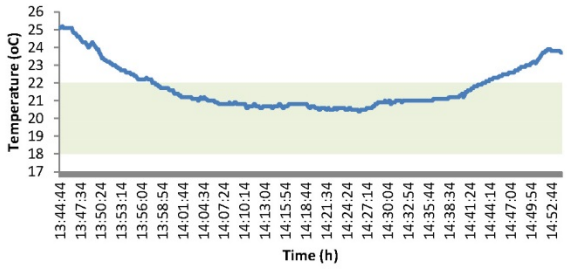
Lighting related symptoms n=4



Place: Operating room 8 **Date:** 26/04/2012 **Time:** 13:43 - 14:32

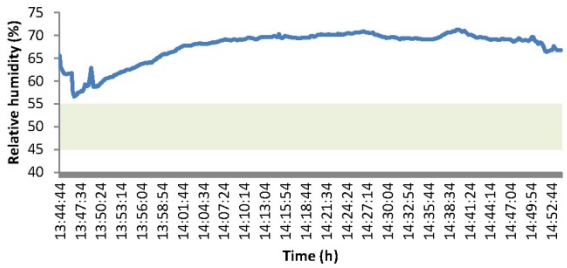
Environmental parameters n=4

Temperature - OR 8



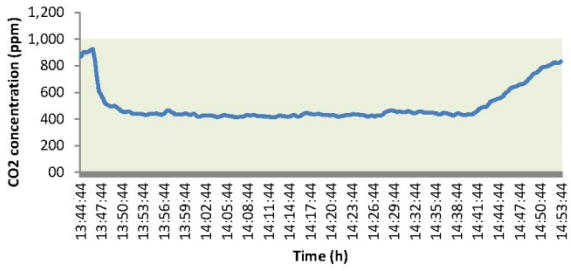
Temperature (°C)	
Mean	21.7
SD	1.2
Max	25.2
Min	20.4
Max-Min	4.8

Relative Humidity - OR 8



Rel. Humidity (%)	
Mean	67.6
SD	3.4
Max	71.3
Min	56.6
Max-Min	14.7

CO2 concentration - OR 8



CO_2 conc. (ppm)	
Mean	494.9
SD	125.1
Max	927.0
Min	413.0
Max-Min	514.0

Regarding temperature, you feel

Comfortable	
Slightly uncomfortable	2
Uncomfortable	1
Very uncomfortable	1

Temperature variations bother you

Never	1
Rarely	1
Sometimes	1
Often	
Always	1

Regarding humidity, this environment is

Dry	1
A little dry	1
Fair	2
A little humid	
Humid	

You are bothered by annoying drafts

Never	1
Rarely	2
Sometimes	
Often	
Always	1

The environment seems stuffy

Never	
Rarely	1
Sometimes	3
Often	
Always	

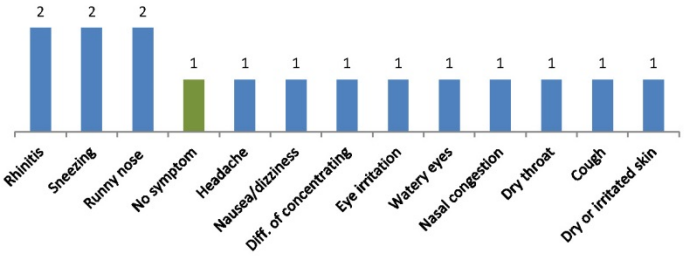
The environment presents unpleasant odors

Never	
Rarely	1
Sometimes	3
Often	
Always	

Air quality in the environment is

Very poor	
Poor	
Acceptable	4
Good	
Very good	

Environmental parameters related symptoms n=4



Place: Operating room 8 **Date:** 26/04/2012 **Time:** 13:43 - 14:32

Power outlets n=4

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never 1
Sometimes 2
Always 1
Not sure

Power plug adapters are used

Never
Sometimes 4
Always
Not sure

Power outlets positioning allows easy access

Never
Sometimes 3
Always 1
Not sure

Adapters are available when needed

Never
Sometimes 2
Always 2
Not sure

Power outlets allow tight connection to plugs

Never
Sometimes 2
Always 2
Not sure

The quality of the adapters is

Very poor
Poor
Acceptable 3
Good 1
Very good

Medical gas outlets n=4

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes
Always 4
Not sure

Medical gas outlets positioning allows easy access

Never
Sometimes 1
Always 3
Not sure

It is easy to identify the medical gas in the outlet

Never
Sometimes 1
Always 3
Not sure

Place: Operating room 10 **Date: 25/04/2012** **Time: 14:04 - 15:12**

Work area n=6

Dimensions	Min	Measured
Total area (m^2)	36.0	**34.32**
Length (m)	5.00	**6.60**
Width (m)	5.00	**5.20**
Height	2.70	**2.80**

Floor	
It is non-slip	**NO**
It is uniform, without unevenness	**YES**
It is reflective	**YES**
There are liquids on the floor	**NO**
There are buckets, seats, other objects in passageways	**YES**
There are cables or tubes in passageways	**YES**
Objects on the floor are visible	**SOMETIMES**

Physical area to perform tasks

Very small	
Small	1
Fair	5
Big	
Very big	

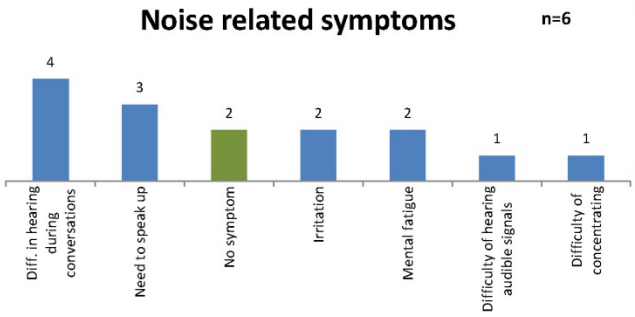
Slip, trip, or fall risk

No risk	
Little risk	4
Medium risk	2
High risk	

You have slipped, tripped of fallen

No	5
Slip	
Trip	1
Fall	

Noise n=6

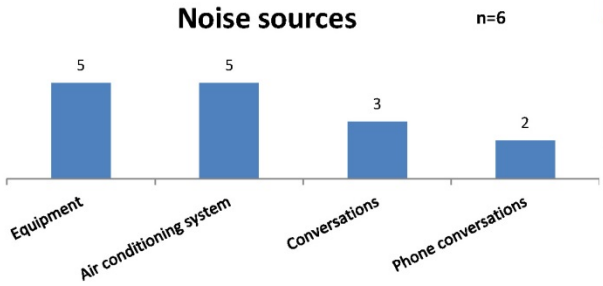


Noise bothers, disturbs, annoys during work

Never	
Rarely	1
Sometimes	4
Often	1
Always	

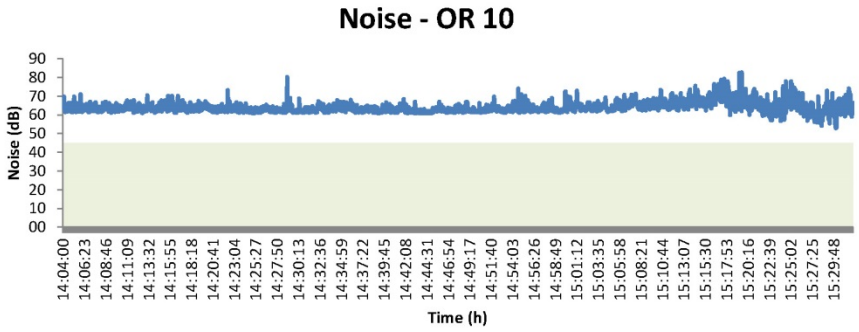
Noise has a negative impact on your job

Never	1
Rarely	2
Sometimes	2
Often	1
Always	



Noise level in the environment

Very low	
Low	1
Fair	1
Loud	4
Very loud	



Noise (dB)	
Mean	65.2
SD	2.1
Max	82.7
Min	52.9
Max-Min	29.8

Place: Operating room 10 **Date: 25/04/2012** **Time: 14:04 - 15:12**

Lighting n=6

Illuminance (lux)	Min	Max	Measured
General illuminance	300	750	715

Parameters related to lighting	
There is lamp flicker	NO
There is natural illumination	NO

Reflex occurs during tasks	
Never	1
Rarely	2
Sometimes	3
Often	
Always	

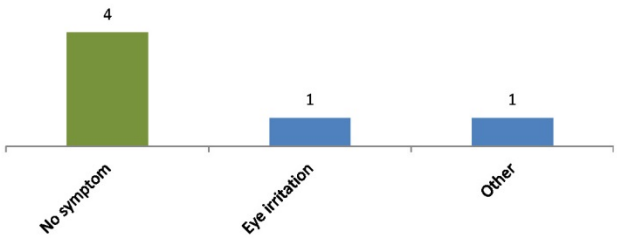
Glare occurs during tasks	
Never	1
Rarely	4
Sometimes	1
Often	
Always	

Shadows are produced during tasks	
Never	1
Rarely	3
Sometimes	1
Often	1
Always	

You perceive the environment as	
Too dark	
Dark	
Fair	4
Bright	2
Too bright	

Lighting provides proper task conditions	
Never	
Rarely	
Sometimes	
Often	3
Always	3

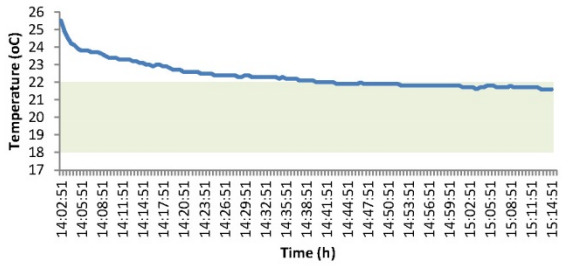
Lighting related symptoms n=6



Place: Operating room 10 **Date:** 25/04/2012 **Time:** 14:04 - 15:12

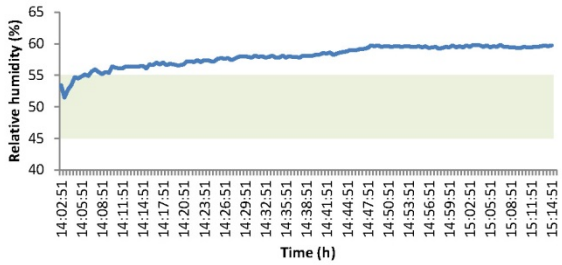
Environmental parameters n=6

Temperature - OR 10



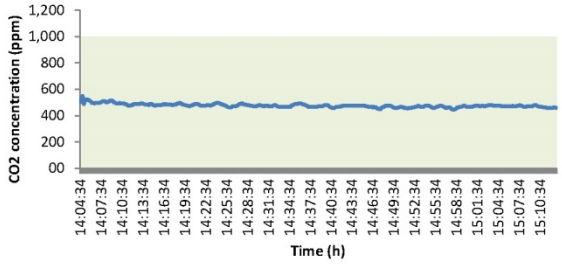
Temperature (°C)	
Mean	22.4
SD	0.7
Max	25.5
Min	21.6
Max-Min	3.9

Relative Humidity - OR 10



Rel. Humidity (%)	
Mean	58.0
SD	1.7
Max	59.8
Min	51.5
Max-Min	8.3

CO2 concentration - OR 10



CO_2 conc. (ppm)	
Mean	488.0
SD	40.3
Max	688.0
Min	446.0
Max-Min	242.0

Regarding temperature, you feel

Comfortable	1
Slightly uncomfortable	2
Uncomfortable	3
Very uncomfortable	

Temperature variations bother you

Never	
Rarely	
Sometimes	3
Often	3
Always	

Regarding humidity, this environment is

Dry	
A little dry	1
Fair	5
A little humid	
Humid	

You are bothered by annoying drafts

Never	1
Rarely	2
Sometimes	2
Often	
Always	

The environment seems stuffy

Never	1
Rarely	1
Sometimes	3
Often	1
Always	

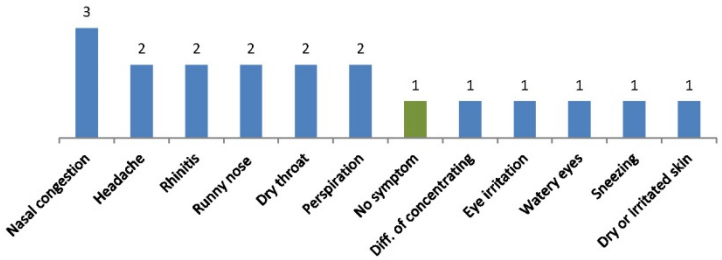
The environment presents unpleasant odors

Never	1
Rarely	2
Sometimes	3
Often	
Always	

Air quality in the environment is

Very poor	
Poor	
Acceptable	4
Good	1
Very good	

Environmental parameters related symptoms n=6



Place: Operating room 10 **Date:** 25/04/2012 **Time:** 14:04 - 15:12

Power outlets n=6

Number and height of power outlets	Min	Measured
Number of power outlets (total)	8	18
Sets with 4 power outlets each	2	3
Number of X-Ray power outlets	1	3
Number of 127 V power outlets		0
Number of 220 V power outlets		18
Power outlets height (m)		1.50

Parameters related to power outlets	
All 220 V power outlets are identified	NO
All X-Ray power outlets are identified	NO
It is possible to plug a 127 V device in an 220 V power outlet	YES
It is possible to plug a 220 V device in an 127 V power outlet	YES

Power plug adapters	
Power plug adapters were used during analysis period	NO
Power cord extensions were used during analysis period	NO

Number of power outlets is sufficient

Never
Sometimes 3
Always 2
Not sure 1

Power plug adapters are used

Never 1
Sometimes 3
Always
Not sure 2

Power outlets positioning allows easy access

Never
Sometimes 3
Always 2
Not sure 1

Adapters are available when needed

Never
Sometimes 2
Always 1
Not sure 1

Power outlets allow tight connection to plugs

Never
Sometimes 2
Always 3
Not sure 1

The quality of the adapters is

Very poor
Poor 1
Acceptable 2
Good
Very good

Medical gas outlets n=6

Medical gas outlets	Min	Measured
Number of Oxygen outlets	2	3
Number of Nitrous Oxide outlets	1	3
Number of Vacuum outlets	1	3
Number of Medical air outlets	2	3
Medical gas outlets height (m)		1.50
Oxygen outlet identified with the gas name		YES
Nitrous Oxide outlet identified with the gas name		YES
Vacuum outlet identified with the gas name		YES
Medical air outlet identified with the gas name		YES

Number of medical gas outlets is sufficient

Never
Sometimes 1
Always 3
Not sure 2

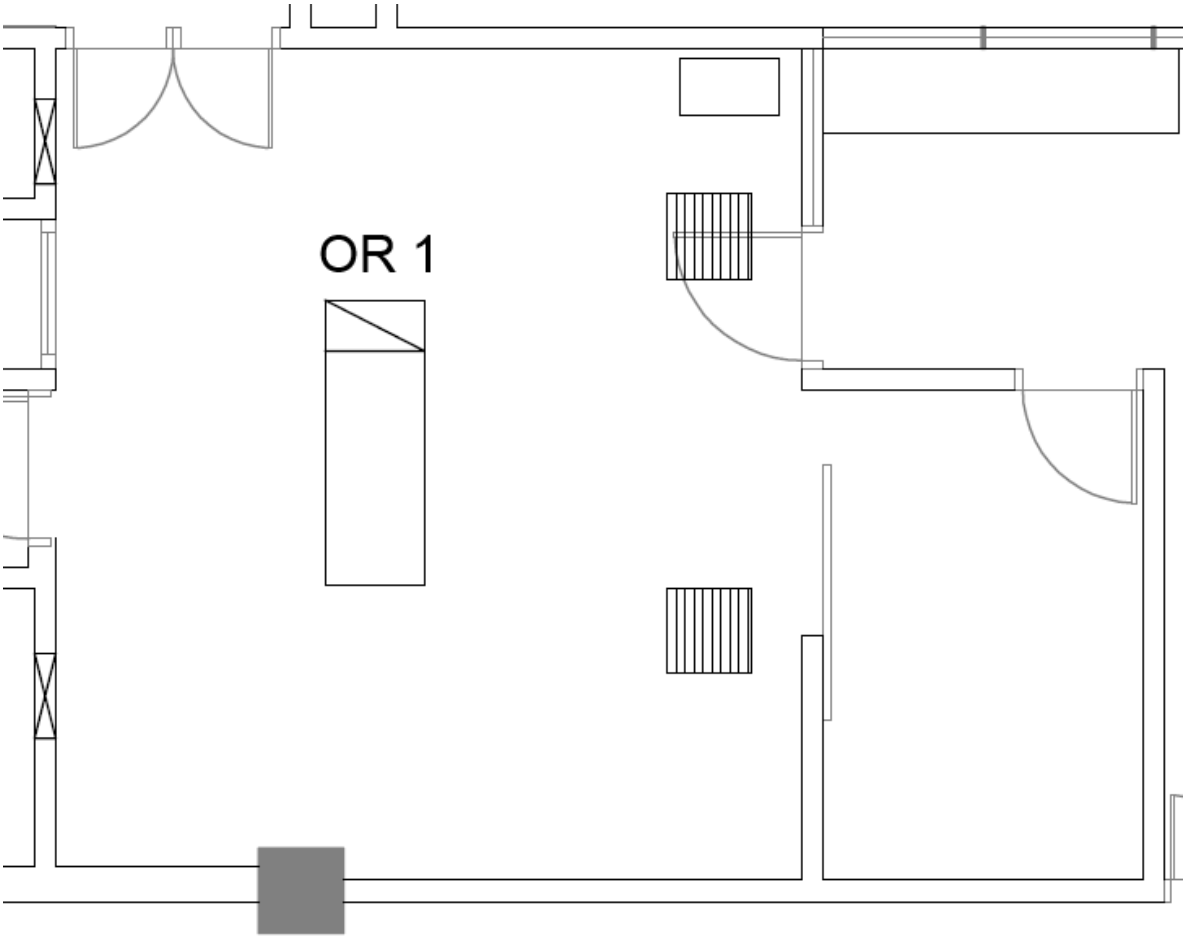
Medical gas outlets positioning allows easy access

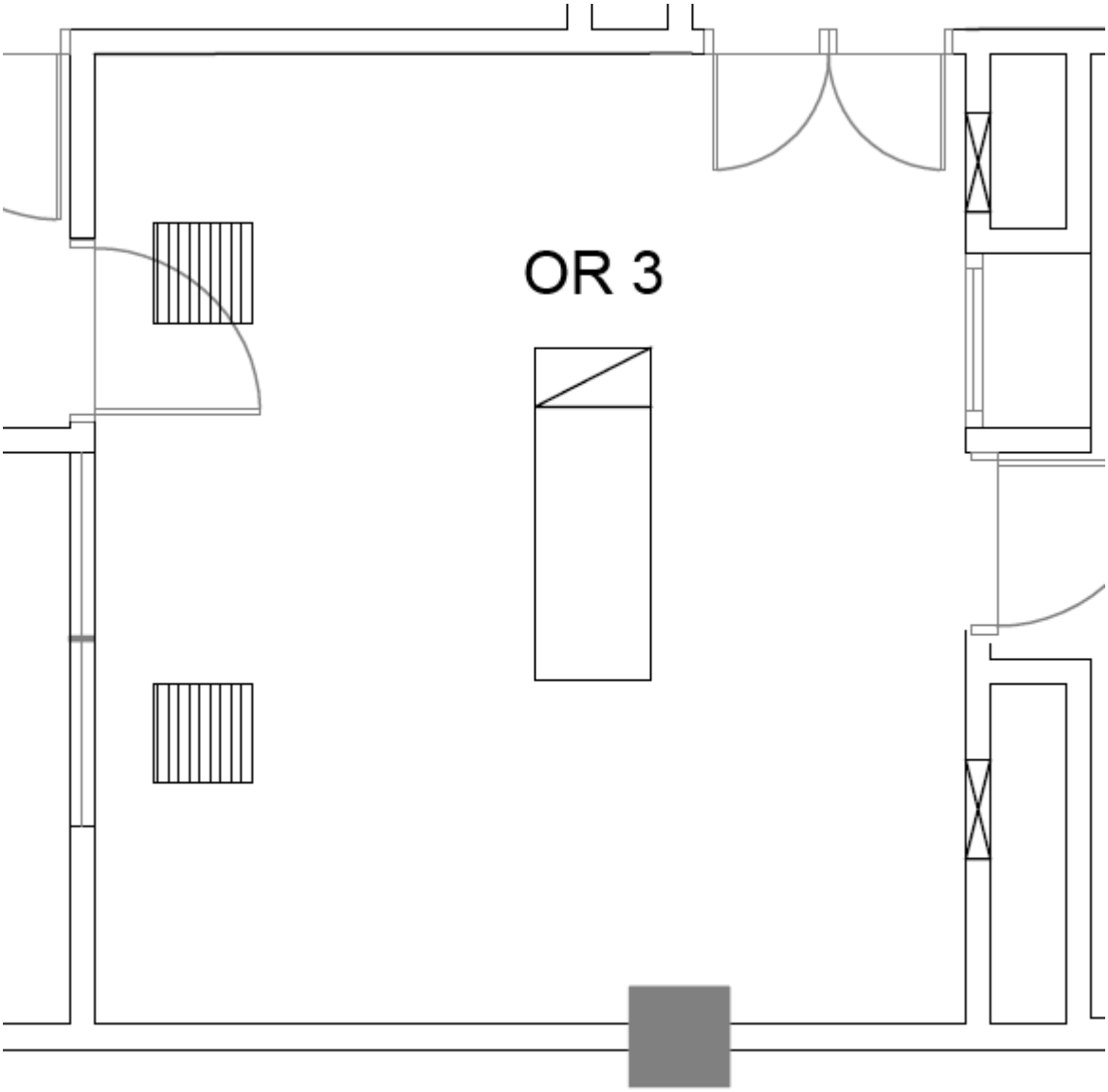
Never
Sometimes 1
Always 3
Not sure 2

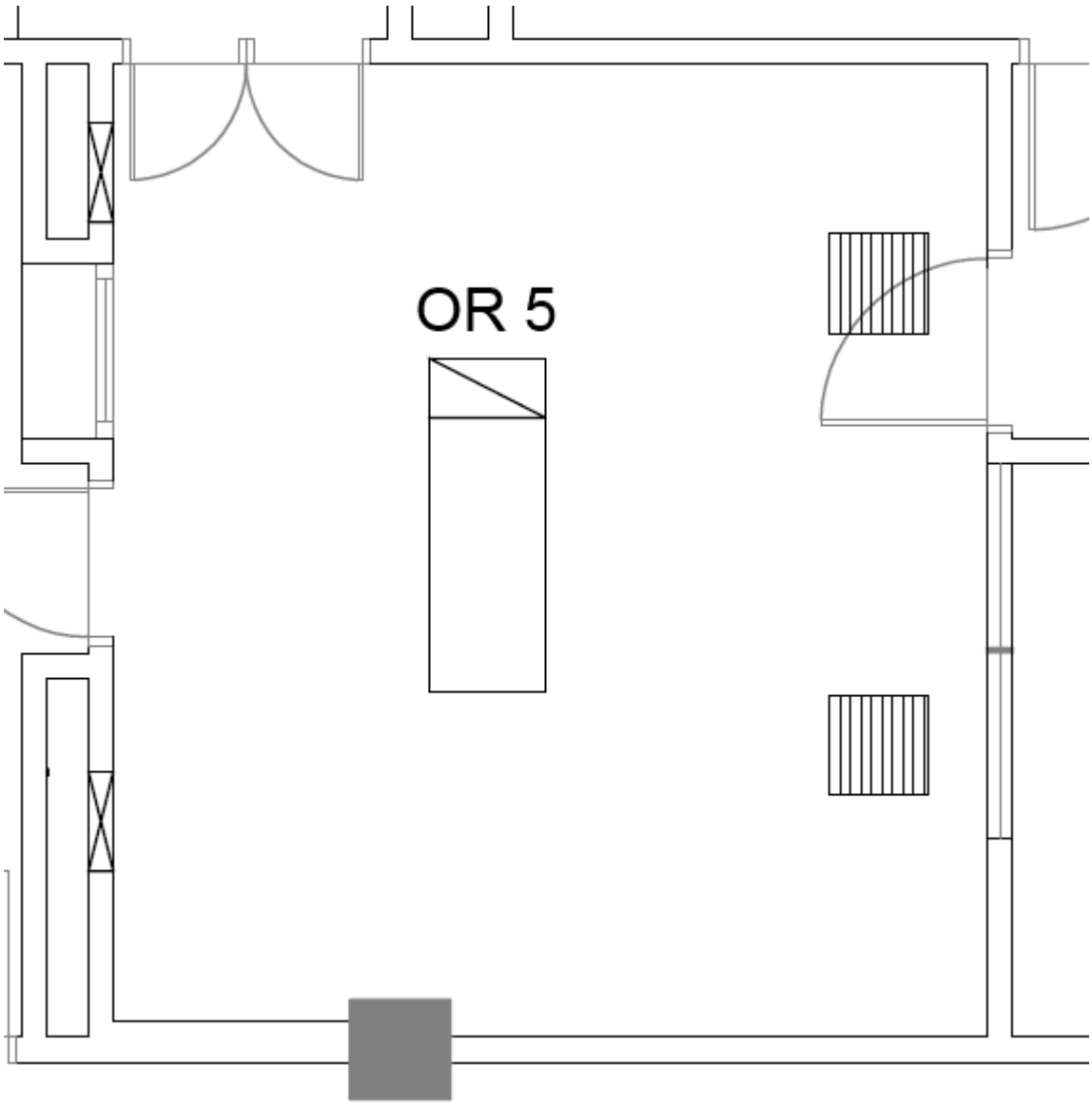
It is easy to identify the medical gas in the outlet

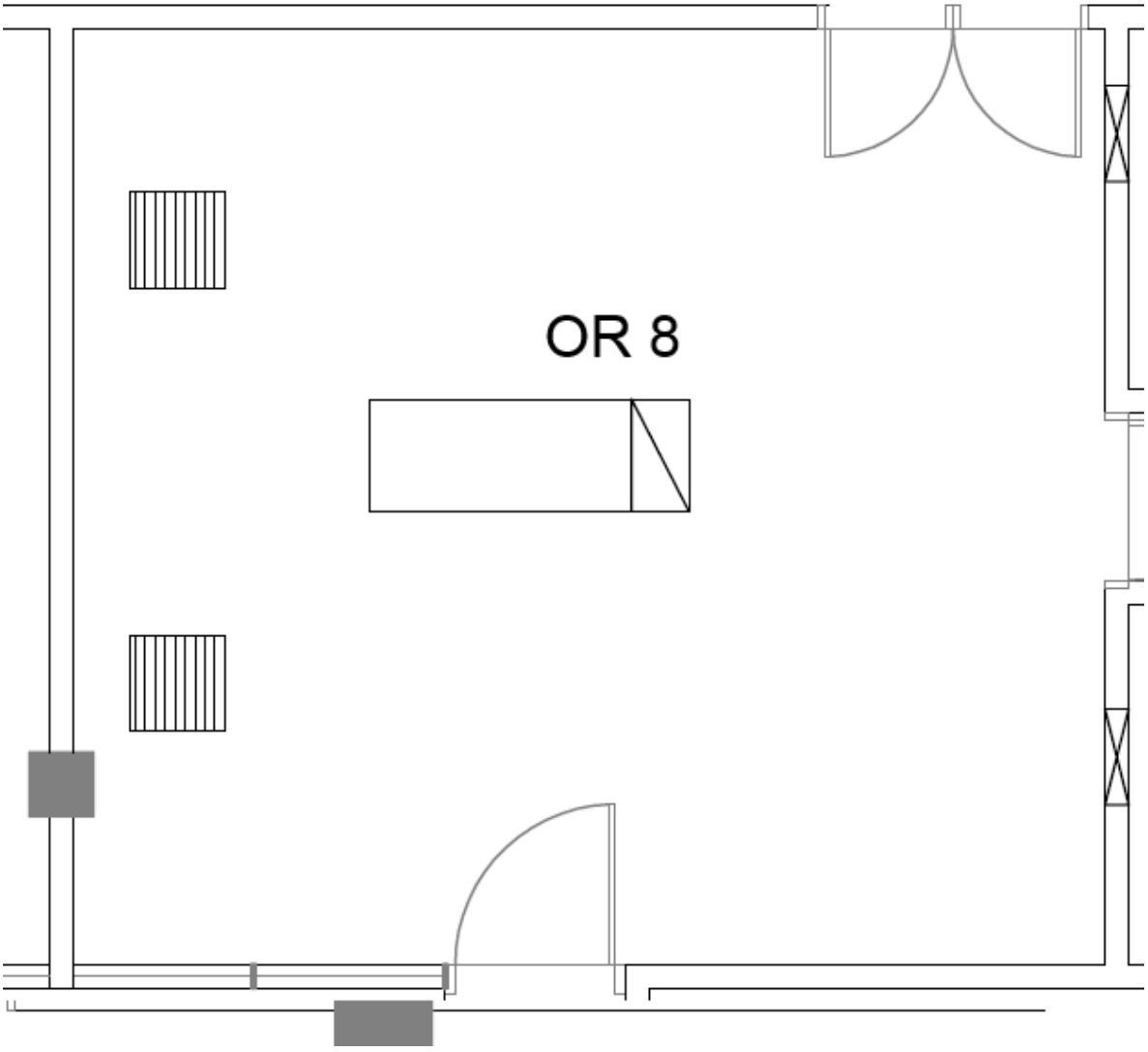
Never
Sometimes
Always 4
Not sure 2

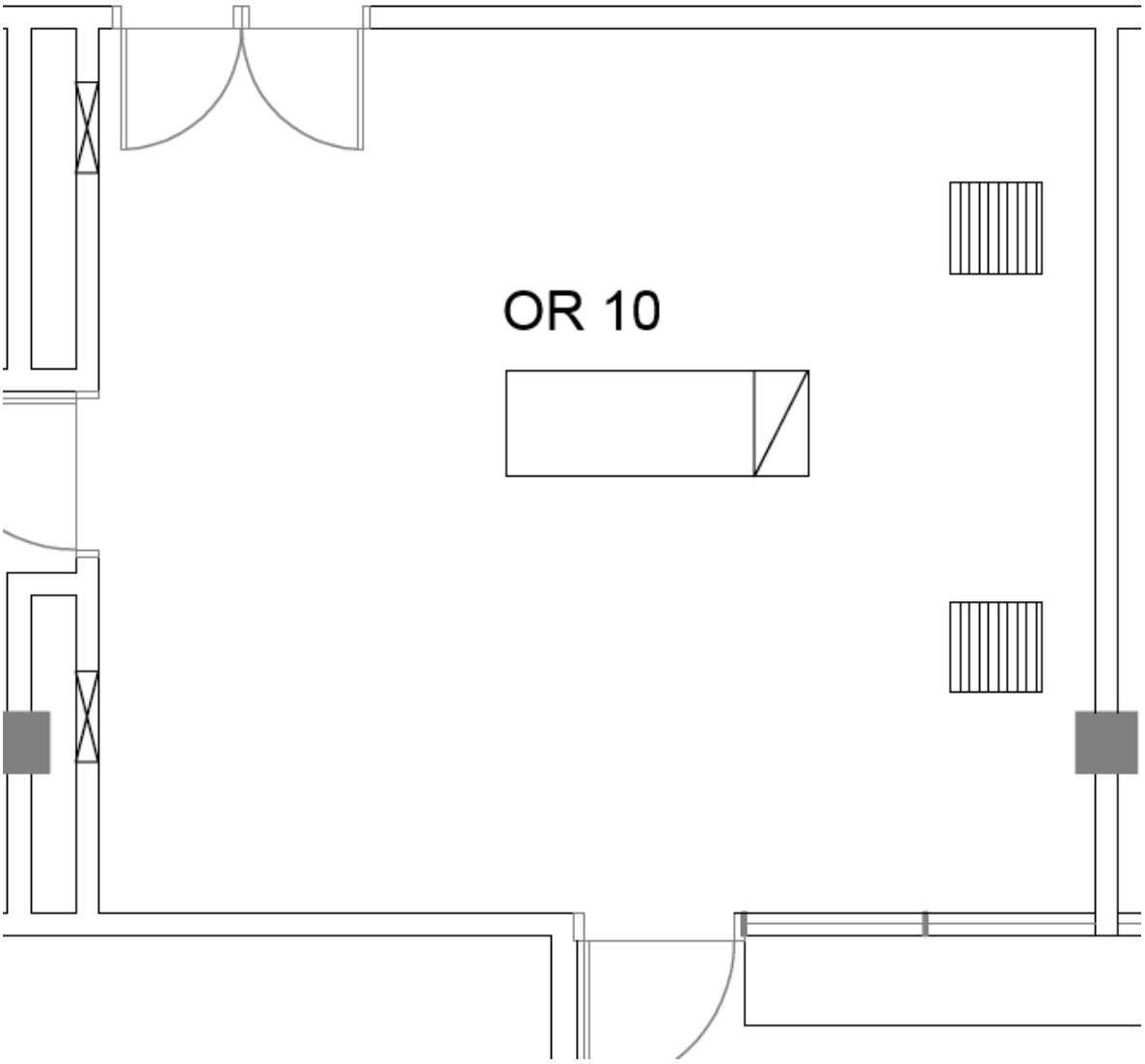
Appendix 7 – OR blueprints




OR 3


OR 5


OR 8


OR 10