# REDUCING HOSPITAL-ACQUIRED INFECTIONS WITH THE USE OF ARCHITECTURAL MEASURES

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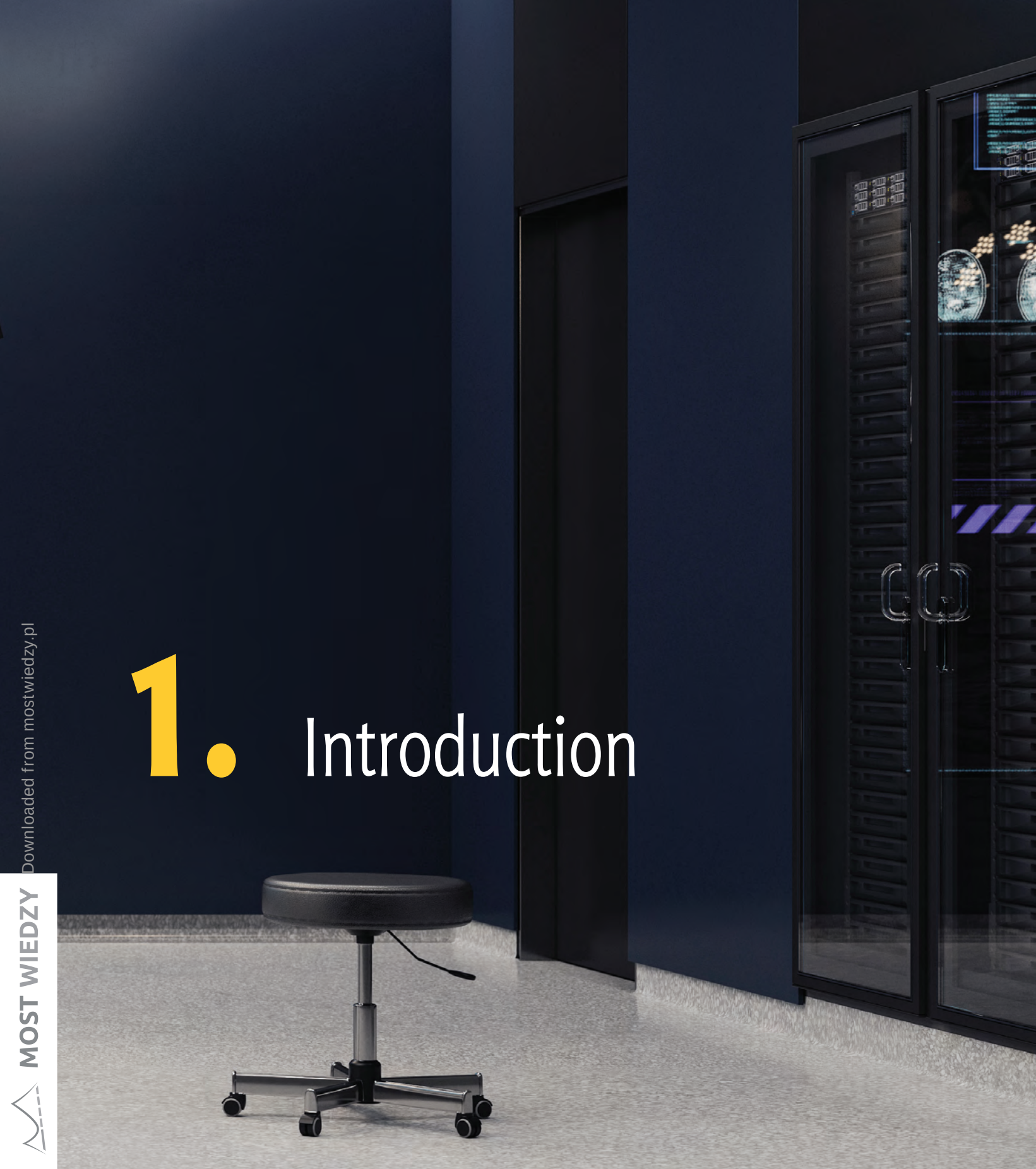
# Contents

# Foreword

As a healthcare facility, a hospital must meet very high hygienic requirements and offer safe environment to its patients, personnel and visitors. Despite numerous safety measures, hospital-acquired infections still come as a serious problem in the operation of medical facilities. Nosocomial infection prevention poses a challenge to – among other groups – hospital technical maintenance staff.

In Poland, the current guidelines in the field of designing medical facilities often seem to be insufficient. Developing an efficient strategy for the prevention of hospital-acquired infections, particularly in the context of continuously changing medical technologies and hazards, requires individual technical solutions adjusted to the possibilities and needs of a particular hospital. In his monograph, Rafał Janowicz decides to face the challenge of evaluating the current constructional structures, with the consideration of conditions resulting from the prevention of hospital-acquired infections and attempts to assess them based on scientific research. Considering the limited funds that can be used by technical maintenance services of public hospitals in Poland, publications that foster undertaking technically rational and economic activities are highly recommendable and needed. Therefore, I would like to recommend this monograph, as an important voice in the field of policy pertaining to the design of spatial solutions applied in medical areas.

Mirosław Klause
Technical Director
of the F. Ceynowa Specialist Hospital
in Wejherowo in the years 1990-2018



# 1. Introduction

## 1.1 Introduction to the discussion of the problem

Healthcare facilities are architectural objects designed under the strong influence of sanitary and hygienic requirements and guidelines of medical technology. During the process of planning future healthcare facilities and modernising already existing units, the need to provide safety to all their users comes as a significant aspect. In medical objects, it depends on the standard factors observed in public utility buildings. Furthermore, it also constitutes a highly complex system of interdependencies resulting from an increased epidemiological hazard in their areas.

*Primum non nocere* (in Latin: *First, do no harm*) is a particular ethical principle that has been in force in medicine for centuries. It refers to the diligence in providing diagnostics and medical treatment that would not worsen the patient's health condition. Unfortunately, considering the context of contemporary collective medical treatment provided at hospitals, this principle turns out to be very difficult to follow. The mass character of healthcare services makes hospital environment hazardous to the health of patients and medical personnel.

Hospital-acquired infections (HAIs) are frequent occurrences observed in healthcare facilities. They are defined as infections acquired during the patient's stay at hospital or during the treatment provided at medical facilities, first of all, at hospitals. It refers to the cases *when a disease*:

a) *was not present or incubating at the moment of providing medical treatment or*
b) *appeared after medical treatment within the time period not longer than its longest incubation time* (Journal of Laws 2008 no. 234, item 1570 with later amendments).

The infection process involves an entire chain of events related to a transmission route of microorganisms from the place where they exist and reproduce to a person susceptible to an infection. During the identification of an infection, it is significant to confirm that the infection was present in the patient's organism before the admission to the hospital or that the disease was not in its incubation stage. Its occurrence and course should be clinically and laboratory confirmed. The advancement in the scientific research in the discussed field has resulted in the fact that hospital-acquired infections undergo analysis also in the context of medical facilities other than hospitals, such as nursing homes for the elderly or for the disabled and outpatient clinics. Medical personnel members are also considered as persons exposed to nosocomial infections. Hospital-acquired infections involve high expenses and they pose a direct threat to medical personnel. HAIs can lead to serious complications or even to death related to providing healthcare services that can be caused by various microorganisms, particularly by multidrug-resistant bacteria (Łyczyńska and Stawiński 2003; Lange et al. 2012; Sadkowska et al. 2016; Unahalekhaka 2016; Bocicor et al. 2017; Sunder et al. 2018).

Hospital-acquired infections are a worldwide problem, regardless of geographical, political, social and economic factors. Focused on the impact of hospital environment on its users, the scientific research studies indicate that HAIs, along with medical errors, account for a high percentage of mortality in patients, even in the countries with advanced healthcare systems. The Centre for Disease Control and Prevention (CDC), the United States federal agency informed that in 2011 over 720 000 cases of hospital-acquired infections were reported. It was also estimated that they caused 75 000 deaths (Ethington et al. 2018). Epidemiological control and prevention activities implemented in the meantime contributed to the improvement of the situation. The research studies carried out in this field in 2015

indicated that patients acquired at least 16% less HAIs in comparison to the data collected during the research studies in 2011. Nevertheless, the occurrence of HAIs continues to be one of the major civilisational hazards (Centers for Disease Control and Prevention 2018).

While analysing the discussed problem, it is possible to observe that the level and the structure of hospital-acquired infections differs, depending on the particular countries. The differences become visible in a comparative review of prevention systems intended to counteract HAIs. It is known that the levels of the occurrence of healthcare-associated infections depend on various factors, such as the types and the sizes of hospitals, the quality of healthcare services, methodological differences in interpreting the definition of healthcare-associated infections, differences in the availability of diagnostic tests, differences in the levels of training and skills of healthcare personnel, differences in reporting in various hospitals and countries (European Centre for Disease Prevention and Control 2013). The contemporary scientific research studies indicate that the occurrence of hospital-acquired infections in the USA, Canada, Great Britain and Mediterranean countries has reached a relatively high level, whereas in Scandinavian countries and in the Netherlands their levels have been much lower (Hamilton 2013).

Provided on an on-going basis, the analysis indicates that statistically 7 out of 100 patients in developed countries and 10 out of 100 patients in developing countries treated at hospitals acquire healthcare-associated infections. It should be emphasized that one patient can develop several clinical forms of HAIs and their occurrence will generate unnecessary costs, human suffering, serious health conditions and even deaths (Ochocka 2017: 7). In 2008, the European Centre for Disease Prevention and Control estimated that the annual incidence refers to 4 131 000 patients in Europe and results in 37 000 deaths. The annual financial loss related to medical treatment and longer stays at hospitals (up to 16 000 000 additional hospitalisation days) was estimated at an approximate level of EUR 7 billion (Unahalekhaka 2016).

Carried out recently in Poland, the scientific research on the extent of healthcare-associated infections indicates that almost 6-7% patients out of 8 000 000 persons provided with hospital treatment have acquired nosocomial infections. Even with the consideration of an overestimation of the results obtained in random testing in relation to the incidence, it allows us to assume that about 5% of patients treated at Polish hospitals acquire nosocomial infections. As a result, the annual number of hospital-acquired infections is 400 000 approximately (Bulanda et al. 2016).

Infections acquired at healthcare facilities come as broad and multi-aspect problems that constitute a very important issue in modern epidemiology (Zieliński 2009). Carried out at the turn of the 20th and 21st centuries, the scientific research studies indicate that despite systematic implementation of prevention programmes, the level of hospital-acquired infections keeps growing around the world (Scott 2004). Some of the first comprehensive research studies on the reasons for the increase in the rate of hospital-acquired infections at American hospitals indicate four main factors, namely:

- too infrequent and too inadequate procedures of hand washing by medical personnel who are in direct contact with patients;
- a higher rate of hospital admission of patients with weakened immunity;
- intensive use of antimicrobial agents at hospitals and long-term nursing centres in the recent decades; as a result, a wide scope of drug-resistant microorganisms have been developed;
- renovation and reconstruction of constructional and technical hospital infrastructure, posing the risk of various diseases (Weinstein 1998).

## 1. Introduction

Undoubtedly, the discovery of antibiotics in the 20th century definitely changed modern medicine. After the Second World War, it was assumed that penicillin was a wonderful cure that could overcome any infection (Hamilton 2013). The introduction of antibiotics briefly raised the hope for solving the problem of hospital-acquired infections. However, the new weapon in the fight against infections soon resulted in the development of new penicillin-resistant Staphylococcus strains (Zieliński 2009: 14). In the 1970s and the 1980s the increase in application of antibiotics and antimicrobial agents in hospitals and in long-term nursing centres resulted in the development of numerous reservoirs of various drug-resistant strains of microorganisms (Weinstein 1998). At present, the problem has become even more serious – new bacteria strains have developed antibiotic-resistance (Capriotti 2003). For instance, the methicillin-resistant *Staphylococcus aureus* – MRSA, which keeps spreading in hospitals and other healthcare facilities despite numerous restrictions and guidelines that have been implemented there (Madeo 2001; van Rijen and Kluytmans 2009; van Knippenberg-Gordebeke 2010; Hamilton 2013).

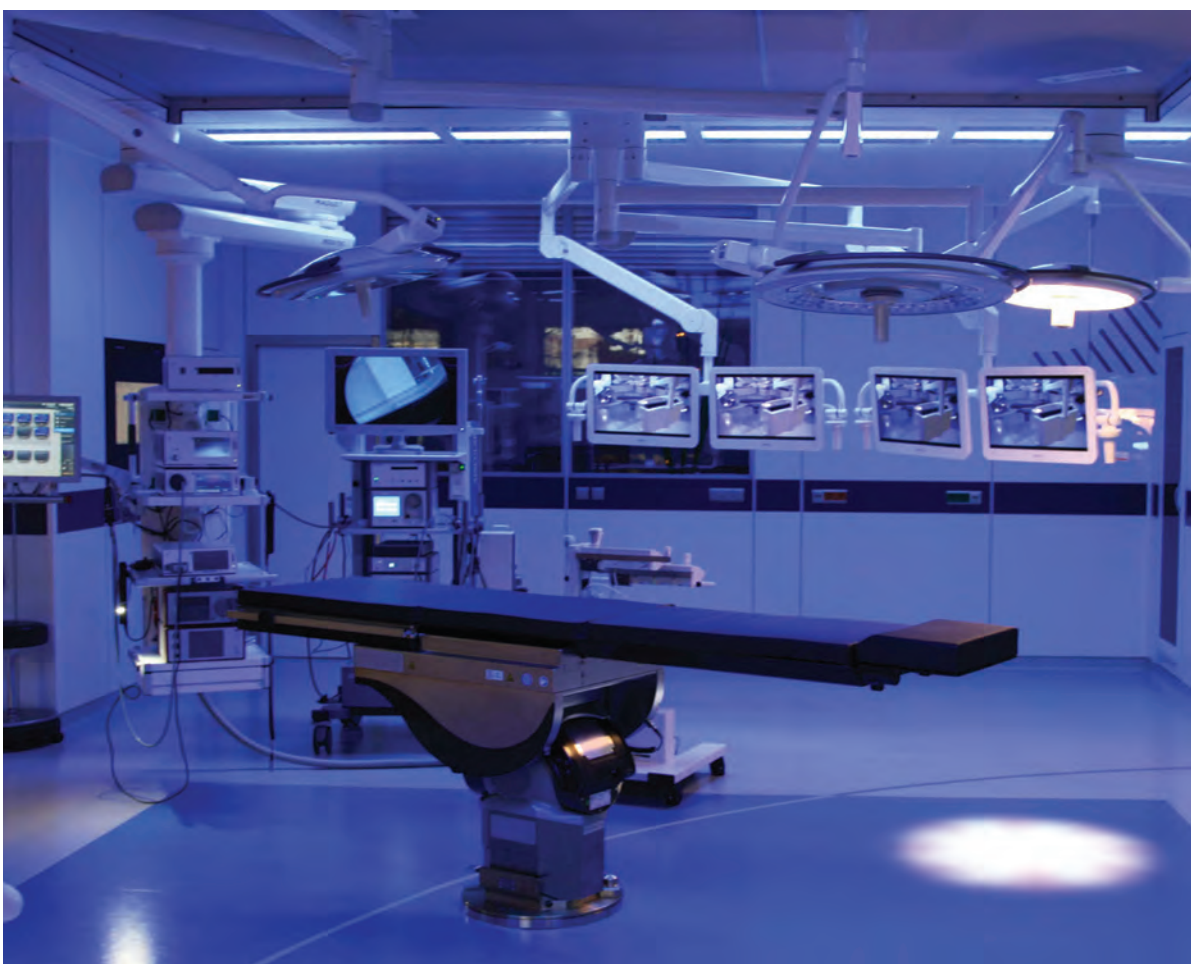
It has been more and more often observed that patients should be protected against hospital-acquired infections regardless of their concurrent diseases. Therefore, considering the aspect of epidemiological safety, the procedures related to the minimisation of infection risk, including the antibiotics policy and organisational and technical conditions, along with architectural solutions, become the most important issues. The dynamic development of medical sciences has resulted in the fact that a lot of medical facilities require modernisation. Their spatial layouts are constantly reconstructed and adjusted to the current recommendations and their architecture is under permanent transformation. As public utility buildings, contemporary hospitals are often compared to town-buildings, where the space characterised with various accessibility levels is created. Their architecture is oriented toward medical functions related to treatment processes, supplemented with some additional elements. The process of designing such facilities has been approached from a wider perspective and now it includes issues resulting from technical advancement, scientific research and attempts made at considering various human needs in a comprehensive way. Apart from medical functions, social needs of patients who stay at healthcare facilities have become more and more important. At present, healthcare facilities are *simultaneously intended to form the spatial framework for the microcosm of social interactions among patients, medical personnel, visitors and inhabitants* (Awtuch 2015: 77). Hence, a necessity arises to search for a balance between architectural solutions confirmed by scientific research and affected by the idea of a hospital that is an open, accessible, public place and the control aimed at reducing the spread of infections and infectious diseases. At present, experts in infection prevention and control (IPC) indicate healthcare-associated infections as a significant problem related to the safety of patients. They also point out that hospital-acquired infections can be often prevented (Soule 2016).

The statistics on hospital-acquired infections in Poland suggest that it would be advisable to look for optimal forms of minimising the risk of infections, including those involving drug-resistant microorganisms. The current system is oriented toward the prevention of spreading highly infectious and drug-resistant pathogens. The elements that are significant to the surveillance system monitoring healthcare-associated infections in Poland include audits, internal inspections, education of medical personnel and activities affecting personnel's behaviour, planning teamwork and evaluation of the results that have been achieved (Bulanda et al. 2016). Nevertheless, the present concepts referring to hygiene seem to underestimate a significant aspect in the process of preventing infections, namely: the architecture of hospital facilities. The proper architectural organisation of a medical facility, its

design process and its implementation come as a way to minimise the possibility of epidemiological risk occurrence. Properly designed and implemented, a functional and spatial layout supported with advanced systems of technical installations, such as mechanical ventilation, tele-technical systems and efficient decontamination, can ensure effective functioning and sanitary and hygienic conditions that will be safe for all users.

The specific character of medical facilities results in a need for scientific research on their structure, particularly in Poland. The insufficient amount of literature on the discussed question indicates the necessity of its updating. A lot of scientific research teams working on epidemiological issues confirm the potential role of architectural factors in preventing hospital-acquired infections and the need for an in-depth analysis of the significance of the purpose-based design of physical environment in relation to safety (Ulrich 2006; Bracco et al. 2007; Hamilton 2013).

On the commencement of this monograph, it has been assumed that today architecture may come as one of the epidemiological safety pillars, providing a rational response to threats resulting from a high level of hospital-acquired infections and development of drug-resistance in microorganisms.



**Photograph 1.0** An operating theatre, photographed by the Author 2018

## 1.2 The field of the research

Epidemiological risks occurring in the physical space of human life constitute a field of scientific research that has been carried out by specialists working in various scientific disciplines. Its interdisciplinary character results from the scale of hazards and also from a very broad research context. In accordance with the classification system of the scientific disciplines suggested by the Organisation for Economic Cooperation and Development (OECD 2007), the scientific problems related to the discussed question can pertain to numerous fields of science, namely:

- in the field of natural sciences, they pertain to biological sciences and research on virology, mycology, microbiology; they also pertain to chemical sciences where scientific research studies are carried out on chemical compounds that are effective disinfectants;
- in the field of medical sciences and health sciences, they pertain to problems related to infections, infectious diseases and epidemiology;
- in the field of social sciences, they pertain to law, pedagogy, economy and management, in relation to scientific research studies carried out on the organisation of processes in the field of epidemiological safety management;
- in the field of engineering and technical sciences, they pertain to materials engineering, medical engineering and medical laboratory technology. The knowledge on automation and control systems is also used for preventing infections;
- in the field of humanities, they pertain to architectural design as the science related to the design of space where epidemiological hazards occur.

Such a wide interdisciplinary scope of the research problem results in the fact that the architectural design of the healthcare space, as an element of a system intended to provide sanitary and hygienic safety, becomes a difficult task that requires cooperation of specialists in various fields. Architecture responds to a natural human need of living in a safe environment (of an acceptable level of risk) through the creation of spatial layouts that foster the implementation of safety procedures and the limitation of hazards resulting both from the regular use of space and from unexpected events. Constantly changing reality and a growing level of knowledge about epidemic threats make architectural design become not only a multi-aspect question but also a problem that keeps evolving in the search of optimal solutions. The changeable character of hazards generates a need for providing continuous analysis and validation of spatial solutions. The discussed problem is also characterised by a wide scope because safety must be provided to all the users of the space – in the case of a hospital, it will include medical personnel, patients and also visitors.

Architecture of healthcare facilities is an applied discipline that is developed through the synergy of science and practice. This is because the principles and theoretical recommendations worked out within this discipline have been applied in medical facilities that have been already constructed. Hence, the solutions and practical research studies become the sources of basic information fuelling theoretical considerations. Understanding the relations and problems related to the development of such solutions becomes a task that requires constant scientific research. It refers to the analysis of the impact exerted by an architectural design project on the variety and structure of the entire set of microorganisms that exist within the constructed environment. It also indicates that buildings are complex ecosystems,

where billions of microorganisms cooperate among themselves, with people and with the environment. Understanding ecological and evolutional processes that determine the variety and composition of the microbiome of the constructed environment – the community of microorganisms living in the space – is important for understanding the relation between architectural design, biological variety and human health (Kembel et al. 2012: 1469).

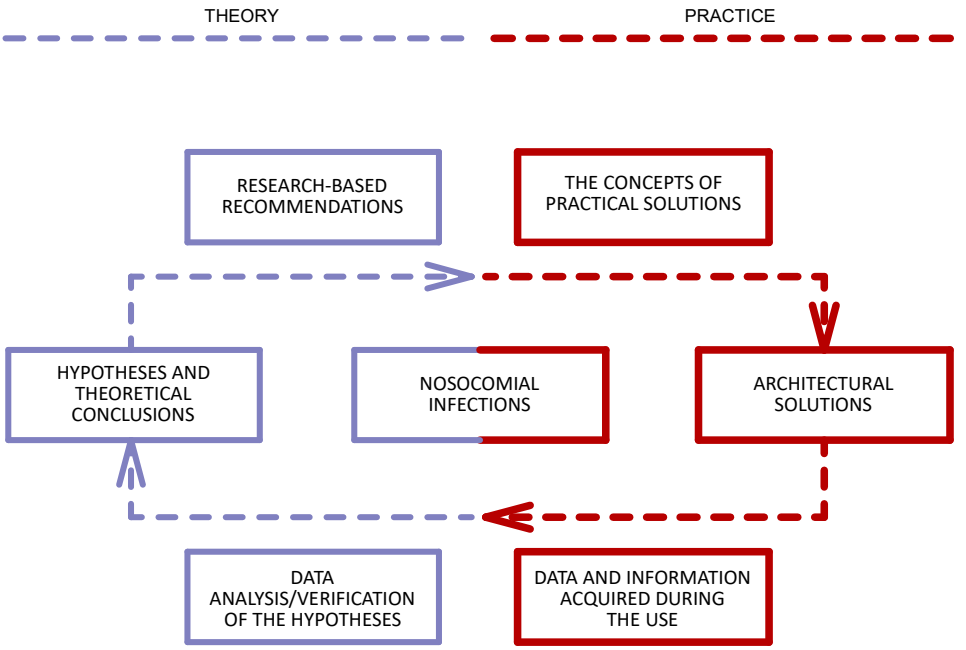



**Figure 1.2.0** A model presenting the relations between theoretical research and practical implementation in the design of architectural solutions dedicated to HAI prevention; elaborated by the Author.

Planned with the consideration of a functional spatial layout, quality of air, lighting and internal design elements, a well-designed environment of medical facilities directly affects its users, minimising the level of hospital-acquired infections and medical error occurrence that can result from non-ergonomic design of the working environment (Anjali and Rashid 2007). The contamination of the indoor air with microbiological contaminants has already been more and more often recognised as a public health problem and it can be responsible for building-related illnesses (BRI). Furthermore, it can also directly contribute to a phenomenon referred to as the sick-building syndrome (SBS). Bio-aerosols, biological factors, such as fungi, bacteria and viruses in the indoor air may trigger allergic responses, cause infections and infectious diseases. Individuals susceptible to external environmental problems complain of a variety of symptoms, such as headaches, fatigue, nausea and irritation of eye conjunctivae (Green and Scarpino 2001). The notion of a building-related illness refers to those adverse health effects, for which there is a clearly determined relation between environmental factors in a particular building and the resulting health disorders. This disease category often refers to the skin and the respiratory tract, considering the ease with which environmental contaminants interact with those tissues.

Factors related to construction work affect human health and they can cause diseases. This occurs through one of the four mechanisms: immunological, infectious, toxic or irritating (Seltzer 1994: 351). Numerous contemporary research studies on hospital-acquired infections have confirmed the relation between an increased epidemiological risk and construction work carried out at medical facilities because of their renovation or reconstruction. Considering most people in good health condition, their environmental exposure to pathogens does not result in the development of diseases, however, individuals with lower immunity are often vulnerable to bacteria, fungi and viruses. This phenomenon has become so significant that scientists have started to refer to the process of releasing adverse microorganisms during construction work carried out in functioning healthcare facilities as to *Pandora's Box* (Clair and Colatrella 2013).

The monograph presents an attempt made at the analysis of architectural solutions considered in the context of designing sanitary and hygienic barriers that contribute to sanitary and hygienic safety. The priority scope of the research study is architecture, however, because of the interdisciplinary character of the problems related to sanitary and hygienic hazards, the research analysis also refers, to a limited extent, to ergonomics, medical technologies and epidemiology.

## 1.3 The aim and scope of the monograph and its research theses

The aim of the monograph is to demonstrate the potential of architectural solutions in reducing the transmission of hospital-acquired infections. The deficiency in specific guidelines in the process of programming and designing architectural objects in Poland results in the deficiencies observed in the system of epidemiological safety. The implementation of medical facilities without any adequate consideration of questions related to the control over epidemiological hazards in architectural design projects is translated into the lower quality of the discussed space and considerable deficiencies in its users' safety.

The monograph is also aimed at confirming the hypothesis stating that architectural solutions come as tools to decrease the level of nosocomial infections and that properly developed design solutions positively affect epidemiological safety. Hence, the costs of treating infections occurring in hospitalised patients are reduced, along with the expenses for the on-going prevention in the field of sanitisation and disinfection.

Considered as an element of a cohesive strategy for reducing epidemiological hazards and developing health safety, the question of the optimal design of the medical facility environment has been rarely discussed in Poland. In this context, an attempt has been made to evaluate the legal status in the field of the guidelines provided for the design of the architectural space regarding the safety of its use in Poland. The evaluation has been carried out with the analysis of the validity and completeness of the guidelines specified in the regulations, in the context of the results obtained during the contemporary research studies, with the discussion of the problems and the conditions of design practice.

The monograph also presents the hazards resulting from negligence toward the fields that have not been legally regulated, where the legislature allows architects to trust their discretion in designing, in accordance with *the principles of their technical knowledge* (art. 20 section 4, Journal of Laws 1994, no. 89, item 414).

Furthermore, an attempt has been made at providing a description of the process in which epidemiological safety is improved by architectural solutions, with an assumption of a possibility to reduce epidemiological hazards with the use of architectural solutions. Considering a wide scope of the subject, the monograph has been limited to the solutions in which architectural tools are used to design healthcare facilities. Hence, the examples provided in the monograph refer to the cases that present the potential of spatial solutions in reducing the risk through functional layouts, material solutions, installations, indoor arrangement, medical technological equipment, communication and information in the facilities.

The references to the research studies and knowledge of epidemiology, ergonomics and medical technologies have been provided to a limited extent. They appear with an attempt made at explaining the conditions and processes involved in the architectural design of medical facilities. In the monograph, the environment of a medical facility is analysed mainly in the context of architectural practice. The specific discussion of problems related to installation disciplines, particularly those related to mechanical ventilation, air-conditioning, water distribution and drainage installations, heating, electricity and telecommunication systems, has been omitted. Also, the problems related to the exploitation of technical infrastructure have not been discussed, despite their obvious influence on epidemiological safety at hospitals. It has been assumed that those elements should be the subject of a publication provided by an interdisciplinary team composed of specialists in the field of sanitary installations, who could provide a full and reliable picture of the potential related to those questions. The subject has been already discussed in Polish scientific publications (Kaiser et al. 2007), however, it should be supplemented with a discussion on the possibilities of a rational use of mechanical ventilation systems in reducing nosocomial infections.

The thematic field of architectural solutions related to epidemiological safety is too extensive to be presented in a comprehensive way that would include all the units and all the problems related to their design. Therefore, the problems have been discussed on the examples that directly refer to the hypotheses stated in the monograph. It has been also assumed that the examples discussed in the monograph refer to hospital-acquired infections (HAI).

The monograph comes as a result of the Author's professional experience based on a number of analytical studies that he has carried out in relation to the analysis of epidemiological hazards observed in the existing and designed facilities and also on the attempts made at the implementation of architectural solutions that would prevent such hazards. The Author's interest in the research problem results from over a dozen years of professional practice of an architect, who develops designs of facilities characterised with a higher sanitary and hygienic regime, such as healthcare facilities, catering facilities, laboratories and industrial manufacturing. The analysis carried out during the implementation of construction projects has already confirmed a relation between architecture and sanitary and hygienic safety of users of these facilities. The research studies based on the examples of various facilities of a higher epidemiological requirements, have allowed the Author to complete the results of the research with some practical elements that provide a confirmation and verification of the research hypotheses. They have also allowed the Author to analyse the dependency between the role of an architect during an investment process and the development of solutions that affect sanitary and hygienic safety.

The need to carry out scientific research on epidemiological safety results particularly from the frequent changes to the legislation, the lack of specific design guidelines that would support epide-

miological surveillance and technological advancement. This situation imposes a specific type of responsibility on architects who, without any sufficiently specified safety standards, must face even more complicated processes of design and investment, due to the necessity of developing relevant standards individually and each time they are needed. Hence, the publication provides a description of the current status of the scientific research on the relations between architecture of medical facilities and nosocomial infections.

The publication also provides a comparative analysis of the selected design solutions that are applied in medical facilities. The analysis is expanded with a critical analysis to confirm the potential of reducing nosocomial infections in Poland with the use of architectural tools. A lot of professional and scientific organisations in the world have published their guidelines on the design of medical facilities in terms of epidemiological safety. Unfortunately, in Poland, publications providing cohesive and comprehensive guidelines on how to use the potential of architecture to implement solutions increasing safety of medical facility users are still very scarce.

## 1.4 The status of the scientific research

The problems of healthcare-associated infections are taken into consideration by various international and local organisations. In the field of legal regulations, the discussed subject comes as an element of the surveillance system described in the current regulations applied by the particular countries in the field of epidemiological control and public health condition. The regulations are primarily aimed at prevention, control and fight against diseases. They are also intended to deal with healthcare problems related with natural environment, work environment and broadly understood prevention and improvement of public health.

One of the international institutions that focus their activities on healthcare problems is the World Health Organization (WHO). Considering its cross-border collaboration with foreign entities, its main task is to undertake activities aimed at fostering international cooperation in the field of health protection and fight against infectious diseases. Another fundamental aim of the WHO is to achieve the highest possible level of health in all countries. The organisation also undertakes the tasks related to the development, establishment and promotion of international standards for food, biological, pharmaceutical and similar products (Constitution of the World Health Organization 2006). Considering the variety of local conditions, international organisations, such as the WHO, do not formulate any comprehensive, specific guidelines on the design of healthcare facilities. In terms of architecture, their work usually takes the form of recommendations regarding specific solutions and spatial standards that should be developed each time when they are implemented on the national level. An example of such guidelines referring to hospital environment can be found in a report of 2005: *World Alliance for Patient Safety: WHO Draft Guidelines for Adverse Event Reporting and Learning Systems: from Information to Action.* The guidelines are focused on the patient's safe stay at a healthcare facility and on the surveillance of the hospital environment. However, the problem is not presented from a perspective of an architect, who is responsible for the spatial design of a medical facility.

In the USA, scientific research on the occurrence of hospital-acquired infections is carried out by the Centers for Disease Control and Prevention (CDC) – a federal agency at the Department of Health

and Human Services. Additionally, *Guidelines for Design and Construction of Hospital and Health Care Facilities* are published periodically in the American market. One of the first publications of this kind was issued in the years 1996-1997 by the American Institute of Architects (AIA). In 1998, the Facility Guidelines Institute (FGI) was established as an independent institution to ensure editorial continuity and up-to-date validity of the guidelines, which are revised on an on-going basis. In 2001, another version of the *Guidelines for Design and Construction of Hospital and Health Care Facilities* was published. In accordance with the publication, the assessment of infection risk comes as a multi-disciplinary organisational process focused on a decrease in the infection risk level. It also acts through the stages involving the planning, designing, construction or renovation of a particular facility; under this process, the knowledge on infections, infectious factors, healthcare environment and human factors related to the expected impact of changes is coordinated and weighed (2001: 166). The data presented in the study was provided in cooperation with several organisations, including the American Institute of Architects Academy of Architecture for Health (AIA/AAH) and the US Department of Health and Human Services. The subsequent editions were published in the years 2006, 2010, 2014 and 2018. The last two editions were published as several separate volumes which contained experts' opinions on separately discussed concepts in the field of healthcare pertaining to hospitals, long-term nursing houses for the elderly and patients requiring long-term care and outpatient clinics.

Similar publications have also appeared in Australia and in Canada. They partially refer to the American guidelines, however they are focused on providing design recommendations developed on the basis of the national healthcare systems and current programmes for infection control and prevention. In 2007 in Australia, the Victorian Advisory Committee on Infection Control published the *Guidelines for the Classification and Design of Isolation Rooms in Healthcare Facilities*. This publication provided the most important principles for the classification of the isolation rooms and the guidelines on their design and equipment. Three years later, the Australian Commission for Safety and Quality in Health Care issued general guidelines on hospital-acquired infection control and prevention, which included some recommendations on architectural solutions: *Australian Guidelines for the Prevention and Control of Infection in Healthcare* (2010). In 2013, based on the similar principles, the Canadian Committee for Hospital-acquired Infections in Quebec (in French: Comité sur les infections nosocomiales du Québec) developed *Infection Prevention and Control Measures in the Emergency Department*.

Since 2005, at the European level, an independent agency of the European Union has been operating under the name of European Centre for Disease Prevention and Control (ECDC). Using the European surveillance system, it analyses and interprets the data obtained from the particular EU countries referring to several dozen infectious diseases. The agency is also responsible for the identification and analysis of potential threats to public health. It coordinates European training programmes in the fields of interventional epidemiology and microbiology in public health. Providing scientific recommendations to the governments of the EU countries and EU institutions, in 2013 the agency issued a report: *ECDC Surveillance Report. Point Prevalence Survey of Healthcare-associated Infections and Antimicrobial Use in European Acute Care Hospitals 2011–2012,* in which the level of HAI occurrence is analysed in the EU countries. The report also provides an analysis of control and prevention programmes applied in those countries. Furthermore, the report lists the analytical studies on some aspects of architecture in the analysed hospitals, in the context of preparations undertaken in the field of prevention of epidemiological hazards. It provides the percentage of single rooms at hospital wards and the level of HAIs

identified in patients, in relation to the size of hospitals and the categories of hospital wards where those patients have been hospitalised.

In some European countries, such reports are used for developing guidelines that support epidemiological surveillance. In 2001 in Ireland, an expert panel was appointed to develop a *Strategy for the Control of Antimicrobial Resistance in Ireland* (SARI). The members of the SARI Committee developed a number of guidelines and recommendations for the Health Services Executive (HSE) and for the Department of Health and Children (DoHC) on the prevention and surveillance of antimicrobial resistance and healthcare-associated infections. In 2008, *Infection Prevention and Control Building Guidelines for Acute Hospitals in Ireland* was published as a guidebook providing a set of specific recommendations on the architectural and technical design of hospital facilities to support the national system of surveillance and prevention of infectious diseases in the optimal way.

A similar publication appeared in Germany in 2008. It was developed by Kommission für Krankenhaushygiene und Infektionsprävention (KRINKO), an organisation operating at the Robert Koch Institute, under the title of *Anforderungen an die Hygiene bei der medizinischen Versorgung von immunsupprimierten Patienten (Hygienic Requirements in Medical Care Provided to Immunocompromised Patients)*. The document states general principles for the design of healthcare environment in which medical care is provided to patients, in particular: the main trends in the design of architecture dedicated to hospitals and healthcare facilities. It provides the principles for designing the functional and spatial layout of a hospital, recommended percentage of isolation rooms in relation to other rooms for hospitalised patients and methods of their equipment. The document defines requirements on the indoor air quality, necessary sanitary areas, dimensions and technical specifications related to functional areas that require special protection.

Ten years later, in 2018, *Bauliche Hygiene im Klinikbau. Planungsempfehlungen für die bauliche Infektionsprävention in den Bereichen der Operation, Notfall- und Intensivmedizin* was published. It was a document commissioned by the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (in German: Bundesinstitutes für Bau-, Stadt- und Raumforschung – BBSR) and developed by a panel of experts including architects and specialists in epidemiology surveillance. The team provided a set of specific requirements for modern medical facilities, especially for operating theatres, intensive care units and emergency departments. The document provides general recommendations for the design of functional and spatial layouts of the particular types of medical units, their sizes, internal equipment in patient rooms and materials for interior furnishing (Sunder et al. 2018).

During the scientific research carried out on epidemiological problems, it has been noted that *knowledge comes as a critical tool and knowledge management is manifested as an ability to translate the (knowledge) research results into politics and practice, as it leads to the improvement in the quality of human life and expands its expected span* (Metaxiotis 2006: 208). Understanding those relations has considerably contributed to scientific publications, disseminating knowledge about the advancement made in the field of epidemiology (Beaglehole et al. 1996; Bzdęga and Gębska-Kuczerowska 2010). Identifying hospital-acquired infections as one of the main sources of civilisational hazards (Weinstein 1998) has also contributed to a number of scientific papers presenting the results of the subsequent research carried out in various medical facilities on various types of microorganisms in the context of various healthcare systems in the world. Since then, a number of scientific periodicals have appeared to disseminate scientific research results and information about prevention and surveillance of infections.

In the recent decade, a lot of those periodicals have presented numerous articles discussing the significance of the design of the space in the environment of medical facilities. Among them, the following should be especially mentioned: *The Journal of Hospital Infection, Healthcare Infection Society Infection Control and Hospital Epidemiology, American Journal of Infection Control, Clinical Microbiology and Infection, Antimicrobial Resistance and Infection Control, Intensive Care Medicine, Emerging infectious diseases, Healthcare Infection*. In Poland, the problems in question are often discussed in *Przegląd Epidemiologiczny* and *Zakażenia Szpitalne*.

Recently, a great number of joint monographs have been published, where the problems related to hospital-acquired infections and hospital hygiene are comprehensively discussed. For instance, in 2011 the International Federation of Infection Control published *Basic Concepts Book*, presenting the current knowledge in the fields of patient safety, organisational structures, epidemiology related to healthcare, the role of microbiological laboratories in infection control, patient isolation, methods of cleaning, disinfection and sterilisation of hospital rooms and their equipment, prevention programmes and costs associated with the nosocomial infections. The publication was revised in 2016.

In 2012 *Epidemic of Medical Errors and Hospital-Acquired Infections: Systemic and Social Causes* was published - a monograph by multiple authors, edited by William Charney, discussing the social impact of infections and evolution in understanding hospital-acquired infections.

Polish literature on hospital-acquired infections includes such publications as *Zakażenia szpitalne. Podręcznik dla zespołów kontroli zakażeń (Nosocomial Infections. A Handbook for Infection Control Teams)* (Eds. Heczko and Wójkowska-Mach 2009), *Profilaktyka zakażeń szpitalnych – bezpieczeństwo środowiska szpitalnego (Prevention of Hospital-acquired Infections – Safety of Hospital Environment)* (Ed. Pawińska 2011), *Zakażenia szpitalne – wybrane zagadnienia* (*Hospital-acquired infections – Selected Problems*) (Ed. Denys 2012), *Prewencja i kontrola zakażeń (Infection Prevention and Control)* (Ed. Vinice 2012), *Zakażenia szpitalne w jednostkach opieki zdrowotnej (Nosocomial Infections at Healthcare Facilities)* (Eds. Bulanda and Wójkowska-Mach 2016).

At the international level, the impact of buildings on their users' health has been already analysed in scientific research studies for a long time, for instance in *Architectural Design and Indoor Microbial Pollution*, a book published in 1988 (Ed. Kundsin). The relations between architecture and medicine are discussed in articles published in such periodicals as *Health Environments Research & Design and The Lancet*. The scientific research studies analysing those two scopes are also presented in the previously mentioned periodicals, directly related to the questions of epidemiology.

Designing healthcare facilities has been more and more often affected by scientific research that combines the physical environment of hospitals with the performance of healthcare units and it has become oriented toward evidence-based architecture and design (EBD). The Center for Health Design (CHD), an international association of architects, healthcare administration representatives, medical employees and scientists who specialise in various fields, defines the EBD as a *deliberate attempt to base building decisions on the best available research evidence, with the goal of improving outcomes and the further monitoring of success or failure in making subsequent decisions* (Malkin 2008: 2).

The first activities undertaken to popularise the EBD trend started in the 1980s. The pioneering research was an analysis carried out by the team of Roger S. Ulrich on the impact of the environment

quality on patients' well-being. It was observed that there was a tendency in which the hospitalisation period became shortened for patients who were provided with the possibility of eye-contact with the nature visible through the hospital windows (Ulrich 1984). In the subsequent years, the intensity of scientific research on architecture of medical facilities became much higher. Carried out in 2004, the analysis of the scientific research resulted in the publication of over 650 scientific articles about the discussed problems. The articles refer to the four main thematic groups, namely: improvement in the general quality of healthcare and lowering its costs, improvement in the safety of patients and the quality of care, reduction of stress and improvement in the functioning of patients, accompanying persons and visitors in medical facilities, reduction of stress and fatigue in personnel (Ulrich 2004 in: Malkin 2008: 4-5). The discussed research was focused not only on elements that affect the constructed environment but also it also applied scientific achievements in a broader context for the development of numerous scientific research initiatives related to the healthcare system aimed at improvement in the conditions of the environment of medical facilities where patients and medical personnel need to function (Ulrich et al. 2006; Malkin 2008; Cama 2009; McCullough 2009). Another review of scientific articles carried out by the team of scientists led by Roger Ulrich (2008) indicated a considerable increase in the number of scientific research in the field on EBD over the last decade. A large number of those articles refer to the possibilities of preventing epidemiological hazards due to the medical facility space that has been designed in an optimal way. A lot of those publications are focused on the question whether architecture of medical facilities can affect the rates of nosocomial infections (Dettenkofer 2004; Jensen et al. 2005; Ulrich and Wilson 2006; Joseph and Rashid 2007; Kembel et al. 2012; Hamilton 2013; Sunder et al. 2018; Tabori and Dettenkofer 2018). A large number of publications discussing these problems refer to patients who are hospitalised in single rooms. They present the results of comparative research and analysis determining the level of HAI occurrence risk, depending on the way patients are located in the spatial layout of the ward and the parameters of the patient rooms that contribute to the lowering of such risk (Noskin 2001; van de Glind 2007; Bracco 2007; Detsky 2008; Berry 2013; Brouqui 2016; Munier-Marion 2016; Pennington and Isles 2013). While analysing the advantages of treating patients in single rooms in the context of epidemiological control, a scientific discourse has developed on the positive and negative impact of isolation on the patient's psyche (Oldman 1998; Gammon 1999; Fleischer 2009; Abad et al. 2010; Barratt et al. 2011).

The number of infections, undesired incidents and errors is particularly significant in intensive care units, where immunocompromised patients are treated, being exposed to an increased risk of infections because of their stay at medical facilities (O'Connell and Humphreys 2000; Rothschild et al. 2005; Hryniewicz et al. 2014; Misiewska-Kaczur 2016; Stiller et al. 2016; Stiller et al. 2017; Teltsch et al. 2011).

Contemporary scientific research in the field of hospital environment also refers to specific solutions, such as the methods in which patient rooms are equipped (Best 2012; Bocicor 2017; Trillis 2008), types of furnishing materials applied during the arrangement of hospital interior (Casey et al. 2010; Schweizer 2012) and optimal methods of its decontamination (Green 2001; Caselli et al. 2018; Ethington 2018 et al.).

The proper hand hygiene in medical personnel who provide care to patients is an acknowledged method of preventing hospital-acquired infections. Most recommendations referring to its optimisation are focused on efficient education programmes. In the context of architectural design, the way of locating hand washing and disinfection points becomes particularly important, along with their types and equipment (Dubbert 1990; Dorsey 1996; Boyce 2002; Pittet D. 2004; Kampf 2009; Sydnor et al. 2012).

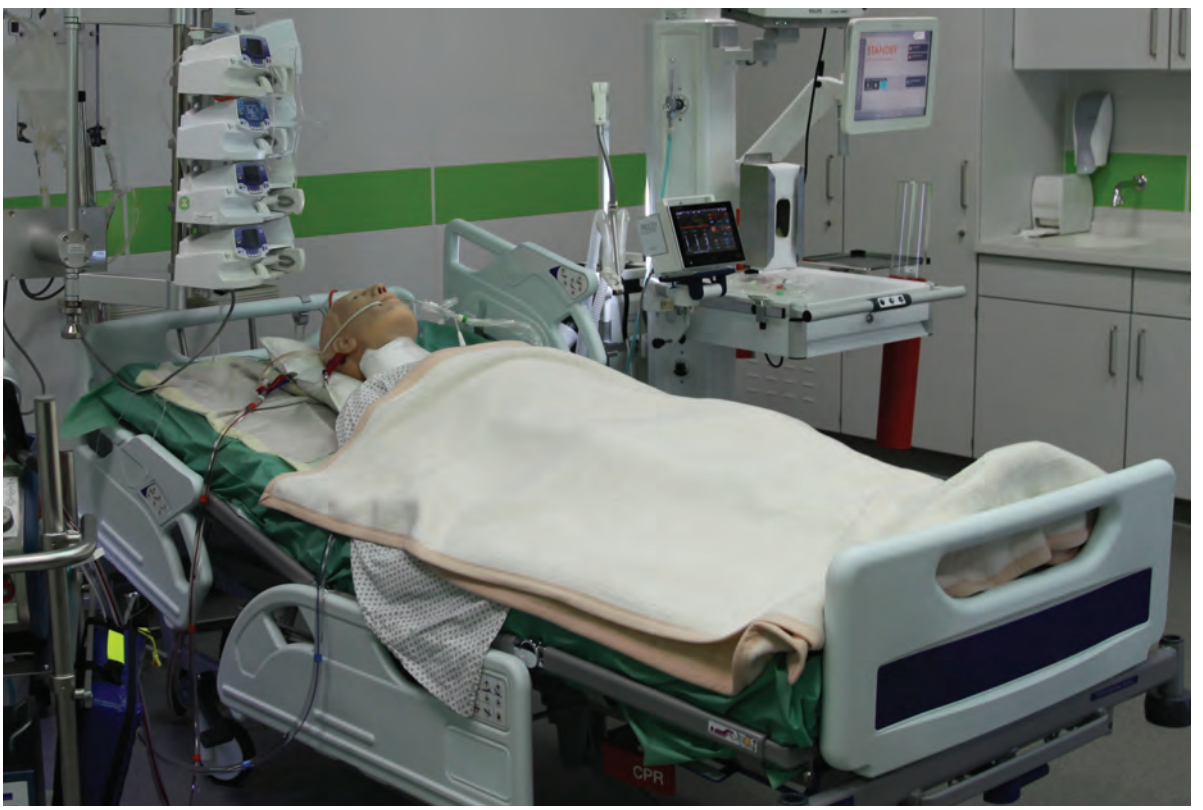
There is a scarce number of Polish publications on architectural solutions providing proper operation of medical facilities. In fact, the lack of regulations and guidelines in the industry scientific studies is particularly noticeable. Developed in 2016 by the Association of Hospital Epidemiology, the Polish Society of Hospital Infections, the Polish Association of Epidemiological Nurses and the Association of Committees and Hospital-acquired Infection Control Teams in Lesser Poland, S*ystem kontroli zakażeń związanych z opieką zdrowotną w Polsce (The System of Healthcare-associated Infection Control in Poland)* does not provide any direct guidelines on the design of hospital architecture.

More detailed scientific research in the field of architectural solutions applied in medical facilities was carried out in the 1970s and the 1980s. At that time, legal acts on the design of medical facilities were supported by studies referred to as *Design Guidelines* developed by the experts from the Office of Healthcare Studies and Design Projects. After their formal approval by the Minister of Health and Social Welfare, these documents then became the basic auxiliary materials referred to during the programming and designing medical facilities (Przygoda 1971; Geppert et al. 1973; Garlińska and Kwiatewicz 1981; Smajkiewicz 1982; Dobrzańska 1984; Makowiecka 1984; Wnuk 1988). Since the 1990s, the main sources of guidelines for architects involved in designing medical facilities have been legal acts issued by the Ministry of Health and Social Welfare (the Ministry of Health since September 1999). At present, the fundamental act is the Ordinance of 26th June 2012 of the Minister of Health on specific requirements to be met by premises and equipment of entities providing healthcare services (Journal of Laws 2012, item 739). Unfortunately, the document does not provide any recommendations on cohesive infection risk management through the design of the hospital space, adequate to the hazards related to HAIs.

The EBD model has been adopted by the Polish healthcare system to a very limited extent (Bil 2014). Despite numerous scientific studies on medical facility architecture, the results of the research are rarely implemented into practical solutions. As already mentioned, the publication of design guidelines on medical facility architecture based on scientific experience of interdisciplinary expert panels was abandoned in the 1990s. However, during the recent decade, architecture of healthcare facilities has come back as a subject of scientific research. Some important scientific studies have been developed by scientific teams at the academic centers in the entire territory of Poland. Among them, *Technologia medyczna w projektowaniu obiektów szpitalnych (Medical technology in Designing Hospital Facilities)* (2015), a publication by Michał Tomanek, seems to be particularly significant. It provides an analysis of functional systems in hospitals, considered in the context of medical technology design. In the monograph, the Author focuses his attention on the problems related to the efficiency in the functioning of healthcare facilities and to the identification of relations between medical technology and architectural design. This is one of very few publications presenting a comprehensive discussion on medical architecture in the context of the Polish healthcare system since the 1970s, when *Projektowanie obiektów służby zdrowia (Designing Healthcare Facilities)* (Juraszyński et al. 1973) appeared as a publi-

cation of the similar thematic scope. Still, it discusses epidemiological issues to a very limited extent. It follows and complements a series of monographic publications discussing the specific aspects of the functioning of medical facilities, such as paediatric hospitals (Niezabitowska and Jamrozik-Szatanek 2015), emergency rooms (Gawlak 2015), and presents the analysis of various functional and technical solutions applied in hospitals and other healthcare facilities (Bąkowski et al. 2012; Eds. Gębczyńska-Janowicz and Idem 2015; Ed. Poplatek 2018).

As the review of specialist literature indicates, the number of scientific studies on the theory of architectural, technological and ergonomic design of healthcare facilities, in the context of contemporary conditions pertaining to epidemiological hazard control, is very scarce. A number of current publications discuss epidemiological problems as secondary questions related to the matter in consideration. The possibilities to use architecture for infection prevention by, for instance, implementation of architectural barriers or modification of spatial layouts, are rarely discussed in Polish scientific literature, mainly by specialists in the field of epidemiology. They do not exhaustively address the problem of dependencies between architectural solutions in the hospital environment and epidemiological questions.




**Photograph 1.4.1** A patient station at the anaesthesiology and intensive care unit (a large amount of medical equipment results in difficulties related to systematic disinfection of potentially contaminated surfaces); photographed by the Author, 2016

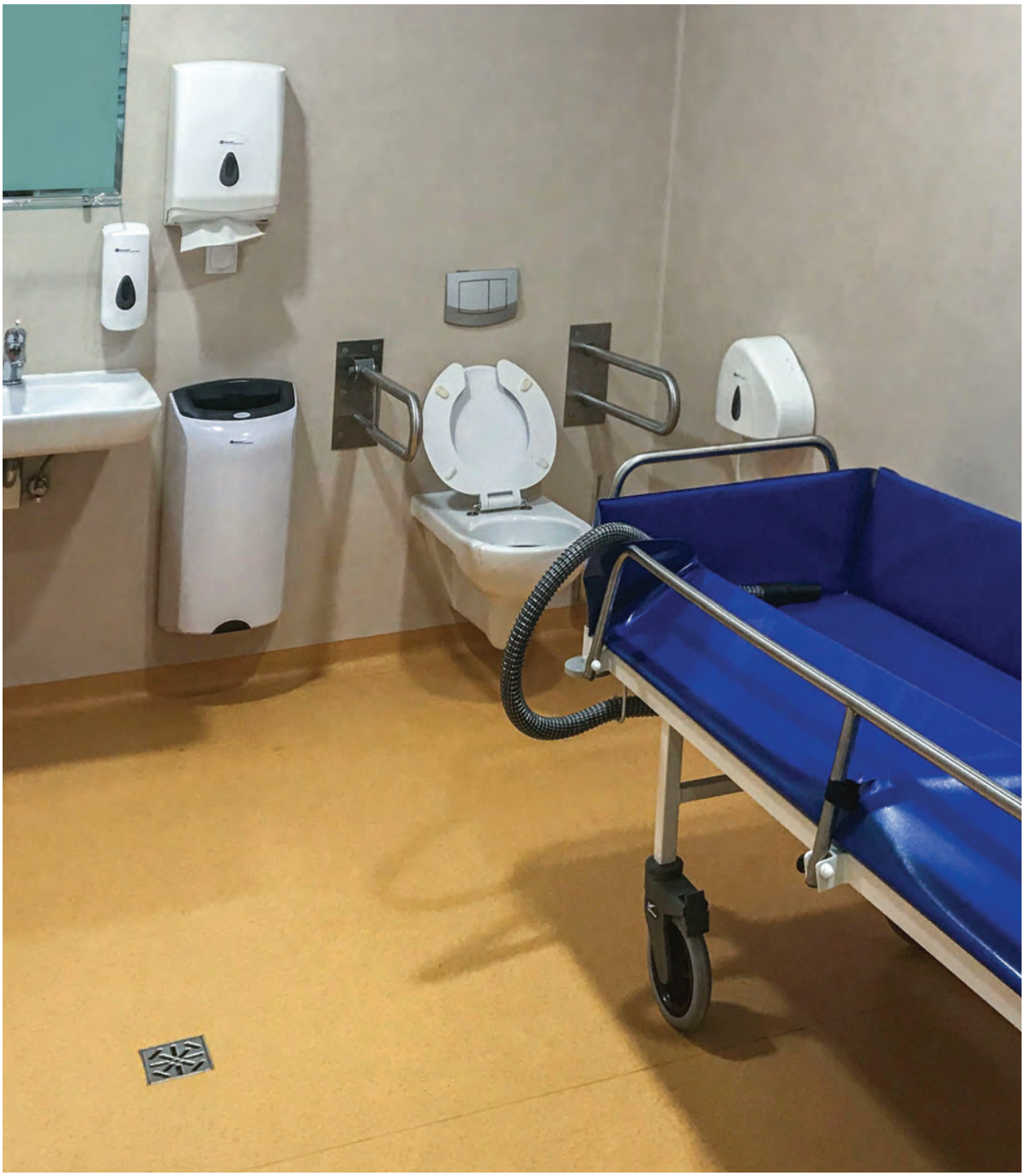
**Photograph 1.4.2** Regardless of the complexity level in the functions performed by medical facilities, aesthetic solutions are implemented to improve comfortable work experience and well-being of medical personnel; designed and photographed by the Author, 2023

**Photograph 1.4.3** A camera, an element controlling an operating theatre lamp (the surfaces of medical equipment, especially those in frequent contact with medical personnel's hands, can easily become vectors of infection transmission); photographed by the Author, 2016

# 2. The background of the discussed problem

As a topic of an in-depth analysis, the risk of hospital-acquired infection occurrence in Poland has been discussed relatively recently (Juszczyk and Samel 2000). In 1981, the first conference on nosocomial infections and their prevention methods was held (Dziąba 2010). At that time, the implementation of the first legal regulations did not result in any improvement in the epidemiological situation of the country. Imposed on attending physicians, the obligation of reporting each case of a nosocomial infection to the State Sanitary Inspectors was not fully respected and only some medical units complied with that regulation. In the years 1984–1997, 24% up to 34% of the provinces did not report any cases of nosocomial infections in hospitalised patients (Juszczyk and Samel 2000). An increased number of programmes dedicated to the analysis of the epidemiological situation contributed to the establishment of the Polish Society of Hospital Infections in 1994. In the second year of its operation, the Society in cooperation with the Institute of Microbiology at the Collegium Medicum at the Jagiellonian University developed and implemented the first Nationwide Programme of Registering Hospital-acquired Infections. The programme stated the most important principles intended to lower the epidemiological hazard (Różańska et al. 2008). The definition of a hospital-acquired infection appeared in the Polish legislation in 2001, as a result of an amendment to the Act on Infectious Diseases and Infections (Dziąba 2010). Initially it read as follows: *a hospital-acquired infection is an infection acquired during the stay at*

**Photograph 2.0** Mobile operating table – a fragment; photographed by the Author, 2018



**Photograph 2.0.1** A bath trolley – a station for washing patients (a solution that allows for hygienic procedures, e.g.: decontamination of patients during their admission to the area of the hospital emergency department); photographed by the Author, 2016

*healthcare facilities providing 24-hour or all-day medical care services and that was not in the incubation period at the time of the patient's admission to the facility* (Journal of Laws 2001, no. 126 item 1384, art. 2, section 26). Several years later, the notion of nosocomial infections was updated in the Act of 5th December 2008 on preventing and combating infections and infectious diseases in humans. The new definition reads as follows: an infection acquired in relation to medical care provided when the disease a) was not in the incubation period at the moment of medical treatment or b) appeared after medical treatment within the period of time not longer than its longest time of incubation (art. 2, section 33, Journal of Laws 2008, no. 234, item 1570 with later amendments). The new version provides a broader definition – it includes not only hospital-acquired infections but also non-hospital-acquired infections related to healthcare services provided by facilities performing other healthcare functions.

Despite the dynamics of development in contemporary medicine, total elimination of pathogens from human life is impossible. Numerous organisations operating at the international level, such as the World Health Organization, as well as those operating at the national level, such as the State Sanitary Inspectorate or the National Institute of Public Health – the National Institute of Hygiene in Poland, undertake activities to monitor and control the level of infections. The evaluation of the efficiency of preventive actions and the surveillance of infection hazard are presented as the statistical data on sanitary and hygienic safety at the international level (World Health Organization 2017; European Centre for Disease Prevention and Control 2018). The statistical data is also collected at the national level (The Report of the Supreme Audit Office 2018, the National Institute of Public Health – the National Institute of Hygiene, 2016) and at the local level (Provincial Sanitary and Epidemiological Stations 2017). Sanitary and hygienic safety management becomes an element included in comprehensive healthcare systems in most countries, also within the territory of the European Union (Directive 89/391/EEC) and Poland (the Act on preventing and combating infections and infectious diseases in humans; Journal of Laws, no. 234, item 1570). Nevertheless, considering the heterogeneous nature of hazards, technical and technological advancement and the impossibility to eliminate epidemiological hazard from human life, the scientific research carried out in the field of preventing epidemiological threats is still a current issue that becomes even more significant in the context of hazards related to infections caused by drug-resistant microorganisms.

## 2.1 Pathogen transmission routes

The analysis of the problems related to biological hazards is underlain by the fact that the ecosystem of humans contains reservoirs of microorganisms, only some of which are harmful to human health and may cause diseases. The human life environment is not confined to the surroundings where people live. The human body itself contains about 1014 bacteria. Some of them exist on the skin and mucous membranes of the human organism. Medical invasive procedures allow bacterial flora to penetrate the areas of the human body that are usually sterile, resulting in an infection (Sunder et al. 2018). Medical microbiology is focused on the analysing the structure, life functions and impact exerted by microorganisms on human health. It also analyses diagnostic methods, epidemiology and medical treatment (Zaremba and Borowski 2013; Heczko et al. 2014). The impact of microorganisms on human health is also considered in various publications regarding public health (Jabłoński and Karwat 2002; Bzdęga and Gęb-

ska-Kuczerowska 2010). In this monograph, the extensive scientific and practical achievements in the field of medical microbiology and public health are considered only in the terms of relations between the prevention of hospital-acquired infection transmission and development of architectural solutions. Healthcare-associated infections can occur in various places, however there are some conditions to be met first. Infections occur *as a result of the interaction among infectious agents, vulnerability of the host and environmental conditions* (Zieliński 2009: 14). In such a case, the probability of acquiring an infection depends on the types of microorganisms, their characteristics, their ability to survive, reproduction in the particular environment, typical transmission routes, invasiveness and also their sources. In a building, an infection source can be another person, an animal, an object or substance from which an infectious agent is transmitted onto the host (Zieliński 2009; Sadkowska and Todys 2016).

Architectural solutions may limit the possibilities of infection transmission by supporting organisational activities and by designing environmental conditions inside an organised space of a building. Contemporary scientific research indicates that inside buildings the numbers of bacteria are higher and they tend to grow in the areas characterised by weaker airflows and lower relative humidity. It has been also confirmed that air temperature, relative humidity, the sources of ventilated air and population density may affect the number and transmission of some pathogenic microorganisms inside buildings (Kembel et al. 2012).

Considering the analysis of the epidemiological process in terms of the proper spatial design in medical facilities, it is important to follow the infection process. It is possible to identify a portal of entry – a place or places through which microorganisms enter the organism of a vulnerable host, and a portal of exit – a place, tissues and organs through which microorganisms leave their infected host's organism (Sadkowska and Todys 2016). It is also possible to provide another classification resulting from the analysis of the infection transmission routes, where the following main groups can be identified:

- direct transmission – an infected person is in contact with the infection source and the infectious agent enters the host's organism through a particular portal of entry;
- indirect transmission – there are intermediate elements between an infected person and the infection source, fomites, such as objects that have been already infected. In such a case, microorganisms are transmitted passively. In healthcare, fomites can be sets of medical instruments or personnel's medical protective gowns;
- transmission by food – an infection occurs when a person eats contaminated food or drinks contaminated water;
- transmission by droplets and airborne particles of aerosols or dust that can stay suspended in the air and enter the lungs through the respiratory tract. In this way, dry particulate matter may transmit fungal spores. This transmission route depends on the size of particles carrying infectious agents. Very small particles may transmit the measles virus to the distance of several meters. Pathogens transmitted by bigger particles may cover the distance limited to 1-2 metres.
- transmission by blood – an infection is transmitted by blood and blood-derived substances; it can be also transmitted by inadequately sterilised equipment. The reservoir of microorganisms transmitted in this way is the human organism (Zieliński 2009)

Architectural solutions in medical facilities are closely related to pathogen transmission routes. The analysis of transmission routes of microorganisms comes as a foundation for the design of spatial solutions in healthcare facilities. It allows architects to assign them with particular architectural activities that - in combination with organisational activities - are aimed at providing an efficient barrier to the transmission of infectious agents.

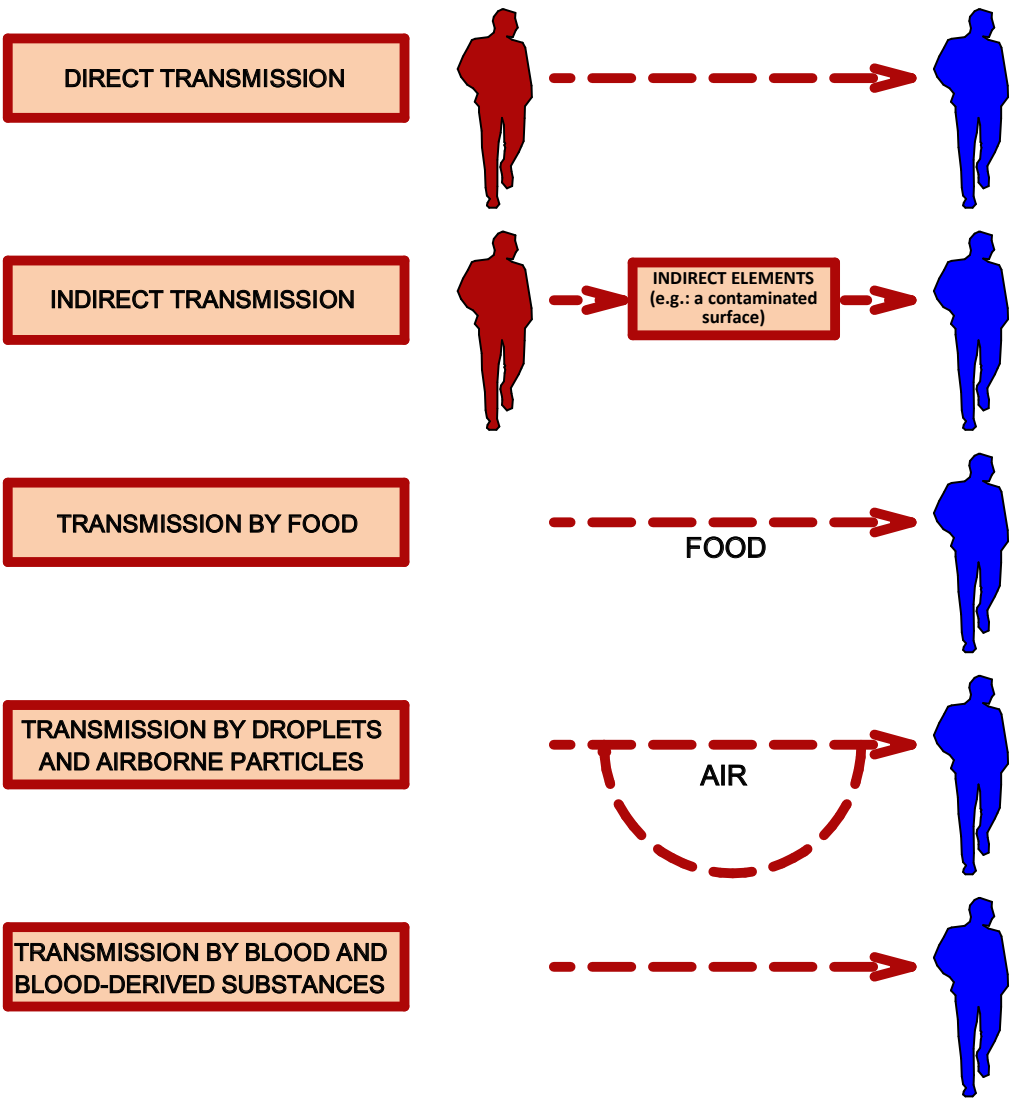



**Figure 2.1.1** A model of transmission routes followed by microorganisms; elaborated by the Author


**Photograph 2.1.2** A sterilisation unit (proper preparation of materials for sterilisation requires a number of activities to be performed); photographed by the Author, 2016

**Photograph 2.1.3** A temporary hospital at AMBEREXPO in Gdańsk; designed and photographed by the Author, 2022

## 2.2 Classification of pathogens

The classification of pathogenic factors can be based on various systematics. In Poland, the basic classification is provided by the Act of 5th December 2008 on preventing and combating infections and infectious diseases in humans. It includes, among others: echinococcosis, cysticercosis, diarrhoea of infectious or unidentified origin in children under the age of 2, diptheria, Lyme borreliosis, brucellosis, Chikungunya virus disease (CHIKV), chlamydiosis and other non-gonococcal infections of the

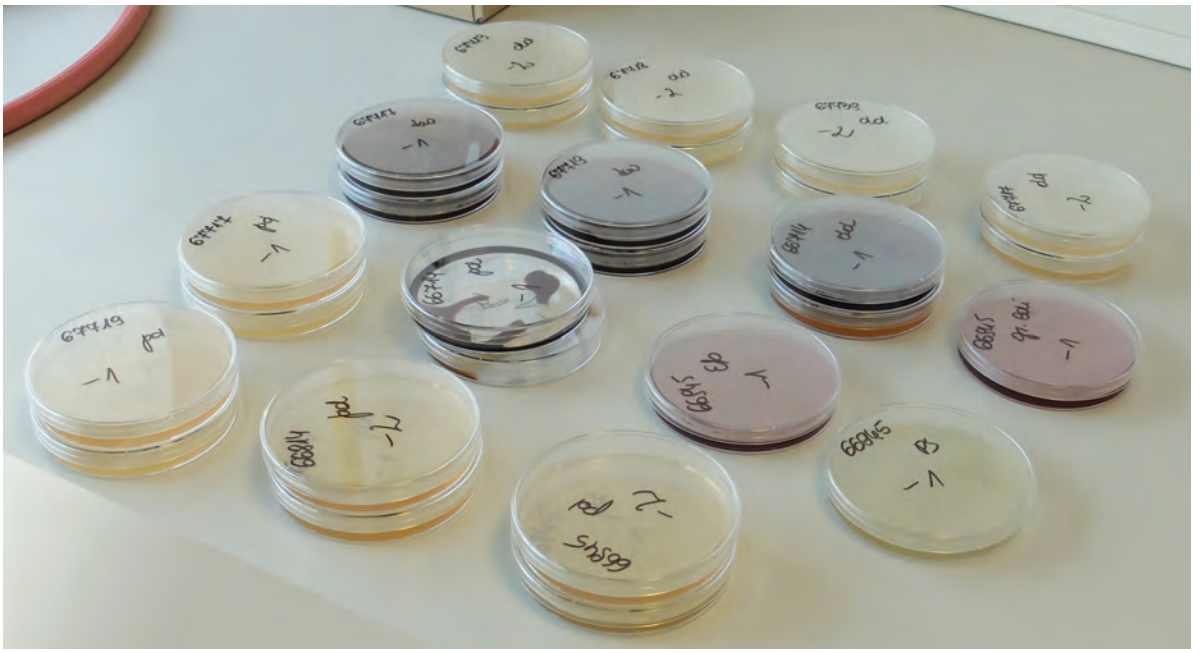
**Photograph 2.2.** The light body of an operating theatre lamp – a fragment; photographed by the Author, 2018

urinary system, cholera, Creutzfeldt-Jakob disease and other spongiform encephalopathies, Ebola virus disease (EVD), shigellosis, typhoid fever and salmonellosis infections, typhus fever (including Brill-Zinsser disease and other types of rickettsiosis), paratyphoid fever caused by the paratyphoids of A, B or C types, infections caused by paratyphoid bacilli, bubonic fever, giardiasis, Q fever, tuberculosis and other mycobacteriosis infections, influenza, avian influenza in people, Neisseria meningitidis invasive infections, Streptococcus pneumoniae invasive infections, Streptococcus pyogenes invasive infections, Haemophilus influenzae invasive infections, yersiniosis, campylobacteriosis, syphilis, pertussis, legionellosis, epidemic parotistis (mumps), measles, smallpox, varicella, gonorrhoea, hepatitis viralis (of type A, B, C and others) and infections caused by hepatitis viruses (Annex to the Journal of Laws 2008, no. 234, item 1570 with later amendments).

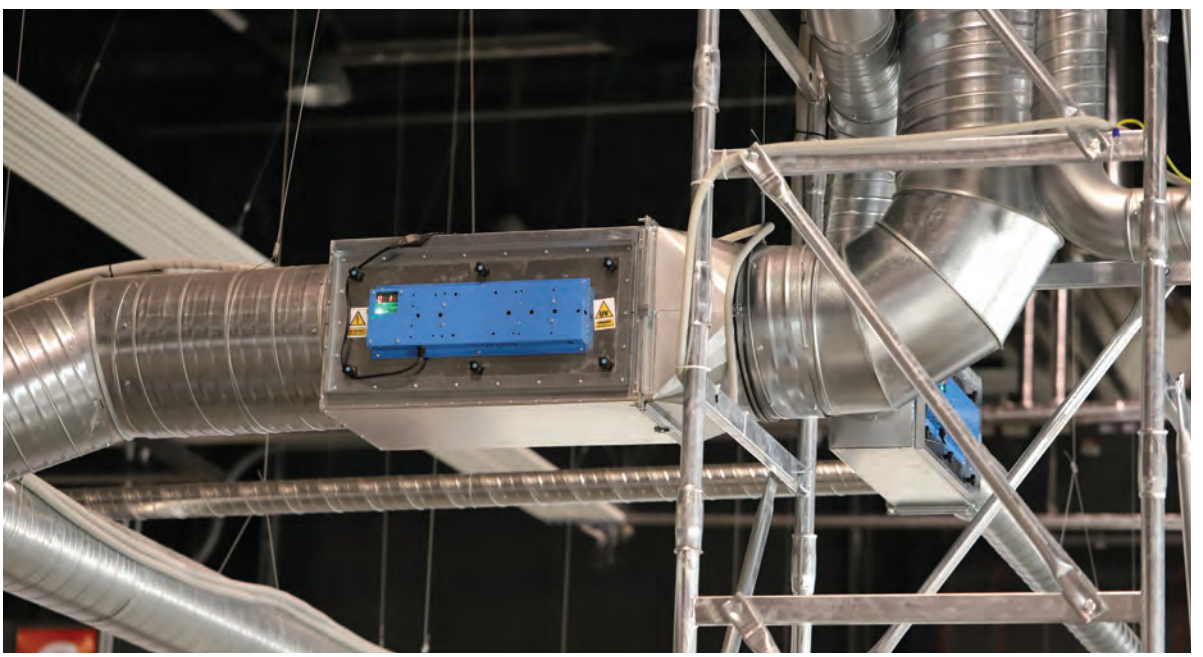
Considering the development of architectural solutions, the above-mentioned list is insufficient, because it provides neither an assessment of risk related to the transmission of infections, nor a definition of the level of risk to human health and life. Furthermore, the list does not indicate any conditions that would allow architects to select design solutions adequate to the level of epidemiological risk. Another classification may be found in the Ordinance of the Minister of Health of 22nd April 2005 on biological factors harmful to human health in workplace environment and on protection of health of employees professionally exposed to such factors (Journal of Laws 2005, no. 81, item 716). This regulation refers to the organisation of medical facilities to a very little extent, by providing principles for the design of workplaces in isolated rooms. However, it provides a classification of harmful biological factors and an identification of hazards caused by cellular microorganisms (including those genetically modified ones), non-cellular entities capable of replicating or transferring genetic material, including genetically modified cell cultures and internal parasites, dividing them into four groups of hazard, representing various levels of harm to human health. It also assigns these four groups with specific architectural solutions. The classification includes the following:

- 1st hazard group – factors that are very unlikely to cause diseases in humans;
- 2nd hazard group – factors that may cause diseases in humans; they can be dangerous to employees, however their spreading onto the human population is unlikely. Usually, there are efficient preventive and medical treatment methods to combat them;
- 3rd hazard group – factors that may cause serious diseases in humans; they are dangerous to employees and their spreading onto the human population is highly probable. Usually, there are efficient preventive and medical treatment methods to combat them;
- 4th hazard group – factors that cause serious diseases in humans; they are dangerous to employees and their spreading onto the human population is highly probable. Usually, there are not any efficient preventive and medical treatment methods to combat them (Ibid.).

The knowledge on the groups of hazard pertaining to biological factors allows for the identification of the levels of risk they pose to humans. In the annex to the regulation, each group of hazard is assigned with a particular hermeticity class and with specific types of architectural protective solutions. Unfortunately, in medical facilities their application has been limited to isolated rooms. Other areas must be individually estimated by hospital infection control teams in terms of risk and architectural solutions.



**Photograph 2.2.1** Material during microbiological tests (microbiological tests are time-consuming processes); photographed by the Author, 2017



**Photograph 2.2.2** An example of air disinfection with the use of UVC lamps used in order to maintain the assumed hermeticity of the rooms; a temporary hospital at AMBEREXPO in Gdańsk; designed and photographed by the Author, 2022

## 2.3 Threats posed by drug-resistant bacterial strains

Contemporary techniques of epidemiological protection are significantly related to the widespread use of antimicrobial agents. Despite the hope pinned on the first antibiotics, such as penicillin, as drugs capable to defeat a large group of infections (Hamilton 2013), the flow of time has lowered their efficiency, due to drug-resistance developed by microorganisms, especially in hospitals and long-term healthcare centres (Weinstein 1998). The phenomenon of drug-resistance increases the epidemiological risk related to the fact that the subsequent modern programmes of control and prevention of infections through the use of pharmacological agents keep losing their efficiency.

Therefore, some activities have been undertaken in Europe to slow down that process. Among other elements, they involve limited application of antibiotics as common drugs, promoted during such events as, for instance, the European Antibiotic Awareness Day (Communicable Disease Threats Report, ECDC, 2018), or the National Programme to Protect Antibiotics run in Poland (NPOA 2018). Those activities are aimed at the promotion of the sensible use of antibiotics and their strategic objective is to reduce drug-resistance developed by microorganisms.

Pathogens are classified according to their resistance to antibiotics. It is possible to list the following:

- MDR (multidrug-resistant) strains – they are insensitive to three or more groups of antibiotics;
- XDR (extensively-drug-resistant) strains – they are sensitive only to one or two antibiotics;
- PDR (pandrug-resistant) strains – they are resistant to all accessible drugs (Minister of Health, National Programme to Protect Antibiotics 2016-2020; 2016)

An example of microorganisms that pose threats resulting from their high drug-resistance to pharmacological agents are *Klebsiella pneumoniae* bacilli producing metallo-beta-lactamases of the New


**Photograph 2.3.1** An example of air disinfection with the use of UVC lamps used in order to maintain the assumed hermeticity of the rooms; a temporary hospital at AMBEREXPO in Gdańsk; designed and photographed by the Author, 2022

Delhi type (NDM). According to the National Consultant in the field of medical microbiology, they form one of the main groups of microorganisms developing the highest drug-resistance. They have developed extremely dangerous resistance mechanisms that can eliminate the effectiveness of all or almost all antibiotics (A Report… NIK (the Supreme Audit Office) 2018: 40). As suggested by the data provided by the Ministry of Health in 2016, the mortality rate in the cases of infections caused by *Klebsiella pneumoniae* in Poland reached the level of about a dozen percent, despite medical treatment (the National Programme… Annex 2016: 2). The epidemiological hazard posed by drug-resistant bacterial strains is monitored at both the local and the international levels. Responsible for monitoring epidemiological threats in Europe, the European Centre for Disease Prevention and Control published the data (ECDC 2018) indicating that invasive infections caused by *Klebsiella pneumoniae* in 2017 were reported in most European countries.

The data presented by the European Centre for Disease Prevention and Control in the *ECDC Surveillance Atlas of Infectious Diseases* allows for the monitoring of recent changes in the levels of infections. It also makes it possible to observe the volatility of infections recorded in the particular countries of the European Economic Community (EEC). In the course of time, some considerable success has been recorded in relation to some epidemic outbreaks, manifested by lower morbidity rates. However, new epidemiological outbreaks keep occurring and the situation is very dynamic. Moreover, considering globalisation and mobility of large groups of people, hosts and infected individuals keep moving all the time. Hence, it is possible to state that the problems related to infections caused by drug-resistant microorganisms are of international nature.

It can also be predicted that new epidemic outbreaks will occur in the nearest future. This is because *those microorganisms have an outstanding potential to spread, easily causing hospital epidemic outbreaks and their carriage in the gastrointestinal tract may persist for several years* (A Report… NIK 2018: 40). Considering the long-time carriage, it is extremely difficult to eliminate such microorganisms completely from the human environment.

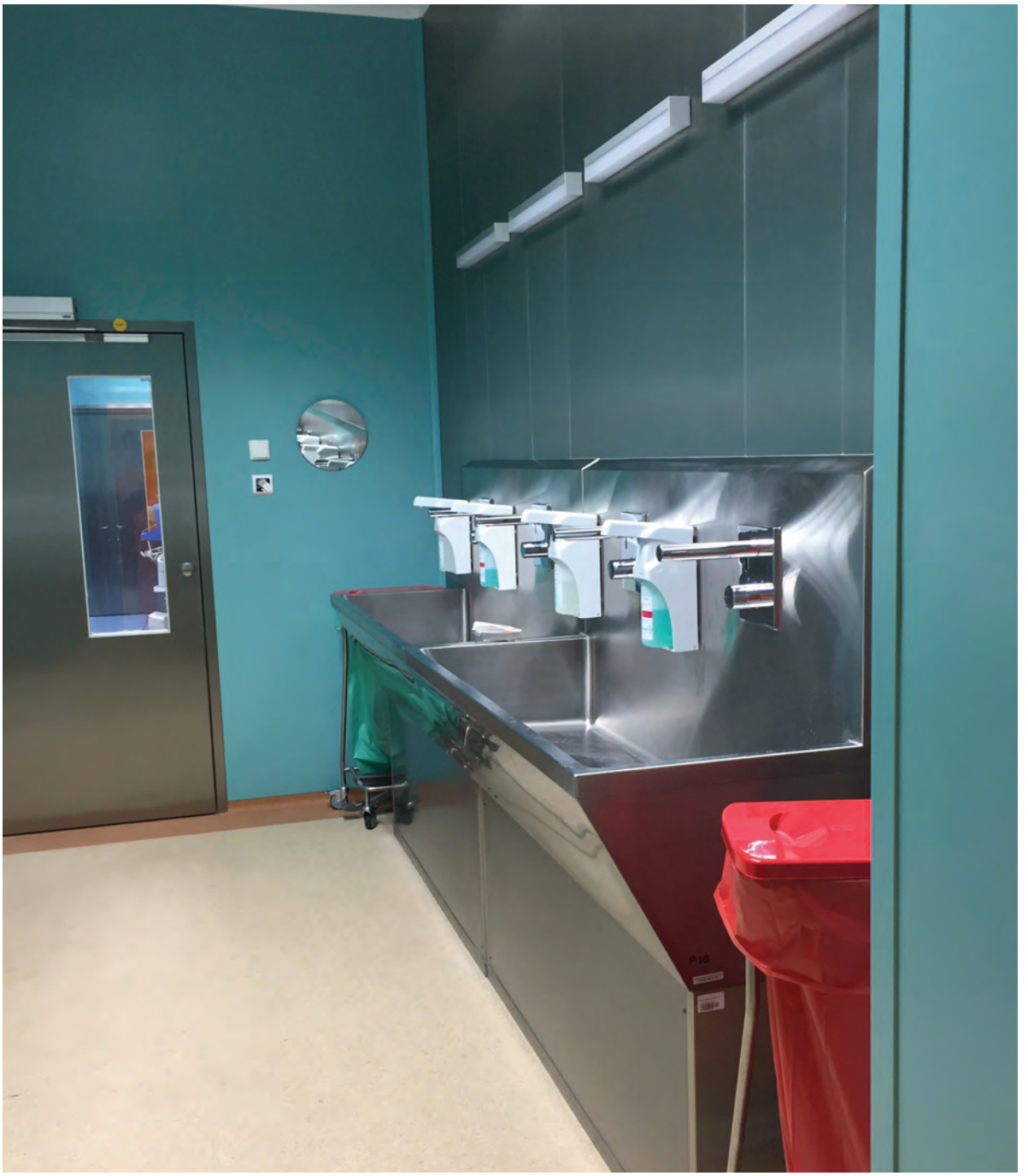
The example of *Klebsiella pneumoniae* allows us to observe a dangerous mechanism of the rapid spread of drug-resistant microorganisms which have become a problem of international significance just within ten years. Drug-resistant bacterial strains come as particular examples proving the necessity of scientific research on non-pharmacological solutions, including architectural solutions in particular, that should limit the spread of infections. In the event of an epidemic caused by drug-resistant microorganisms, such research studies will be of the fundamental importance for epidemiological safety. The implementation of preventive hygienic procedures and the use of architectural protective solutions may reduce the level of infections, for which there have not been any effective treatment methods developed yet, and may lead to the elimination of epidemic outbreaks.

In this context, it is worth noting that architectural and organisational solutions may not only slow down the process of developing drug-resistance in the long-term perspective. In a model theoretical approach, eliminating the possibility of infection transmission may eliminate epidemic outbreaks of exogenous infections caused by drug-resistant microorganisms in medical facilities.

The Author believes that the limited use of antibiotics can be achieved not only by promoting their rational application but also by limiting infection transmission with the use of the potential offered by optimal architectural solutions, as it is discussed in the further parts of the monograph.

| Region | The total number of confirmed infections (N) |
|---|---|
| Austria | 1109 |
| Belgium | 791 |
| Bulgaria | 169 |
| Croatia | 302 |
| Cyprus | 71 |
| Czech Republic | 1051 |
| Denmark | 1185 |
| Estonia | 143 |
| Finland | 758 |
| France | 2807 |
| Germany | 3549 |
| Greece | 1363 |
| Hungary | 681 |
| Iceland | 0 |
| Ireland | 478 |
| Italy | 2634 |
| Latvia | 116 |
| Lithuania | 325 |
| Luxembourg | 99 |
| Malta | 117 |
| Netherlands | 1190 |
| Norway | 781 |
| Poland | 1161 |
| Portugal | 2720 |
| Romania | 334 |
| Slovakia | 450 |
| Slovenia | 312 |
| Spain | 1442 |
| Sweden | 1033 |
| United Kingdom | 5274 |

**Figure 2.3.1** The numbers of invasive infections caused by *Klebsiella pneumoniae* in Europe in 2017 (ECDC Surveillance Atlas of Infectious Diseases, 2018)



**Photograph 2.3.2** A hand hygiene station in front of the operating theatre (proper hand hygiene is of fundamental significance to the prevention of hospital-acquired infections); photographed by the Author, 2014

## 2.4 Architectural achievements in the design of healthcare facilities

Architectural solutions implemented in medical facilities are affected by the advancement of medical knowledge. Among various fields related to healthcare, it is particularly noticeable in epidemiology, considering the ability of architecture to introduce passive protective barriers to infection transmission. *As a field of practical activities and as a branch of medical knowledge, epidemiology originates from infectious diseases and preventive actions undertaken to reduce their occurrence* (Miller and Gębska-Kuczerowska 2009: 290). Epidemiology is defined as *a science about infection transmission and factors that determine the occurrence of situations or events related to the public health conditions in the particular populations and also as a scientific discipline applied to control health problems* (Beaglehole et al. 1996: 15). Epidemiological safety is highly significant to the contemporary society – it comes as one of the elements that affected civilisational advancement at the turn of the 20th and 21st centuries. Today, hospital architecture follows the needs generated by the functions related to the healthcare services. It is possible to observe an interdependency between the state of knowledge about medicine and medical technologies and medical facilities (Tomanek 2015: 22). The concern for the utilitarian character of designed medical facilities is particularly taken into consideration, along with attention paid to safety provided to patients hospitalised there. Each stage in the development of medicine has affected both medical procedures and hospital architecture. A cross-sectional analysis of the transfor-

**Photograph 2.4** A city as a multi-layered structure (an increase in knowledge, advancement of technology and the flow of time change the requirements set to buildings, especially to medical facilities); photographed by the Author, 2018

mations observed in architectural forms of medical buildings indicates that the question of including considerations related to epidemiology has also contributed to such transformations.

Scientists have been looking for the origin of epidemiology in ancient history, when Hippocrates and his contemporary theoreticians expressed the opinions that environmental factors might affect the occurrence and development of diseases (Beaglehole et al. 1996). The very first epidemiological recommendations can be found in the Biblical times (the Bible; the Book of Leviticus 13, 45-46). In the ancient times, diseases were seen as *a manifestation of demons' maliciousness and gods' anger and as a punishment for offending sacred rights and religious rituals* (Juraszyński et al. 1973: 15). The fear stemming from such an attitude often led to the search of adequate remedies. Monumental temples were complemented with facilities where ancient priests – considered to be intermediaries during the process of medical treatment, usually focused on appeasing deities – used to take care of patients. In the culture of ancient Greece, the Asklepieon was built as a temple dedicated to Asklepios (the god of medicine). It was designed as a complex of buildings dedicated to the sick, which was a centre of cultic medicine and experimental therapy practised by priest-physicians (Encyklopedia PWN). One of the most famous project implementations of this type was created in Epidauros in the 6th century BC. In a fenced area covering almost 100 ha, several buildings were constructed to perform functions associated by the ancient people with the concept of physical and mental health. They included a theatre, a stadium, a gymnasium, a bath and some other auxiliary buildings (Przybyłek 2011).

In medieval Europe, hospitals were initially created as religious centers where clergymen and priests were responsible for their management and medical care provided to patients. In medicine, a miasma theory of diseases started to be disseminated. According to the theory, infectious diseases (including bubonic plague and cholera) were caused by contaminated air, putrid vapours of rotting animal organisms and plants. At that time, various types of hospitals could be found: monastic hospitals, diocesan hospitals, municipal hospitals, hospitals and nursing houses located outside the city walls (Juraszyński et al. 1973).

The Middle Ages are also associated with leprosaria. A leprosarium was an institution for isolating leprosy patients from the society to prevent the spread of the disease. It was a kind of the first laboratory dedicated to medical treatment of infectious diseases. Despite the fact that the existence of such facilities was historically documented, starting from the records made in the ancient times, historians identify the time when the first European leprosaria appeared as the 7th or the 8th century, indicating the famous facility in St. Gallen constructed in 759 AD (Llopis Verdú et al. 2018). Since then a lot of other specialised facilities were constructed to provide shelter and care to the ill in the entire area of the Middle East and in Europe. Quickly, large numbers of leprosaria were established and funded by the Catholic Church or other Christian organisations, such as the military Order of Saint Lazarus of Jerusalem. The characteristic architecture of those facilities included complexes of buildings with chapels, common rooms and gardens, usually located outside urban areas. Some isolation units were small "nursing houses for lepers", other units were larger hospitals where medical care was provided to more patients. Frequently, they were located near a larger hospital complex or in the vicinity of a monastery; however, they were still independent centers with their own chapels and cemeteries. Care was provided to patients by monks and nuns who used to live under the regime of the monastic clause and who had often been trained in medical care (Meek 2016). Over the centuries, leprosaria became a common sight in the entire territory of Europe. They frequently took a form of a fortress isolated on an island, where

the ill existed as a community isolated from the world, as it occurred in the fortresses of Sanatorio San Francisco de Borja (Spain) and Leprosaria Nacional Rovisco Pais (Portugal), the islands of Spinalonga (Greece) and Venetian San Lazzaro degli Armeni (Italy) (Llopis Verdú et al. 2018). In the course of time, the numbers of leprosy cases decreased, so a lot of leprosaria, especially those belonging and managed by the Church, were transformed into nursing houses or they still functioned as hospitals, however, they were dedicated to patients who were suffering from various diseases other than leprosy.

At the turn of the 12th and the 13th centuries in England, the medieval European revival of sacral architecture was accompanied by the establishment of a large number of nursing facilities dedicated to the ill and the poor, usually referred to as hospitals and alms-houses. The first European hospitals, such as St Bartholomew's Hospital founded in 1123, were dedicated to *poore dieased till they get well,* as stated in the foundation act. It also provided shelter for pregnant women and orphans. At St Bartholomew's Hospital simple surgery procedures in the field of traumatology were also carried out. In the 13th century, the facility was reconstructed and its redevelopment significantly contributed to the establishment of the first hospital complex characterised by *the spatial decentralisation of the elements of the complex and distribution of patients in several separate buildings.* Today the hospital is recognised as the first hospital constructed in the pavilion system (Porębowicz 1962b).

During the Renaissance, architectural achievements in the design of hospitals continued. Dedicated to care provided to the poor and the sick, medical facilities started to be passed under secular administration. Their aesthetics started to lose sacral stylistic features and they were often located in central parts of the urban tissue. At the beginning of the 15th century in Florence the Hospital of the Innocents (in Italian: *Ospedale degli Innocenti*) was established. It was one of the first Renaissance project implementations, originally designed by Filippo Brunelleschi as an orphanage. It was founded by the Florentine guilds of silk merchants and goldsmiths (Olenderek and Borowczyk 2016). Another famous Renaissance hospital, Ospedale Maggiore di Bologna, was built in 1456. Designed by Antonio Averlino, an architect called il Filarete, the building was an example of a hospital that went beyond the usual medieval spatial layout, following the architectural aesthetics of the Renaissance. The building represented a new approach toward hospital characteristics. Among patients under medical care, there were fewer people suffering from infectious diseases, as they were usually referred to separate facilities. The hospital employed mostly secular physicians, who based their professional activities on the knowledge acquired through practical research studies. During that time, spatial complexes with comprehensive design solutions started to appear. They incorporated then modern architectural measures to provide epidemiological safety, taking patient segregation by disease into account. Patient rooms were equipped with gravity ventilation and sanitary fixtures for efficient water supply needed for hygienic purposes and for sewage disposal. Separate treatment rooms and medicine and medical equipment storage rooms were also designed. Undoubtedly, some considerable advancement was observed in comparison to simple spatial layouts applied without any particular design at medieval hospitals. Medical facilities of that time *can be considered to be the first modern inpatient healthcare centres* (Porębowicz 1961a). Later on, they were followed by other project implementations, such as Hôtel-Dieu de Paris established in 1561, Juliusspital in Würzburg established in 1576 and St Louis Hospital built in Paris during the years 1607-1612 (Porębowicz 1961b).

The subsequent changes to the architecture of hospital facilities were related to the development of surgery and gradual recognition of the phenomenon of infections. The main organisational modifi-

cations in medical treatment that directly affected the design of the spatial layout occurred at the turn of the 18th and the 19th century. They resulted from the methods of clinical research that were carried out at that time and the commencement of the classification of disease entities. Another significant stage was commenced with the sterilisation of medical instruments and operating theatre equipment, applied after the recognition of the importance of asepsis proved by the research studies carried out by Ernst Bergmann and Curt Schimmelbusch. At that time, autoclaves and sterilisation cans were introduced (Tomanek 2015).

While discussing the development of hospital treatment, the scientific studies by Jacques-René Tenon are often mentioned. He analysed several hospitals operating in Europe at that time in order to describe their architecture seen as a spatial layout fostering medical treatment. He published the results of his research in *Mémoires sur les hôpitaux de Paris* in 1788. The French surgeon pointed out the advantages resulting from the organisation of the horizontal space of a hospital designed as a pavilion system. He also indicated advantages resulting from proper ventilation and the significance of the natural light as methods of changing the two most unhealthy elements in the hospital environment, namely: air stagnation and humidity. Furthermore, he suggested that proper dimensions in each hospital pavilion should be applied, the maximal numbers of patient beds in hospital wards that could provide each patient with the assumed minimal amount of air (Costeira 2015).

In the 19th century, the intensification of the research studies on the impact of the environment inhabited by people on their health could be observed, along with the interest in the analysis of a phenomenon conditioning the spread of diseases in large urban populations. An example of such research studies are observations made by John Snow, an outstanding British physician considered to be a pioneer of contemporary epidemiology (Beaglehole et al. 1996). Due to the analysis carried out during the epidemic outbreaks of cholera in 1848 and 1853 in London and its vicinities, Snow related the risk of the disease occurrence with the method used by water supply companies for providing fresh water to the city inhabitants (Gańczak 2014). Some similar research was carried out by another English physician, William Farr, a pioneer of medical statistics. These were the first scientific studies that took the significance of the urban environment to its inhabitants' health into consideration.

A breakthrough in the modern understanding of nosocomial infections occurred relatively late. At the beginning of the 19th century, John Bell still continued to advise his patients to leave hospital as quickly as possible after their treatment, because staying there exposed them to gangrene followed by death (Dziąba 2010). At that time, surgery was the ultimate medical intervention, considering the high mortality rates – almost 75% of all the cases - among patients who underwent medical operations (Głowala 2018). Despite the fact that he noticed the harmful influence of keeping patients in crowded urban hospitals, the famous surgeon was not able to find any efficient preventive solution (Barber 1961).

The problem of hospital-acquired infections was analysed as an epidemiological phenomenon at the time when the first organised hospital units started to appear. The precursor who provided the definition of that phenomenon was Ignaz Semmelweis. In the guidelines published in 1943, Semmelweis pointed out that diseases might be spread on the hands of medical personnel, who used to work with corpses in the morgues in the mornings and then used to provide care and assistance to patients located at various parts of the hospital. In 1847 the physician recommended medical personnel to wash their hands in chloramine before they performed any medical tests or treatment procedures. As a re-

sult, a decrease in the number of deaths was recorded among patients suffering from puerperal fever at that time (Best and Neuhauser 2004; Dziąba 2010). Over four decades later this observation was confirmed by Louis Pasteur, who clearly stated that the indirect cause of puerperal fever are members of medical staff, who transmitted microorganisms (Głowala 2018). Around the same time, in her *Notes on Nursing*, Florence Nightingale (1859) made an observation on the possibility of the negative influence exerted by hospital environment on patients. In her publication, she formulated the key principles on the design of hospital environment. Nightingale associated hospital cleanliness with the improvement in patients' health. According to her recommendations, hospital architecture should provide fresh air, clean water, efficient sewage systems and clean rooms, well-lit with natural light (Verderber 2010).

The fundamental change in the perception of hospitals and hygienic control was brought about by scientific research in the field of microbiology, including the discoveries made by Louis Pasteur in the 1850s and Robert Koch in the 1880s. Another milestone was the introduction of the principles pertaining to antisepsis, that is namely: disinfection of the skin, mucous membranes, injured tissues with agents that are not harmful to human tissues (Heczko et al. 2009). The principles of antiseptic treatment were first introduced by Joseph Lister. In the 1860s, referring to his clinical observations and basing his inspiration on the results achieved by Pasteur, he recommended the use of antiseptic agents (on the basis of carbolic acid) for hand washing by medical personnel and disinfecting medical instruments in operating theatres. In that way, he contributed to the revolution in surgery (Barber 1961; Dziąba 2010).

In 1886 a German surgeon, Gustav Neuber published his scientific study, in which he justified the necessity of using aseptic separation and septic procedures in operating theatres (Głowala 2018). At the same time, the concept of a hospital built in the pavilion system was reformulated as the implementation of a postulate for segregation and isolation of patients as the tools applied to prevent infections inside hospital environment. Based on that principle, several hospitals were constructed, for example, Hopital Lariboisière designed by Martin-Pierre Gauthier, an architect, and built in Paris in the years 1846-1854 and the Rudolf Virchow Hospital, designed by L. Hoffmann and built in Berlin in the years 1899-1906. However, the pavilion hospital model had also some disadvantages related to the difficulties with transporting patients across the vast hospital areas and to the problems resulting from the lack of expansion possibilities. Those problems caused that the pavilion hospital model was gradually abandoned in favour of several-storey hospital buildings, where electric lifts were used for vertical communication. Since then, the compact block hospital model was applied in the subsequent project implementations, a European example of which was Hopital Beaujon-Clichy designed by Jean Walter and built in Paris in the years 1933-1935 (Juraszyński et al. 1973; Zieliński 2009).

At the beginning of the 20$^{th}$ century, the promotion of aseptic practices aimed at preventing tissue infections and contamination of sterile surfaces (Heczko et al. 2009) strengthened the significance of hospital architecture understood as an important element in infection control. Protection against infections did not refer only to the patient's body but it was extended to cover the entire medical facility and, in that way, it permanently combined safety and comfort of medical treatment with the ideas of disinfection and sterilisation.

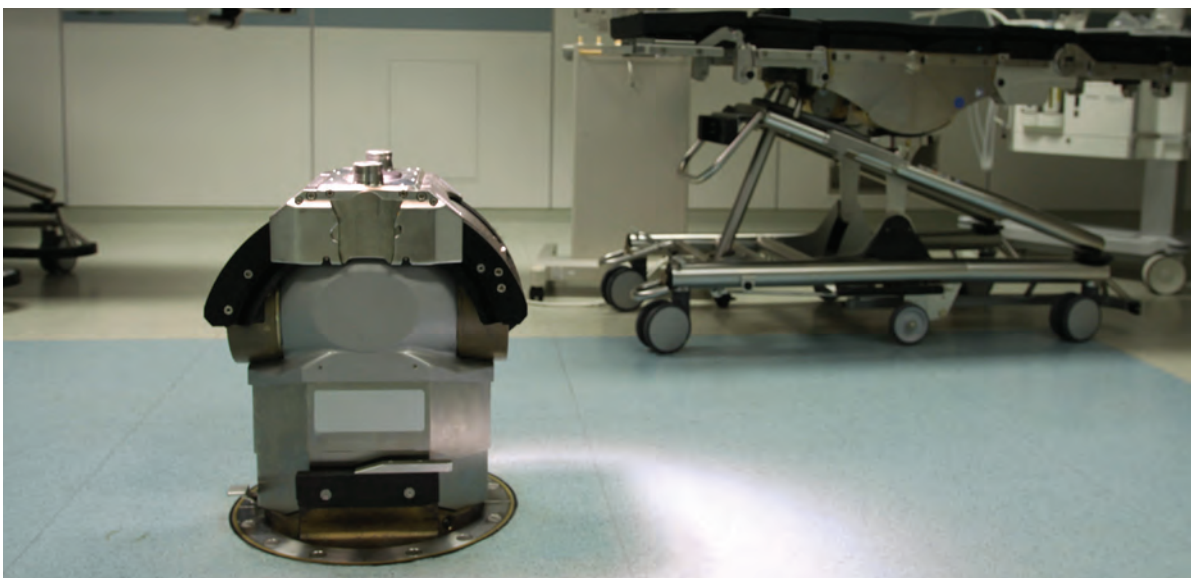
Considered from the perspective of architectural solutions related to epidemiological safety, the 19$^{th}$ century became a turning point. At that time, some fundamental changes to the design of medical facilities were made. During the subsequent years, they formed a long-term process of an evolving character, adjusted to the advancement of knowledge. Large-scale epidemiological research studies and

the development of their theoretical and methodological foundations were commenced in the 1950s. In the subsequent decades, the development of digital calculation technologies started the application of advanced statistic methods and development of theoretical models that were applied to explain multi-causal aetiology of diseases. At first, epidemiological research studies were focused on aetiology (identifying the reasons) of infectious diseases. This type of activities prevailed until the moment when preventive methods were discovered (Beaglehole et al. 1996).

The appearance of penicillin antibiotics in the 1940s initially seemed to be the ultimate response to the threats posed by nosocomial cross-infections. At that time, the era of antibiotics was heralded but the early hopes pinned on antibiotics were never fulfilled. Initially, antibiotic treatment was effective in the cases of streptococcal infections (in Latin: *Streptococcus*), however, it failed in the cases involving infections caused by many other microorganisms, especially by Staphylococcus strains (in Latin: *Staphylococcus*) that were able to develop drug-resistance. So far, these bacterial strains have become drug-resistant to commonly applied antibiotics and the problem related to their growing share in the numbers of nosocomial infections has become more and more serious (Barber 1961).

In the 1960s in larger hospital complexes in the United States the establishment of hospital infection control committees was recommended. Similar recommendations were issued by the Council of Europe in 1972 (Wójkowska-Mach 2009; Dziąba 2010).

In 2005 the European Centre for Disease Prevention and Control (ECDC) was established as an independent agency of the European Union, with the headquarters in Sweden. It is responsible for the recognition, evaluation and information about the current and on-coming threats related to infectious diseases. Initially, the guidelines in the field of control and prevention of nosocomial infections referred to the implemented procedures, however in the recent decade some recommendations have been issued that are directly related to hospital architecture and the design of its technical infrastructure (*ECDC Surveillance Report…*, 2013).

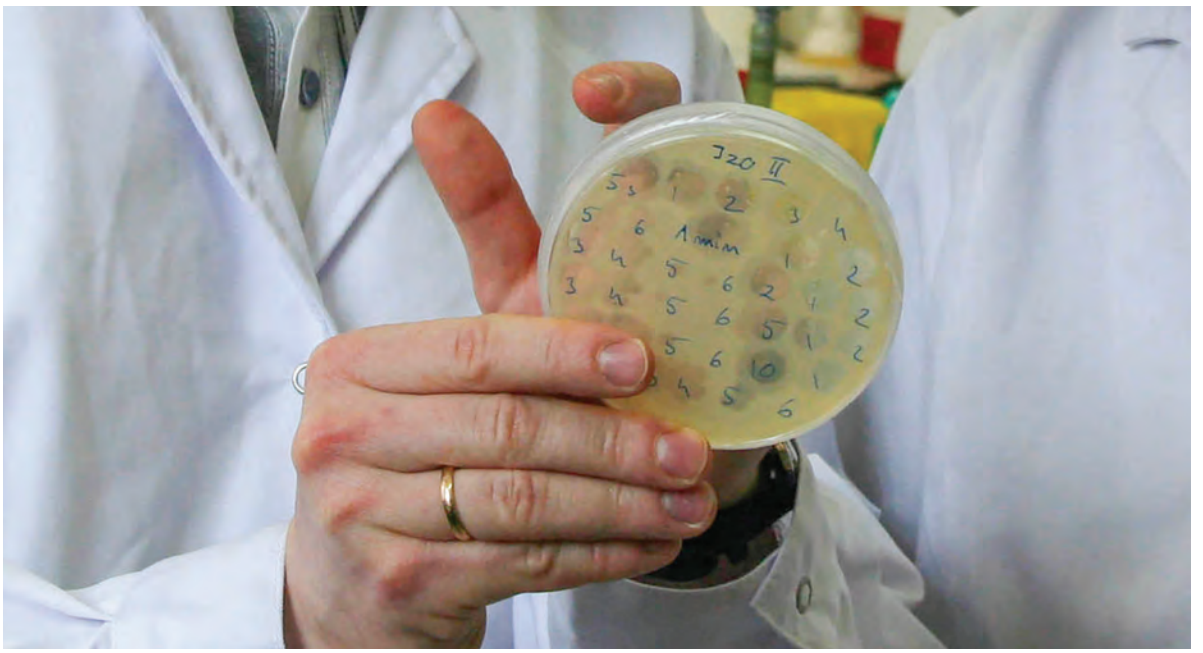


**Photograph 2.4.1** A mobile operating table (an example of the impact exerted by the technology on the design of medical facilities); photographed by the Author, 2014

# 3. Hospital-acquired infections in Poland

According to the information and statistic reports provided by the Central Statistics Office in Poland, in 2016 7.8 million patients were hospitalised in Poland (*Information…* GUS 2017: 81). In accordance with the data provided by the National Consultant for epidemiological nursing, since that time the situation concerning nosocomial infections has been stable and even slightly improving. However, the problem still seems to be an issue of a large scope and scale. Healthcare-associated infections may refer to approximately 700 000 patients annually, which is about 8-10% of all hospitalised patients. This is an estimated number (in specialist literature, it is possible to find estimations assuming the levels of 5-10% of hospitalised patients) and the precise determination of the scale of the occurrence is impossible due to the lack of any nation-wide, standardised and globally recognised tools and research programmes dedicated to healthcare-associated infections (Ochocka 2017). The problem related to the limited reliability of the infection surveillance system in Poland makes statistical evaluation of threats and the efficiency of the solutions applied to reduce them even more difficult. Similar conclusions are presented in a report issued by the Supreme Audit Office. It is stated that during the time period between 2015 and the first half of 2017, nosocomial infections were acquired by 1.5% of patients hospitalised in the surveyed hospitals (*The Report…* NIK 2018: 44). The report also indicates that the real number of hospital-acquired infections can be even five times higher than the number provided by the Ministry of Health in the maps of healthcare needs (Ibid.: 11). Such data would allow us to determine the nosocomial infection rate at the level of 7.5% of hospitalised patients.

Regardless of the assumed rate, the above-mentioned data suggests that the problem of nosocomial infections comes as an issue of a vast scope and significance and that infections inside medical facilities may refer to about one up to several percent of the entire population in Poland annually.



**Photograph 3.0** A colony of bacteria on a microbiological basis (proper identification of microorganisms allows for adequate selection of remedial measures); photographed by the Author, 2016

The high discrepancy between the reported and actual levels of nosocomial infections indicates the limited possibilities of analysing the efficiency of the current system, based on the reported statistical data. The data comes as a basis for identification of places that differ in their infection numbers from the assumed levels, which may become a reason for a more detailed, multi-aspect analysis and evaluation of architectural solutions.

Moreover, the report of the Supreme Audit Office states that in 2018 the share of alert pathogens – understood as biological pathogenic agents of particular virulence or resistance - in the group of analysed nosocomial infections reached the level of 65.5% (*The Report…* NIK 2018: 44). The consequence of that occurrence, which has become of particular concern at medical facilities, is the mortality caused by nosocomial infections. At present, hospital-acquired infections can be perceived as medical, organisational, social and economic problems, considering longer medical treatment and the necessity of undertaking additional actions that require additional measures, the value of which might be difficult to estimate (Graves 2018). Hence, the search of solutions that could reduce the scale of infections by, for instance, proper design of medical facilities should be considered as well-justified and rational.

**Photograph 3.0.1** A multi-bed patient room (the distance between patients affects the possibility of infection transmission); photographed by the Author, 2012

## 3.1 The structure of nosocomial infections in Poland

The structure of infections caused by alert pathogens varies in time, as it can be observed on the European scale by following the information presented in the *ECDC Surveillance Atlas of Infectious Diseases* (2018). In Poland, according to the report issued by the Supreme Audit Office, during the time period between the years 2015 and the first half of 2017, the largest share in nosocomial infections among 7809 alert pathogens was identified for the following:

- gram-negative bacilli – *Enterobacteriaceae spp.* that produce beta-lactamases of the extended substrate spectrum (e.g.: ESBL, AMPc, KPC) or resistant to carbapenems or two other groups of drugs or to polymyxins – 37.4% of the total number of isolated pathogens and 24.8% of the total number of nosocomial infections;
- pathogenic strains of *Clostridium difficile* anaerobic bacilli and the A and B toxins they produce – 22.6% of the total number of pathogens and 14.9% of the total number of nosocomial infections;
- *Acinetobacter spp.* resistant to carbapenems or two other groups of drugs or to polymyxins – 10.4% of the total number of pathogens and 6.9% of the total number of nosocomial infections;
- biological pathogens isolated from blood and cerebrospinal fluid responsible for general and invasive infections – 7.8% of the total number of pathogens and 5.2% of the total number of nosocomial infections;

**Photograph 3.1** Laminar ventilation flow above an operating table (a solution providing clean air in the surgery area); photographed by the Author, 2018

- *Staphylococcus aureus* resistant to methicillin (MRSA) or to glycopeptides (VISA or VRSA) or to oxazolidinones – 6.9% of the total number of pathogens and 4.6% of the total number of nosocomial infections;
- Rotavirus – 5.7% of the total number of pathogens and 3.8% of the total number of nosocomial infections;
- *Pseudomonas aeruginosa* resistant to carbapenems or two other groups of drugs or to polymyxins – 4.4% of the total number of pathogens and 2.9% of the total number of nosocomial infections (*The Report…* NIK 2018: 44).

As presented above, the information allows us to state that during the analysed period of time, the particular groups of microorganisms differ as far as the levels of the observed numbers of infections are concerned. The most frequently isolated alert pathogens are: *Enterobacteriaceae spp.* and *Clostridium difficile* that together account for 39.7% of the total number of nosocomial infections. The knowledge about the structure of infections allows interested parties to estimate the probability of an epidemic outbreak at a medical facility and it can be used for the requirements of the risk analysis. It also comes as one of the prerequisites in analysing the efficiency of the activities undertaken by medical units to fight specific microorganisms.

The changes to the structure pertaining to the share of alert pathogens causing epidemic outbreaks can be observed by comparison of the data reported in the Pomorskie Province in 2015 (Fig. 3.1.1) with the data reported in 2016 (Fig. 3.1.2).

**Photograph 3.1.1** A corridor (technical infrastructure in a modern hospital is an extended, complex structure that requires the HAI risk analysis); photographed by the Author, 2014

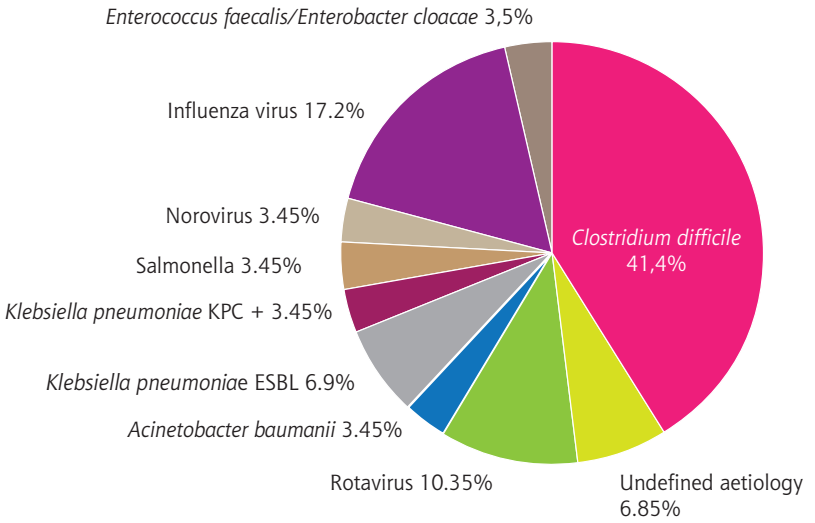



**Fig. 3.1.1** The percentage of alert pathogens causing epidemic outbreaks in 2015 in the Pomorskie Province; the Provincial Sanitary Inspector of the Pomorskie Province 2018

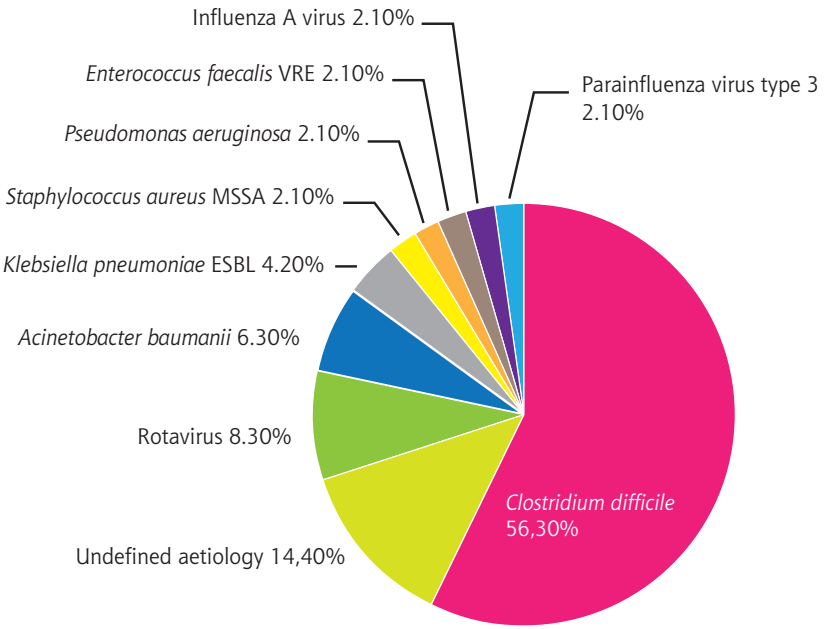
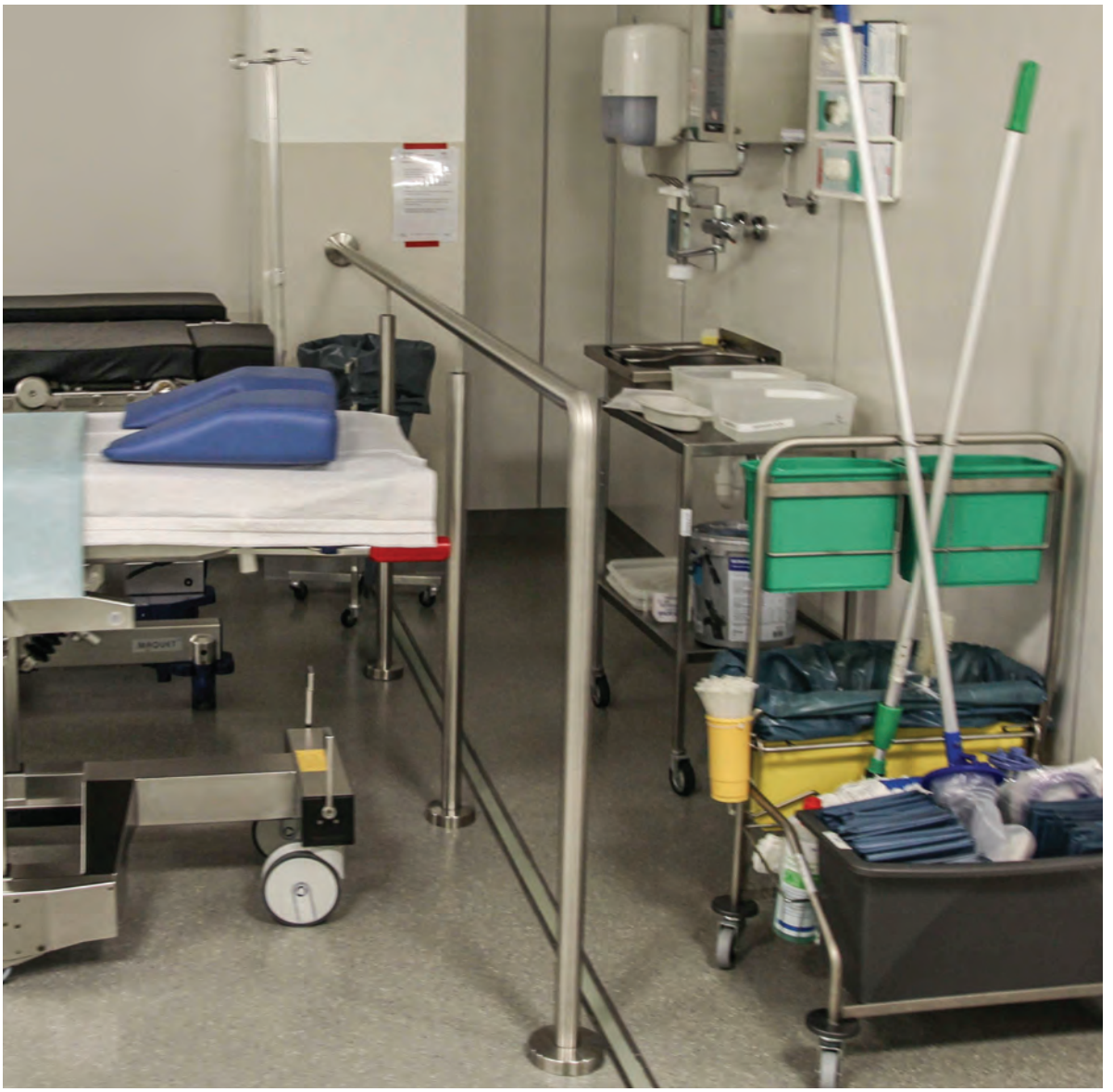



**Fig. 3.1.2** The percentage of alert pathogens causing epidemic outbreaks in 2016 in the Pomorskie Province; the Provincial Sanitary Inspector of the Pomorskie Province 2018

The knowledge about the structure of infections and transmission routes of pathogens allows for the analysis of pathogen transmission ways in the context of architectural and organisational solutions and to implement additional solutions aimed at the elimination of epidemic outbreaks. In the further parts of the monograph, the impact exerted by various tools applied to design the space of medical facilities on infection transmission is analysed.



**Photograph 3.1.4** A decontamination station for operating tables (the management of materials and disinfectant agents is an important aspect in the prevention of hospital-acquired infections); photographed by the Author, 2015

## 3.2 The distribution of infections in hospital environment

The general structure of infections in Poland is not identical with their distribution considered in the scale of a hospital or located within an organisational unit of a hospital. The analysis of the HAI statistics provides an opportunity to observe infections typical of some nursing departments, treatment departments or auxiliary departments, such as central sterilisation units. The statistical data allows for the analysis of infections in terms of the types of microorganisms or areas where infections have been identified. In Figure 3.2.1, the data collected in the Pomorskie Province are presented in reference to infections caused by *Clostridium difficile,* gram-positive anaerobic bacteria forming spores and producing toxins. Figure 3.2.2 presents the data on infections caused by *Enterococcus VRE* – bacterial strains that belong to the group of Enterococci that develop resistance to vancomycin.

The comparison of the information on infections caused by rotaviruses and noroviruses in the Pomorskie Province is presented in Figure 3.2.3, and it indicates that during the analysed period of time, such infections were mainly reported in paediatric nursing departments. Additionally, it is possible to observe the intensity of nosocomial infections that varies in time (Figure 3.2.3) and to identify areas of the higher infection risk (Figure 3.2.4). Considering the scale of a medical unit, it allows for creating and updating infection maps. An infection map is a document that allows interested parties to refer the observed data to the planned and referential values. In the context of architectural solutions, the confirmation of excessive numbers of infections should result in the analysis of environmental and spatial conditions.

**Photograph. 3.2** Dirty utility room; photographed by the Author; 2018

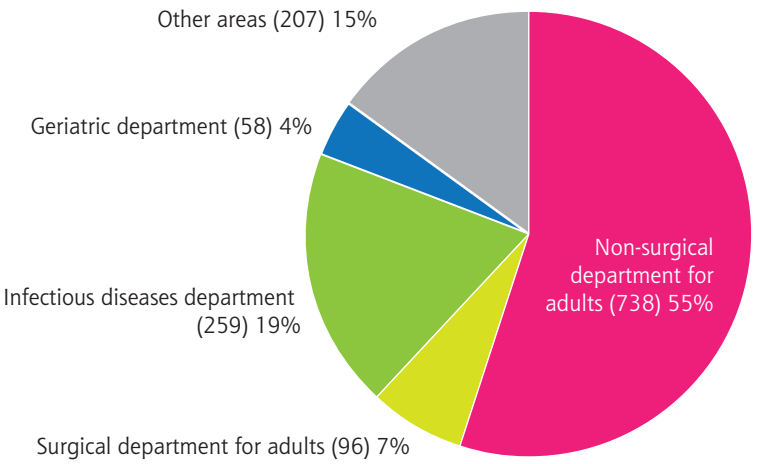



**Fig. 3.2.1** Distribution of infections caused by *Clostridium difficile* in a statistical unit with the indication of the number of the reported cases, their types and the areas of their occurrence in the Pomorskie Province (The State Sanitary Inspector of the Pomorskie Province, 2018)

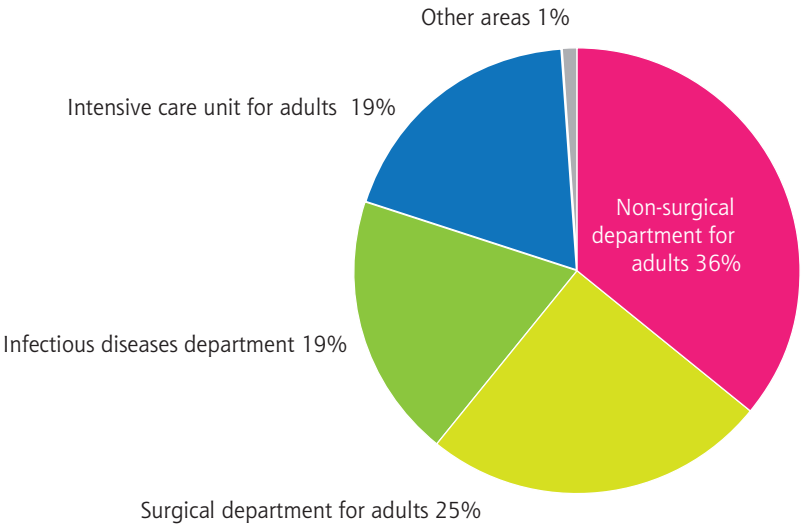



**Fig. 3.2.2** Distribution of infections caused by *Enterococcus VRE* in a statistical unit with the indication of the number of the reported cases, their types and the areas of the occurrence in the Pomorskie Province (The State Sanitary Inspector of the Pomorskie Province, 2018)

The statistical data presented in Figures 3.2.1 and 3.2.2 confirms the volatile nature of threats posed by the selected microorganisms, depending on the type of a hospital department. The data also indicates the significant overall share of non-surgical areas in the spread of some nosocomial infections. In Poland, nosocomial infections reported within the areas of medical treatment departments reach low levels in relation to the total number of hospitalised patients, as respectively stated in percentage: 1.76%

(2015); 1.8% (2016); 2.3% (1st half of 2017) (*The Report…* NIK 2018: 44). However, while analysing the particular types of infections, the infections caused by *Clostridium difficile* should be considered as significant in the quantitative approach in 2017 in the Pomorskie Province, as they referred to 54% of nursing departments for adults, where 738 cases were reported (*The Information...* Provincial Sanitary and Epidemiological Station 2018).

The analysis of the data allows the reader to note that the selected infections are typical of some areas, as it is presented in Figure 3.2.3, on the example of the statistics on infections caused by rotaviruses and noroviruses, where the numbers of infection cases are compared to the areas of their occurrence.

| DEPARTMENT | ROTAVIRUSES | NOROVIRUSES |
|---|---|---|
| Non-surgical for adults | 79 5% | 3 2.5% |
| Non-surgical for children | 1395 84% (1180+215) | 114 95% (106+8) |
| Haematology | 32 2% (14+18) | 2 2% |
| Infectious diseases | 148 9% (136+12) | 0 0 |

**Figure 3.2.3** A comparison of the statistics on infections caused by rotaviruses and noroviruses in the Pomorskie Province, with the number of the reported cases, their types and areas of their occurrence (The State Sanitary Inspector of the Pomorskie Province, 2018)

The statistics on infections caused by rotaviruses and noroviruses indicates an increased level of morbidity reported in paediatric non-surgical departments. Today, transmission routes of these microorganisms have been already known. Hence, there is a need for an individual analysis of architectural solutions applied at paediatric departments with the consideration of the epidemiological aspect. Due to the confirmation of increased levels of infections caused by various pathogens, it is possible to undertake architectural activities to reduce their transmission. The problem is further discussed in the following parts of the monograph.

| | The number of hospitalised patients | The number of patients with confirmed infections | Percentage |
|---|---|---|---|
| Anaesthesiology and intensive care units | 2340 (2015)<br>2938 (2016)<br>1414 (1st half of 2017) | 775 (2015)<br>1037 (2016)<br>537 (1st half of 2017) | 33.11%<br>35.29%<br>37.97% |

**Figure 3.2.4** The statistics on nosocomial infections at anaesthesiology and intensive care units in Poland (*The Report...*, NIK 2018: 44)

Epidemiological data also indicates the areas where especially high levels of nosocomial infections have been reported. A particularly high level of hospital-acquired infections has been observed at anaesthesiology and intensive care units. The data on the confirmed infection cases presented above is provided in the report published by the Supreme Audit Office.

In accordance with the data provided by the Supreme Audit Office, in Poland the risk of hospital-acquired infections is about 18 times higher at the anaesthesiology and intensive care units than at medical treatment departments: in 2015 from 33.11% to 1.76%, in 2016 from 35.29% to 1.8% and in the 1st half of 2017 from 37.97% to 2.3% (*The Report…* NIK 2018: 44). This situation indicates the need for an analysis of the current requirements defined for this area. In the subsequent parts of the monograph, the analysis of architectural solutions required by the current regulations defined for the anaesthesiology and intensive care units is provided, with the reference to the research studies and the possibility of reducing infection transmission with the use of additional spatial solutions that go beyond the current regulations.

The analysis of epidemiological information allows interested parties not only to analyse the risk of infections in the particular areas but also to measure the levels of infections in various groups of medical facility users. According to the information provided by the State Sanitary Inspector of the Pomorskie Province, in the years 2014-2016 epidemic outbreaks posed threats both to patients and medical personnel (Figure 3.2.5). Statistically, in the case of an epidemic outbreak, several patients become infected and there is approximately 50% of the chance that at least one member of medical staff at the medical unit shall be infected too. The data indicates the need for an analysis in the field of architectural and organisational solutions, not only in the context of infection transmission among patients but also between patients and medical personnel members.

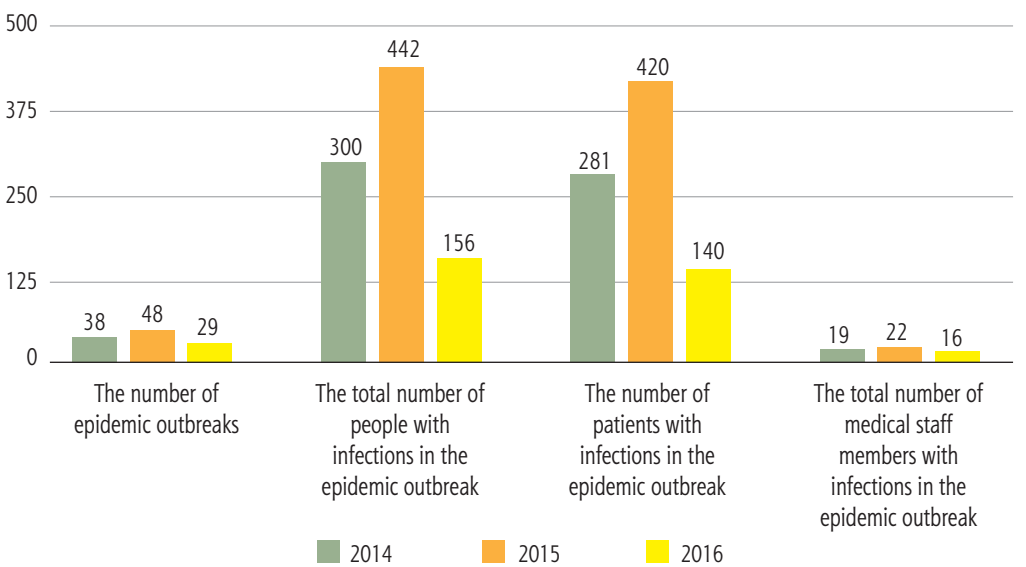
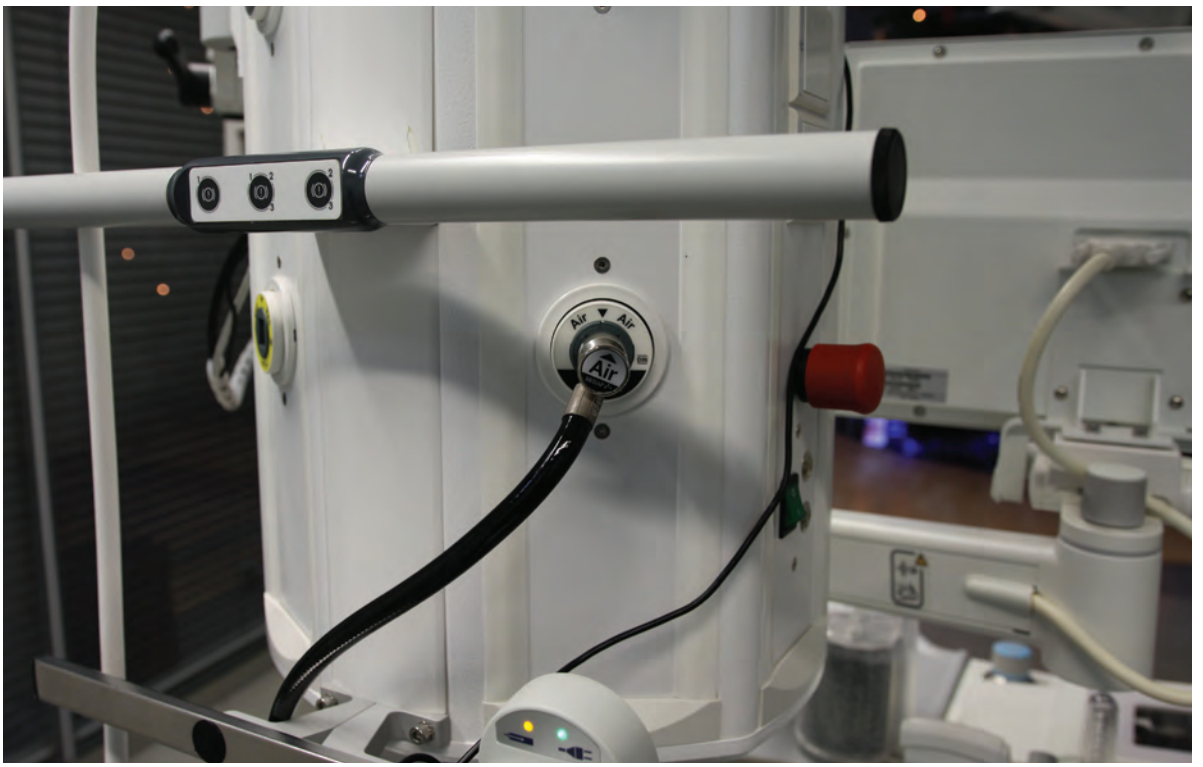



**Figure 3.2.5** A comparison of the structure of infections in an epidemic outbreak, in accordance with the data provided by the State Sanitary Inspector of the Pomorskie Province, 2018

## 3.3 Basic elements of the epidemiological surveillance system in Poland

In Poland, the institutional basis of the public epidemiological safety system is the State Sanitary Inspectorate of a complex structure. At the national level, it is represented by the Chief Sanitary Inspector, whereas at the regional and district levels by the Provincial Sanitary Inspectors and District Sanitary Inspectors. The institution carries out inspections in the field of implementing activities aimed at prevention and elimination of infections and infectious diseases in humans (Journal of Laws 2008, no. 234, item 1570, i.e.: Journal of Laws 2018, no. 151, item 1669). The role of the State Sanitary Inspectorate in the Polish epidemiological safety system consists *in the implementation of tasks in the field of public health, especially through the supervision over (…) hygienic and sanitary conditions that must be met by medical personnel, medical equipment and facilities where healthcare services are provided, in order to protect human health against adverse impact of environmental harmful factors and nuisance, prevention of diseases, including infectious and occupational diseases* (Journal of Laws 1985, no. 12, item 49, i.e.: Journal of Laws 2019, item 59). The activities in the field of infection prevention with the use of architectural design are carried out by a specialised organisational department, whose tasks include the following:




**Photograph 3.3** An anaesthesia column; photographed by the Author; 2018

- agreeing on design documentation in terms of hygienic and health requirements;
- providing information and consultation on preventive actions in the field of sanitary surveillance and supervision;
- issuing opinions on the fulfilment of the requirements stated in the current regulations for facilities dedicated to healthcare activities (*The Information…* State Sanitary and Epidemiological Station 2018).

These tasks prove the involvement of the state bodies in the surveillance and design of architectural solutions facilitating epidemiological safety. In Poland, the current legal system is based on the control over the implementation of solutions described in the current regulations. In the field or architectural solutions pertaining to epidemiological safety, these regulations have the character of minimal requirements. The guidelines referring to the principles of designing healthcare facilities are described in the current regulations, however their scope is inadequate to the actual current needs.

The insufficient description of standards in the field of epidemiological safety in the Polish law is still being completed by numerous initiatives aimed at developing efficient infection control programmes. These problems are analysed by various associations and organisations. Among them, the following should be listed: the Polish Society of Hospital Infections, the Polish Association of Epidemiological Nurses, the Polish Society for Medical Hygiene, the Polish Society for Clinical Microbiology. A panel of experts appointed by those organisations has developed a report with the suggestions of changes and improvement guidelines for the current infection control system related to healthcare in Poland (Bulanda et al. 2016).

Unfortunately, the current system of legal regulations in Poland does not allow the Preventive Supervision bodies to implement upon demand any non-standardised solutions coming from sources other than architectural solutions stated by the law. In accordance with the Constitution of the Republic of Poland of 2nd April 1997, *the public administration authorities act upon the basis and within the limits of the law* (Journal of Law 1997, no 78, item 483 art. 7). Hence, it results in limited effectiveness of executing the guidelines included in the documents issued by various medical organisations, which however are not stated in the current legal regulations.

Any possible implementation of additional solutions may result from activities undertaken at the level of particular medical units and from recommendations provided by nosocomial infection control teams or it may take place upon decisions made by managers of healthcare facilities. In accordance with the legal regulations in Poland, healthcare facility managers are responsible for the implementation of sanitary and hygienic solutions intended to prevent the spread of infections and infectious diseases. In particular, they should undertake the following activities:

1) *evaluating the risk of the occurrence of healthcare-associated infections;*
2) *monitoring alert factors and healthcare-associated infections within the scope of medical services that are provided;*
3) *developing, implementing and supervising the procedures for the prevention of healthcare-associated infections and infectious diseases (…);*
4) *applying individual and collective protective measures in order to prevent the transmission of biological pathogenic agents onto other people;*
5) *carrying out laboratory tests and providing the analysis of the local epidemiological situation in order to optimise prevention and antibiotic treatment;*

6) *providing internal supervision in the field of task implementation (…) (Journal of Laws 2008, no. 234, item 1570 art. 11, section 2, with later amendments).*

For the purpose of implementing and ensuring the proper functioning of the prevention and elimination of nosocomial infections, healthcare facility managers appoint hospital infection control teams composed of medical unit employees, including physicians, nurses and microbiological diagnostic specialists. According to the Act, such teams are responsible for the following:

1) developing and updating the system of prevention and elimination of hospital-acquired infections;
2) providing internal control (…) with the results and conclusions drawn after the internal control and presenting them to the hospital manager and hospital-acquired infection control committee;
3) training staff members in the field of hospital-acquired infection control;
4) providing consultations to people suspected of developing an infection or an infectious disease and to people who have developed an infection or an infectious disease (Journal of Laws 2008, no. 234, item 1570 with later amendments, art. 15, section 2).

Today, in Poland, the role of architectural solutions in the system of epidemiological protection is underestimated. Even a broad analysis of the healthcare-associated infection control carried out and presented in *The System of Healthcare-associated Infection Control in Poland* (Bulanda et al. 2016) does not unequivocally refer to the methods of using the potential of nosocomial infection prevention provided by architectural solutions. It defines the key elements of the hospital infection control programme as the following:

- *structures responsible for the development and implementation of the programme;*
- *support to the hospital administration;*
- *risk management;*
- *HAI monitoring;*
- *the internal and external communication system;*
- *development and implementation of procedures on the basis of evidence-based medicine;*
- *an educational programme dedicated to medical personnel and patients;*
- *periodical identification of priorities for the operation of the HAI control programme with an evaluation of the achievement of intended objectives* (Bulanda et al. 2016: 40).

The analysis of the system mentioned above does not allow us to state clearly whether modifications to the architectural design of medical units resulting from the current knowledge based on scientific research is required in Poland. There are some prerequisites indicating that it is not required, as it does not result from the current legal regulations, in particular, from the Ordinance of the Minister of Health of 26th June 2012 with later amendments, on specific requirements stated for healthcare facilities and their equipment (Journal of Laws 2012, item 739). However, it can be also assumed that the implementation of such solutions is mandatory and it should result from the monitoring of epidemiological risk or the analysis of the current procedures.

The potential of non-standard solutions in comparison to the minimal requirements indicated in the current regulations is considerably significant, as it is described in the further parts of the monograph. Nevertheless, the implementation of optimal, cohesive and comprehensive solutions of the character defined by scientific research or the implementation of solutions formulated on the

basis of the design methods, with the consideration of EBD, have been so far rarely applied in Poland. The difficulties are caused by some basic elements of the safety system, such as appointment of people responsible for the implementation of these solutions. Despite the fact that the legal regulations mentioned previously impose a number of responsibilities on various participants of the epidemiological protection process, they do not clearly refer to the necessity of searching for optimal spatial solutions that would facilitate minimisation of hospital-acquired infections in medical facilities.

**Photograph 3.3.1** The colour palette of an operating suite should allow for the possibilities of optical inspection of cleanliness; designed and photographed by the Author, 2023

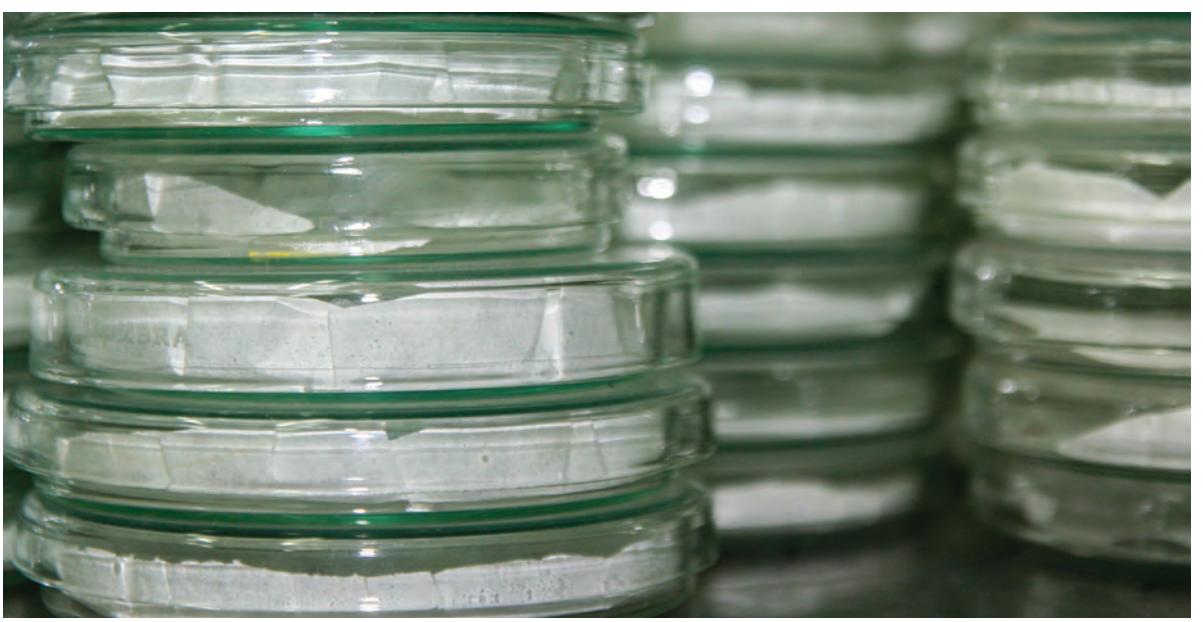
**Photograph 3.3.2** Maintaining cleanliness in medical facilities (footwear used at the operating suite, prepared for disinfection); photographed by the Author, 2022

# 4. The history of hospital architecture in the context of epidemiological hazards

# 4.1 Development of healthcare facilities in Poland after the Second World War

Poland has got a long tradition of developing hospital services (Jaśkiewicz-Sojak 2013). Today, some hospitals operating in Poland are located in the buildings constructed in the 19th and 20th centuries. As a result of dramatic events during the Second World War, numerous healthcare facilities were destroyed. The reconstruction and extension of the healthcare system on a larger scale was started in the 1960s. The highest number of the post-war hospital facilities were constructed at the turn of the 1960s and the 1970s. Hospitals were built with the consideration of typical design projects – a district hospital with 320 beds, a provincial hospital offering from 620 to 1000 beds and a specialist hospital with 500 beds. After 1990, new hospital investments were commenced and the process has been continued until the present day (Orłowski et al. 2013).

After the Second World War, some activities were undertaken to provide the unification of architectural solutions applied in medical facilities. These activities included the promotion of typical design projects developed by specialised state-owned architectural studios and the implementation of unified design standards. At that time, the Ministry of Health and Social Welfare published a number of guidelines, including *Vademecum projektowania szpitali ogólnych (A Handbook on General Hospital Design)* (Przygoda 1971); *Vademecum projektowania zakładów przyrodoleczniczych (A Handbook on the Design of Natural Medicine Facilities)* (Geppert et al. 1973), *Wytyczne projektowania zakładów prze-*



**Photograph 4.1** Laboratory glassware (the advancement of scientific research in the field of microbiology affects the design of architectural solutions); photographed by the Author, 2014

*mysłowej służby zdrowia (The Guidelines on the Design of Industrial Healthcare Facilities)* (Dobrzańska 1984), *Wzorcowy program szpitala czterooddziałowego o 295 łóżkach (A Model Programme for a Four-ward Hospital with 295 beds)* (Makowiecka 1984), *Wytyczne projektowania ośrodków zdrowia na wsi (The Guidelines on the Design of Rural Healthcare Facilities)* (Wnuk 1988). Formulated in that way, the order was reflected in the method of organising hospitals at that time. Commonly applied during the discussed decades, the standards of hospital design imposed the need of distinguishing organisational units and hospital units, with the necessity of proper isolating and organising the central sterilisation unit and selecting installation fixtures, including mechanic ventilation in some areas (Przygoda 1971). The above-mentioned publications include a number of design recommendations aimed at providing proper hospital environment. Some hospital facilities implemented in accordance with those guidelines have been used until the present day, in several cases – with only some minor modifications resulting from the current renovation work. However, in the course of time, the guidelines have turned out to be outdated and a lot of them should be considered as antiquated (including the use of some materials, such as asbestos). That period of time is characterised with a relatively large collection of specialist publications, whereas at present, specialist literature and organisations responsible for standardisation seem to be very scarce, considering scientific research and epidemiological risk analysis in the field of architectural solutions and guidelines.

In the epidemiological aspect, the architectural structure of contemporary hospitals has been strongly affected by the achievements of the 20th century science. The paradigms developed in the 19th century and at the beginning of the 20th century have been still current, along with their postulates on protection against infections (Gębczyńska-Janowicz and Awtuch 2015). It may result from the fact that most elements of the epidemic process in the basic nosocomial infections are of universal nature and they have been analysed quite well (Zieliński 2009). At present, in Poland, the development of an architectural design is carried out with the consideration of the highly heterogeneous and general character of the guidelines provided in the relevant legal regulations.

The modern trends in the design of medical facilities usually follow two general streams. The first one is related with the holistic approach toward the human being. This perspective has been gradually entering the medical sciences and as a result, patients are perceived as human beings whose needs are discussed in three equally important aspects: biological, social and psychological (Awtuch et al. 2017). Consequently, the holistic approach to patients changes the way of their perception and they become customers (Goyen 2006). Also, solutions applied in medical facilities acquire the features so far typical of hotel facilities, completed with some functional elements characteristic to commercial facilities. A postulate has been formulated to open hospitals to some typical urban functions and to design hospital facilities as open forms (Nikl 2018). Through material solutions and architectural forms, the traditional style of medical facilities has been already abandoned. Developed in such a way, hospital architecture affects the attitudes of medical personnel through its qualities. Hence, medical staff members may identify themselves with their workplaces more easily and due to the visually attractive space, they perform their duties more efficiently (Wilkstrom et al. 2012).

This trend becomes more and more visible in Poland. While describing the design concept of a hospital, the architects of the Archdeco studio, who are the authors of the design project of the Invasive Medicine Centre in Gdańsk, indicate the implementation of additional functions: *apart from its communication function, a glassed passageway becomes the central point of the entire object – combining*

*the recreational, relaxing and commercial services functions. Along the internal alley, we have designed commercial premises, a cafe bar and green areas. The space, the elements of structural landscaping, the greenery and the sun-lit interior of the passageway make the entire building friendly for patients, visitors and students, despite its compact shape. The passageway has acquired the character of an urban structure, a street that follows the axis of the entire complex, integrating it into one entirety* (Archdeco 2018).

This approach assumes positive social effects, however, in terms of epidemiology, it is in opposition to the concept of a pavilion hospital, which assumes isolation of patients and limited common space. The design concept of a hospital space open to perform urban functions brings about additional epidemic risks. Extended common areas dedicated to all the groups of patients may become elements that potentially increase the risk of infection transmission within a particular medical unit. Considering the limited set of guidelines referring to architectural elements of epidemiological protection, the structure of medical units in Poland is particularly sensitive to such changes.

**Photograph 4.1.1** Samples during the freezing procedure (under some conditions, microorganisms can survive for a long time); photographed by the Author, 2014

**Photograph 4.1.2** A hand hygiene station in the operating suite circulation pathways (a solution excluded by the Polish legal regulations and applied in other countries); photographed by the Author, 2015

The other approach assumes implementation of changes in the functioning of the current medical units, with the consideration of the research carried out in relation to the particular elements of the system. Generally, it is possible to describe this process as the implementation of modifications resulting from the advanced level of knowledge and related to the optimisation process. This method is applied in the Anglo-Saxon countries and involves evidence-based design. Architectural design of medical objects refers to scientific research on the particular elements of the healthcare system (Cama 2009; McCullough 2009). The combination of the research and analysis carried out for the practical project implementations allows medical units to search for optimal solutions and to abandon the practice of meeting the requirements only to the minimal extent. Unfortunately, in Poland this design method has not been adapted yet (Bil 2014). Despite the intensive modernisation of the constructional tissue of medical facilities that is being continued in Poland today, the recommendations on the design of hospital buildings are mainly based on the guidelines issued by the Minister of Health that indicate the selected minimal parameters for spatial solutions.

**Photograph 4.1.3** Medical care stations at a hospital emergency unit – the implementation of temporary boxes as a solution applied to reduce transmission of infections among patients (the COVI-19 pandemic); photographed by the Author, 2022

# 5. Evaluation of solutions applied in Poland

## 5.1 Deficiencies in the organisational solutions of the current epidemiological surveillance system

The basic units responsible for the surveillance and the protection of the epidemiological safety in medical facilities are hospital infection control teams. In Poland, such teams are assigned with numerous responsibilities. The Author believes that they are not always ready to meet such requirements. Hence, some questions might be posed about ensuring the optimal conditions for providing epidemiological protection in hospital facilities.

The circumstances that confirm that hypothesis refer to an obstacle formed by the insufficient number of professional personnel in the system of eliminating and preventing nosocomial infections. As indicated by the Supreme Audit Office, in Poland the number of specialists who are vital for the safety system, such as physicians specialising in medical microbiology and epidemiology, is too low to ensure its proper operation. On 30th June, 2017, in Poland only 110 physicians practised in those

**Photograph 5.0** A corridor in front of the entrance to the operating theatre; photographed by the Author 2016

specialisation fields. Considering the national scale, this number is too low to guarantee the efficient epidemiological surveillance (*The Report…* NIK 2018: 12). The deficiency level in the Polish system can be visualised by comparing the number of active physicians who specialise in microbiology in Poland and in other countries of the European Union. In Poland, this number is the lowest, namely: 0.29 physician specialising in the discussed field per each 100 000 inhabitants. The highest number is recorded in Estonia – it is 10.3 physicians. In France this number is 4.47 (Ibid.: 22). It means that in Poland the availability of physicians specialising in microbiology is 35 times lower than in Estonia and 15 times lower than it is in France.

In Poland, in accordance with the applicable regulations, this small group of medical specialists should participate in numerous activities, including those related to administrative and reporting tasks. As indicated by the experts, hospital infection control teams are burdened with bureaucratic activities in order to meet legal requirements and inspections carried out by sanitary and epidemiological stations (Ider et al. 2012 in: Bulanda et al. 2016: 7). Hospital infection control teams should carry out control activities including numerous elements in the field of tasks being implemented to prevent the spread of infections and infectious diseases. Such control activities should be carried out at least once every six months and if any inconsistencies have been disclosed – at least once every 3 months (Journal of Laws 2012, item 739).

Still, in order to implement the above-mentioned tasks, medical units in Poland have got insufficient amounts of epidemiological data acquired from microbiological research tests (statistically, in Polish hospitals on average, such research tests are carried out approximately twice less often for a hospital bed than in other EU countries). As a result, the knowledge about microorganisms occurring within the environment of a medical unit is limited (The Report… NIK 2018: 13). This situation results in difficulties in the analysis of epidemiological conditions, with the consideration of biostatistics, among other factors. *The results of the surveillance must allow for a comparative analysis, also referred to as benchmarking. In practice, it is a continuous, systematic process of measuring and comparing products (effects), services and operational methods applied not only in management and quality management but also in risk management pertaining to, for instance, nosocomial infections* (Wójkowska-Mach 2016: 219). The limited amount of data on microbiological diagnostics results in limited knowledge on the actual level of epidemiological risk.

The organisational deficiencies of the current system of epidemiological protection in Poland pertain to the very foundations of the safety system. As mentioned previously, the reported level of the reliability of the data acquired from the infection surveillance system has been defined as low. The deficiencies identified by the Supreme Audit Office indicate that only one out of five nosocomial infections has been reported. As suggested by the reports, the hospital-acquired infection rate was 1.6% in the first half of 2017, whereas its actual value was estimated at the level of 7.5% of hospitalised patients (*The Report…* NIK: 8–12). Hence, the comparison of the data makes it possible to state that in Poland non-reported nosocomial infections reach a high level.

Medical units in Poland undergo evaluation in terms of epidemiological safety. The evaluation process is carried out, among other institutions, by the State Sanitary Inspectorate and one of the measures identifying the level of safety in medical units is the HAI level. *Undoubtedly, nosocomial infections reflect the quality of medical services* (Denys 2012: 20). The evaluation is based on the information about the level and the structure of infections in a medical unit, which allows for the verification of preventive

activities undertaken there and for the evaluation of the efficiency of activities carried out by hospital infection control teams. The insufficient amount of reliable data on hospital-acquired infections results in difficulties in providing the reliable evaluation of activities undertaken to prevent nosocomial infections in medical facilities. The problem is also analysed by independent medical organisations that have observed that the current system is characterised by: *collecting data on nosocomial infections and alert microorganisms first of all for the local departments of sanitary and epidemiological stations, without any feedback information and conclusions. Frequently, the statistics present unreliable data in the form that is difficult for interpretation and that is not properly used by hospital personnel and other recipients of the reports* (Ider et al. 2012 in: Bulanda et al. 2016: 7). In terms of epidemiology, this is a highly dangerous situation. The World Health Organization warns against threats resulting from errors and incomplete data in reporting, indicating limited possibilities of drawing the right conclusions based on such unreliable information: *errors in the field of healthcare are caused by weak systems and they often stem from the common sources that can be generalised and improved. Despite the fact that each case is exceptional, the risk sources are similar and they follow similar patterns, which in some other cases might be unnoticed, if their previous incidence was not reported and analysed* (WHO 2005: 2).

Another element that proves the weakness of the current epidemiological safety system is the lack of a necessity for hospital infection control teams to consult other specialists from various non-medical fields, for instance, from the field of hospital environment design. The Act on preventing and combating infections and infectious diseases in humans indicates the necessity of appointing hospital infection control teams in medical facilities, which should be composed of a physician, a nurse or an obstetrician and possibly a laboratory diagnostician (Journal of Laws 2008, no. 234, item 1570 art. 15 with later amendments). Such a composition of the team assumes that there is no need to cooperate with the representatives of other specialties in work related to epidemiological safety, including those who are responsible for the design and supervision of the environment of medical facilities, for example, employees of technical departments. It means that according to the legislature, while carrying out epidemiological inquiries, the members of hospital infection control teams have to evaluate the impact of architectural and installation elements in a medical facility on the possibility of HAI occurrence all by themselves. Considering the heterogeneous nature of threats, various transmission routes and methods applied to reduce them, the scope of the research problem goes beyond one scientific area and requires integration of knowledge resources pertaining to many other scientific fields. Hence, the effective reduction of infections in medical facilities usually exceeds the competences of individuals, strongly indicating the need for cooperation among specialists in various scientific fields, who should form interdisciplinary teams (Janowicz 2018). The current system limits the efficiency of hospital infection control teams, as they are composed of medical personnel representatives only.

All these conditions allow for providing a critical assessment of the current organisation of the epidemiological safety system. As noted by Polish experts, the system is oriented more toward meeting legal requirements rather than toward achieving actual results, including the reduced rates of HAI morbidity and the limited antibiotic resistance (Bulanda et al. 2016: 14). The scarcity of specialists in the discussed field, their work overload, the wide scope of responsibilities and the lack of reliable data do not really foster the development of specific and extensive guidelines in the field of designing elements of architectural epidemiological protection by medical specialists and nurses. Hence, the optimal solutions to epidemiological problems through the use of architectural safety tools cannot be guaranteed.

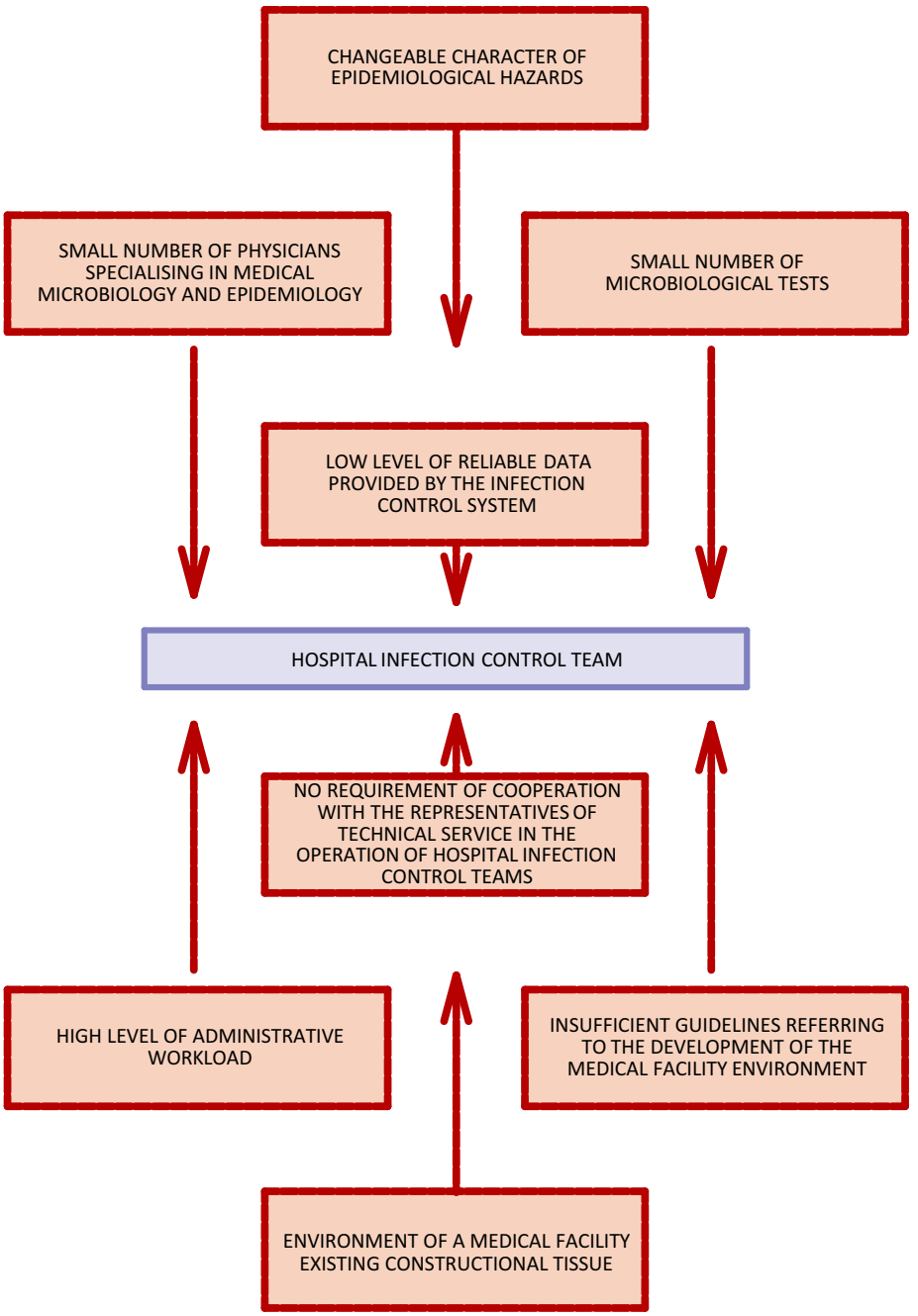



**Figure 5.0.1** The conditions decreasing the efficiency of hospital infection control teams' work in Poland; elaborated by the Author

## 5.2 Legal deficiencies in the field of architectural solutions applied in healthcare facilities

In Poland, organisational deficiencies in the field of effective organisational and spatial prevention of nosocomial infections are considerably related to the deficiencies in the field of the current legal regulations. Defining the principles for the architectural design of medical facilities, the current legal regulations state the minimal requirements, assuming the high level of knowledge represented by users and designers in the field of developing medical facilities.

The character of numerous requirements should be considered as maladjusted to the actual needs. At present, in order to verify the compliance of a medical entity with the following requirement: *the shape and the surface of the rooms in a healthcare facility shall provide the possibility of proper accommodation, arrangement, installation and use of equipment and appliances indispensable for its functioning* (Journal of Laws 2012. item 739 § 16), it is first necessary to define the notion of *proper* and,

**Photograph 5.2** An operating theatre (the disruption of the patient's tissue continuity results in an increased risk of hospital-acquired infections); photographed by the Author, 2016

in consequence, to select the criteria for describing and separating correct and incorrect solutions and criteria for selecting indispensable and complementary elements. Such a task should be treated as a complex research problem and its solution that is provided with the use of quantifiable evaluation criteria should be approached as a difficult, complex and time-consuming task that requires integration of knowledge in various scientific fields, as it certainly goes beyond the knowledge in the field of epidemiology, spreading further onto the fields of architecture and ergonomics.

Hence, the current legal status results in the increasing significance of medical organisations that have the capacity of complementing the general requirements. In specialist literature, it is possible to find opinions stating that this would be a desirable situation: *the Polish law should define the minimal requirements in the field of HAI control and drug-resistance. More specific solutions pertaining to the HAI control should stem from the updated recommendations provided by relevant associations and accreditation requirements. The provisions stated in the legal acts should be interpreted within the scope of the recommendations provided by the Ministry of Health on the optimal solutions for the implementation of the individual provisions of the legal acts* (Bulanda et al. 2016: 32). Unfortunately, recommendations issued by the relevant associations are not mandatory. The Author believes that the lack of the system that would combine uniform, comprehensive and cohesive standards defined for architectural solutions, the implementation of which should result from the current regulations, causes significant discrepancies in the approach toward sanitary and hygienic problems. The supervisory bodies responsible for the execution of sanitary and hygienic regulations are forced to interpret general guidelines provided in the current regulations. As a result, the discrepancies in the execution of individual regulations are observed in various regions of Poland.

The imperfect character of the current regulations can be observed on the example of establishing the right height of rooms in buildings, especially in medical facilities. In Poland, it is defined at the minimal level of 2.5 m for the rooms dedicated to people, working, studying and other purposes, where no nuisance or detrimental factors occur. The minimal height in the rooms where nuisance and factors harmful for human health occur is defined as 3.3 m (Journal of Laws 2002, no. 75, item 690, art. 72). Due to these regulations, architects are imposed with the necessity of evaluating the space of medical facilities in terms of harmful factors. In the human life environment, there are lots of microorganisms and in the human body only their number is estimated to be 1014 (Sunder et al. 2018). Among them, some microorganisms may – under specific circumstances – have a negative impact on human health. However, it is impossible to define all the reservoirs of pathogenic agents and the precise limits of their occurrence. Pathogenic agents may periodically appear anywhere where people live and stay. It results from the common character of some infections, for example influenza infections. It is worth noting that the occurrence of reservoirs of pathogenic microorganisms may refer to a broadly understood public and private space. Discussed previously, the drug-resistant strain of *Klebsiella pneumoniae* can exist in its host's digestive tract for several years (*The Report…* NIK 2018: 40).

Considering this context, the potential pathogenic microbiological agents occur in kindergartens, schools, offices, hotels, households and particularly in medical facilities, including those organised at private premises and entities providing healthcare services. Therefore, the distinction between the occurrence of nuisance or factors harmful to human health stated in the Ordinance of the Minister of Infrastructure (Journal of Laws 2002, no. 75, item 690) in the epidemiological context is difficult. Considering healthcare facilities in Poland, this provision is interpreted in two ways, namely:

- the first interpretation assumes the rigid understanding of the regulation. It means that the epidemic risk occurs in all healthcare facilities, in all their rooms. Hence, it is necessary to provide the usable height of 3.3 m;
- the second interpretation assumes making the threats more realistic by relating the epidemic risk occurring in medical rooms to other functions or rooms for which the height is defined by the regulations as 2.5 m at the minimum. In the case of medical facilities, an indication of assigning the required height to the character of a room is provided in the guidelines issued by the Minister of Health. The minimal height for the areas of diagnostic imaging, such as X-ray rooms, is required to be not less than 2.5 m (Journal of Laws 2006, no. 180, item 1325).

In this way, assigning the required minimal height of a room to its intended function becomes a decision burdened with the risk of the various interpretation of the legal regulation by architects and the commissioning entity, but first of all, it does not foster the optimal design of the space. The situation in which a medical unit has to struggle with the proper determination of the minimal value required for such a fundamental architectural parameter as the height of the room, does not foster the uniform application of legal regulations and optimal solutions to epidemiological problems.

Considering the legal solutions applicable in Poland, the problems can be observed not only in their interpretation but also in complications related to the evaluation of the required architectural protective measures in medical facilities, through the exclusion system. A relevant example comes with the provisions of the Ordinance of the Minister of Health on biological factors harmful to human health in the workplace environment and on the protection of health of employees professionally exposed to such factors (Journal of Laws 2005, no. 81, item 716), which limits the application of architectural guidelines resulting from the harmful character of biological factors in medical facilities exclusively to isolated rooms. Viewed from the perspective of the workplace environment, this regulation is significant, because it categorises harmful biological agents into four hazard groups, starting form the first group of agents which are unlikely to cause diseases to the fourth group of agents that cause serious diseases in humans and are dangerous to employees and their spread in the human population is highly probable. Usually, there are not any effective methods of prevention or treatment against them (Journal of Laws 2005, no. 81, item 716, annex no. 1). By assigning the particular hermeticity classes, this classification allows the interested parties to automatically assign the acceptable architectural solutions for the expected or observed threats (Figure 5.2.1).

| | B. Hermeticity class | | |
|---|---|---|---|
| Hermeticity measures | Hazard group 2 | Hazard group 3 | Hazard group 4 |
| 1. A workstation isolated from other rooms in the same building or situated in a separate building | not required | recommended | required |
| 2. Air extracted out of and introduced into the workplace by HEPA similar filters | not required | required for the extracted air | required for the extracted and introduced air |
| 3. Access for authorised personnel only | recommended | required | required through an airlock |
| 4. A workstation adjusted for disinfection through fumigation | not required | recommended | required |
| 5. Specific disinfection procedures | required | required | required |
| 6. Negative pressure at the workstation in relation to its immediate environment | not required | recommended | required |
| 7. Efficient protection against infection vectors, e.g.: rodents, insects | recommended | required | required |
| 8. Waterproof and easily washable surfaces | required for tables | required for tables and floor | required for tables, walls, floor and ceiling |
| 9. Surfaces resistant to acids, alkalis, solvents and disinfectants (…) | recommended | required | required |

**Fig. 5.2.1** Table assigning hermeticity measures to the particular hazard groups (Journal of Laws 2005, no. 81, item 716, annex no. 4)

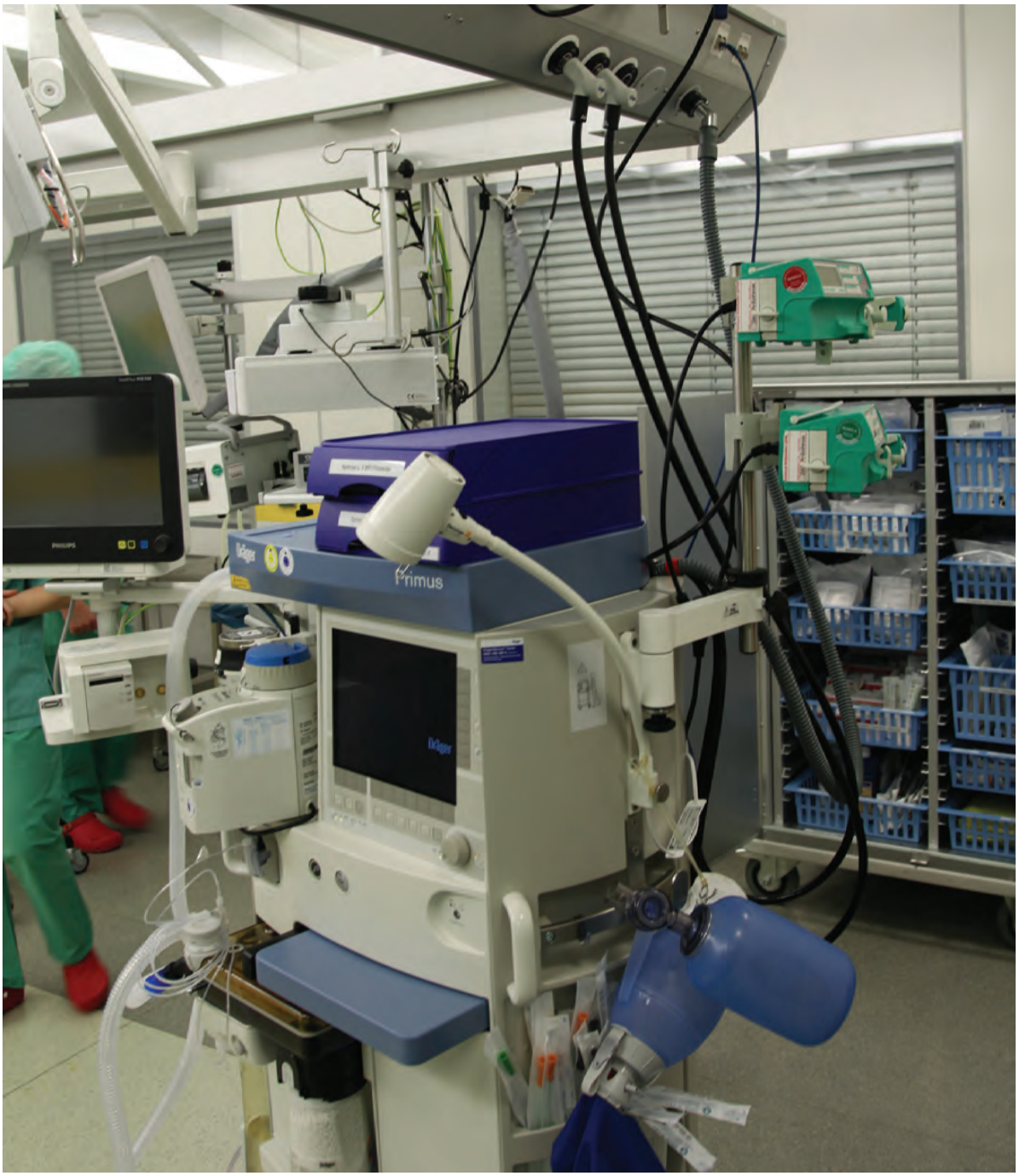
The provisions of the ordinance mentioned previously indicate that employees of healthcare units constitute a professional group particularly exposed to the impact of biological agents (Journal of Laws 2005, no. 81 item 716, annex no. 2). Hence, *in order to protect employees against the hazard posed by active biological agents, the employer is obligated to apply (…) any available measures eliminating the hazard or limiting the level or the hazard (…). If microorganisms of unidentified species, which are suspected to be of pathogenic nature, are observed in the work environment, the employer provides employees with preventive measures dedicated to eliminate harmful biological agents classified into the highest hazard group* (Journal of Laws 2005, no. 81, item 716 art. 4).

For medical units, this regulation limits the application of the requirements for architectural solutions related to the hermeticity groups, described in the annexes to the Ordinance, only to isolation rooms dedicated to people (Journal of Laws 2005, no. 81, item 716, annex no. 4). In this way, the classification of hermeticity is mandatory only in relation to employees working in the hospital isolation rooms. The exclusion of most rooms in a medical unit from the obligation to follow the provisions of the regulation causes difficulties in the selection of solutions that should be applied in some areas, for instance, at anaesthesiology and intensive care units. As mentioned previously, the scientific research results indicate the occurrence of drug-resistant microorganisms in the area of anaesthesiology and intensive care units. At the same time, these results prove that in the case of infections confirmed in the area of anaesthesiology and intensive care units, it is observed that antibiotic-resistant bacterial strains have the ability to survive in the hospital environment despite the disinfection procedures applied there (Vickery et al. 2012).

The systematisation of biological pathogenic agents in terms of their harmfulness allows them to be classified as drug-resistant microorganisms of the third or fourth hazard groups, as the agents that *cause serious diseases in humans, are dangerous for employees and their spread in the human population is highly probable. Usually, there are not any efficient preventive and treatment methods to eliminate them* (Journal of Laws 2005, no. 81, item 716, annex no. 1). As a result, the exclusion of the anaesthesiology and intensive care areas from the architectural requirements defined for the hermeticity classes seems to be unjustified and indicates the need of verifying the discussed regulations.

The Author believes that the reference of the hermeticity standards (Journal of Laws 2005, no. 81, item 716) to other medical areas is possible and rational. It would make it possible to assign the particular solutions to the specific hospital-acquired infections. Such a system would become an element of standards broadly applied in medical units, referring also to the principles on the flows of patients suspected of carriage or infections through various areas of medical facilities.

In Poland, the need of developing uniform standards for designing medical facilities is of extensive nature. The scientific research studies indicate that in a situation when tissues are damaged within the treatment areas, patients are particularly vulnerable to infection transmission (Wierdak et al. 2016). In accordance with the current regulations, medical treatment procedures can be performed within the premises complying with two standards defined by the legal regulations. These are areas that differ fundamentally in terms of the minimal requirements in the field of their spatial design. Operating theatres must comply with the mandatory requirements implementing a number of architectural and installation solutions applied to limit infection transmission. An example of an operating theatre layout is presented in Figure 5.4.1. As it is possible to observe, within the operating suite, outside the operating theatre where surgical operations are performed, a number of other rooms are located there to




**Photograph 5.2.2** An operating theatre (a large amount of medical equipment results in difficulties related to efficient decontamination of the operating theatre between the subsequent surgery operations); photographed by the Author, 2016

increase the safety level in the entire area. Similar recommendations are not mandatory for treatment rooms that can consist of only one room available from the level of general circulation. The lack of uniform standards results in a situation where the same treatment procedures can be carried out in areas representing very high or very low levels of architectural and installation protective solutions. The applicable regulations do not provide any intermediate solutions and they do not clearly define a place where medical treatment procedures are to be performed.

Therefore, the above-mentioned examples indicate that the current legal regulations in Poland do not allow for the efficient implementation of the optimal design of medical facilities. Furthermore, they do not guarantee the rational epidemic risk management and the optimal application of architectural solutions.

## 5.3 The need of standardising architectural solutions applied in healthcare facilities

The difficulties in the description of sanitary and hygienic requirements for medical facilities stem from the heterogeneous character of threats in various areas of medical units, limitations to the existing constructional tissue, evolution of guidelines defined for architectural solutions resulting from technical advancement, available solutions, volatile risk levels and improvement of knowledge based on scientific studies. Hence, legal regulations should not be limited to minimal requirements only but they should encourage the implementation of optimal solutions. The first attempts of providing comprehensive guidelines for medical facilities aiming at the popularisation of optimal architectural solutions in terms of the understanding the contemporary level of knowledge and technology were made in the 1970s by the state-owned Health Service Facilities Design Office (Biuro Projektowania Obiektów Służby Zdrowia) in Warszawa, a leading unit in the Specialist Centre for Industrial Cooperation and Coordination in Health Service Facilities Design and Construction (Specjalistyczny Ośrodek Współpracy i Koordynacji Branżowej w Projektowaniu Budownictwa Służby Zdrowia) (Przygoda 1971). Developing standards that go beyond minimal requirements can be also observed outside Europe. In the United States of America, the guidelines are developed by an independent institution, namely: the Facility Guidelines Institute (FGI), which develops evidence-based guidelines and recommendations for the design and construction of medical facilities, including recommendations for hospitals and dispensaries (FGI 2018). The need for the optimisation of medical units is also analysed by specialists working in the fields related to architecture: *the implementation of the principles of ergonomics into the activities undertaken to improve patients' safety and reliability of the healthcare system requires the development of a standard set of ergonomic criteria allowing for a system and systematic evaluation of healthcare units, procedures and equipment in terms of any probability of error occurrence resulting from their ergonomic imperfection, by both: healthcare specialists and patients* (Pokorski et al. 2010). In Poland, it confirms the need of developing clear quality standards, with the consideration of scientific research and interdisciplinary teams. In the context of the scope of the necessary activities to be implemented and the limited accessibility of specialists (*The Report…* NIK 2018), it should be carried out at the level of the nation-wide guidelines. Today, the strategy for the modernisation of healthcare facilities is determined

by the legal requirements. However, despite the intentions of the legislature, they do not always come as a rational response and do not match the requirements of healthcare facility design in terms of epidemiological safety. The development of accreditation systems that define the acceptable levels of risk and architectural standards applied in healthcare facilities may contribute to the improvement in the efficiency and epidemiological safety in medical units.

Usually, architecture involves the implementation of a particular prototype and the scientific research studies in the field of architecture do not often indicate one optimal solution to the problem in question. It also refers to solutions applied in the field of epidemiological safety in medical facilities. Based on the implementation of the minimal requirements, the current system is inefficient because the implemented solutions are incoherent and maladjusted to the actual threats. In some cases, they turn out to be ineffective and in some other cases, they might be excessive for particular medical procedures that are carried out.

**Photograph 5.3** A post-treatment and observation room (an example of a room for which the architectural solutions have been defined by the current legal regulations only to a very limited extent); designed and photographed by the Author; 2016

By itself, architecture rarely solves epidemiological problems, however it does provide the proper framework for solutions considered to be acceptable. These problems have their economic aspect in a situation when resources are limited. In a situation when there are several competing programmes or interventions, the choice among them should be based on the analysis carried out in terms of the most significant health advantages achieved with the use of limited resources (Graves 2018). The weakness of the Polish epidemiological safety system is discussed in medical circles, who – while describing its deficiencies – observe *the lack of the efficient prevention of hospital-acquired infections and drug-resistance, understood as achieving advancement evaluated with the use of objective rates, an approach which is mainly oriented toward the presence of the structures, observing the process and undertaking activities aimed at the achievement of positive outcomes after external audits through the preparation of extensive reports* (Bulanda et al. 2016: 32).

Considering such a context, it is worth noting that the search of optimal solutions in the field of medical facility architecture should be of the permanent character. The basis of their implementation should incorporate interdisciplinary analysis combined with risk analysis and provided with the participation of auditing teams. The spatial standards should evolve, adjusting to the changes in the current situation, threats and needs.

## 5.4 Deficiencies in the use of architectural measures in the prevention of hospital-acquired infections

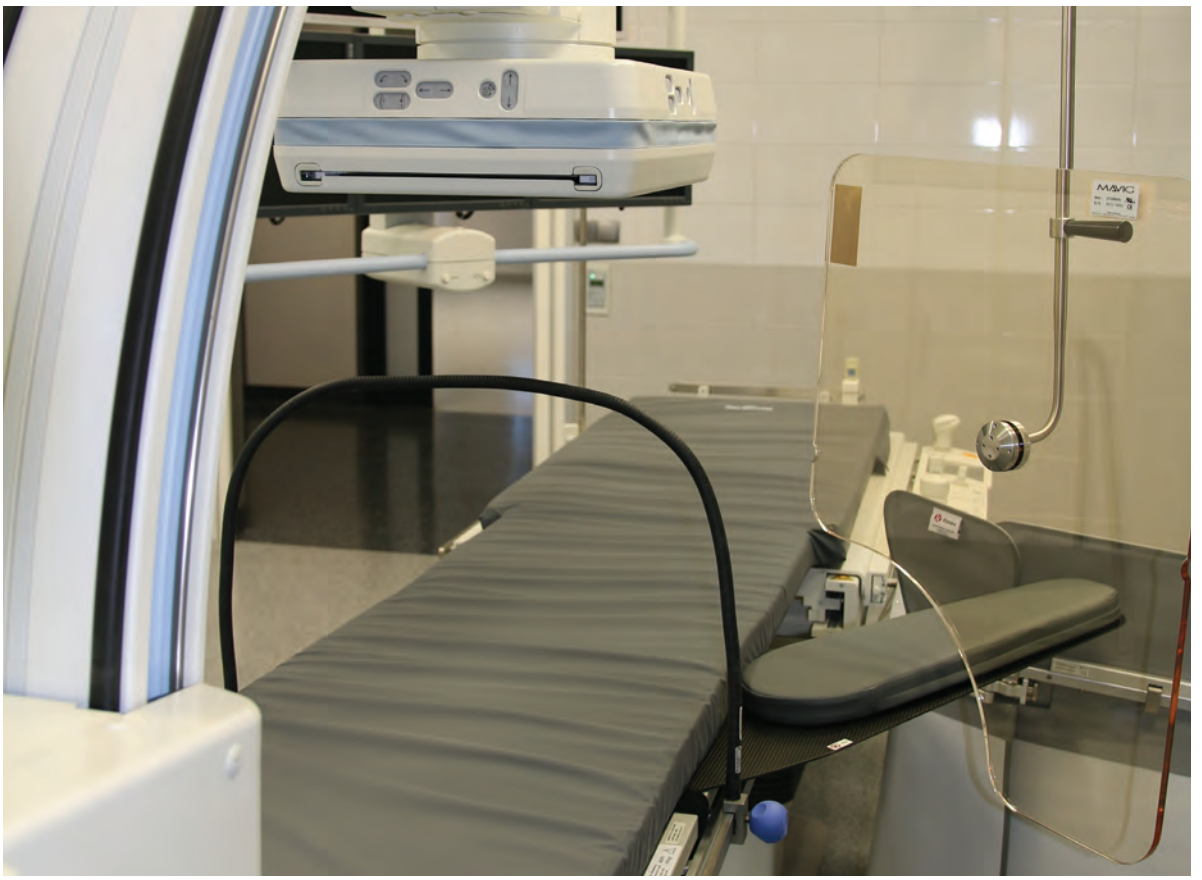
In Poland, the applicable regulations define the minimal requirements that have to be met by the architecture of healthcare facilities. As obligatory by nature, they constitute the foundation of the current epidemiological safety system. Considering the general character of the provisions defined in legal regulations, they do not form a cohesive and unambiguous set of principles to be followed in designing of medical facilities, leaving numerous decisions to architects and managers of medical units. The analysis of the problem should emphasize the fact that architectural means should be applied to increase the safety level and it should also disclose the deficiencies of the current catalogue of design solutions.

The architectural means applied to manage epidemiological safety are of various nature. Hence, they can be divided into three main groups:

1) separating surfaces of a defined sanitary and hygienic risk, usually with partitions, such as walls, ceilings, floors, and implementing protective actions within those surfaces that involve characteristic solutions, such as finishing materials, ventilation standards, medical technology and colours;
2) managing processes or flows of people or materials through the use of architectural means. Actions implemented on the basis of risk analysis, medical procedures and infection transmission routes should allow for the implementation of activities that impose the required attitudes and behaviour;
3) ergonomic architectural solutions within the premises, including the arrangement of medical equipment in the rooms, the circulation and information system. Such solutions help to reduce the nuisance resulting from the complying with the sanitary and hygienic procedures that have to be followed by the users and to foster their desirable behaviour.

In Poland, the way of using these tools can be analysed with the consideration of the requirements imposed by the Minister of Health in the Ordinance on the specific requirements to be met by the premises and equipment used by entities providing healthcare services (2012). The document provides references to all three groups of architectural impact mentioned previously. In each of these groups, it is possible to observe the areas where a more specific description or complementation is required.

The relation between legal requirements and design solutions can be observed in the analysis of an operating suite, in the context of the required architectural standards. During the arrangement of this area, it is assumed that architectural means should be implemented for process management. They include walls and technological equipment to determine the flow of personnel, patients, materials, equipment and waste. Furthermore, during the organisation of the discussed area, it is necessary to implement the division into functional zones, to impose the obligation of determining numerous rooms and to implement their design principles, including those pertaining to the finishing work at the premises. An example of the scheme presenting the functioning of an operating suite is provided



**Photograph 5.4** A haemodynamics room (an example of coexisting radiologic and HAI risks); designed and photographed by the Author 2016

in Figure 4.4.1. Architecturally designed in such a way, the space allows for some modifications to the applied solutions only within the scope defined by the accepted principles. For instance, the location of the post-anaesthesia care unit is not specifically imposed and the decision is to be made by the manager of a medical unit and the architects (Janowicz 2017). According to the guidelines provided by the Minister of Health (2012), in the area of an operating suite, the following rooms should be located:

- at least one operating theatre directly connected with the dirty utility room, in order to remove and dispose of the used materials, with one-way circulation;
- a patient airlock, through which patients are transported in and out of the operating suite;
- changing room airlocks used by medical personnel to pass through;
- a material supply airlock used for the supply and short-term storage of clean and sterile materials;
- at least one preparation room for medical personnel, with a surgical hand-washing station, which is used by medical personnel enter the operating room;
- at least one preparation room for patients;
- at least one room for medical personnel with a sanitary and hygienic room;
- at least one storage room for medical instruments and equipment;
- at least one storage room for clean linen;
- at least one storage room for short-term storage of soiled linen;
- at least one storage room for cleaning equipment.

*The layout of the rooms in an operating suite makes it possible to maintain the principles of separating medical personnel, patients, clean and soiled materials, dirty medical instruments, soiled linen and post-surgery waste* (Journal of Laws 2012, item 739, § 29–§ 31; annex no. 1, item IX).

Indicated by the legal regulations, the list of the required rooms does not constitute a closed set. In practice, it is necessary to complete the system with some additional areas that are not stated by the regulations. There are numerous elements of an operating suite that are not defined by the legal provisions, for example, the areas that have appeared with the advent of modern technologies. Operating suites are equipped with the systems of mobile operating tables that require the arrangement of the space for their cleaning and disinfection. Some of them are also fitted with angiography equipment and as a result, a need appears to find space for technical appliances that allow for its proper and safe operation. Despite the fact that the above-mentioned provisions of the ordinance indicate the necessity to design a number of separate rooms, they do not describe sanitary and hygienic standards that would allow the current system to be supplemented with additional elements. Referring to a closed set of minimal requirements and to a general formulation of finishing recommendations causes numerous difficulties in the organisation of the operating suite area.

The current legal status leaves a lot of space for the interpretation of the requirements that are not stated by the regulations referring to the proper organisation of the operating suite area. As a result, various architectural solutions are applied. Considering the example of mobile operating tables, two extreme solutions can be observed. The first one allows for decontamination and preparation of mobile operating tables within the area of the general circulation in an operating suite, as it occurs in some European countries (Figure 5.4.2). The other solution is more restrictive and it assumes the arrangement of numerous additional rooms that allow personnel to maintain the progressive circulation during the decontamination procedures: there has to be a room for storing soiled operating tables, a room

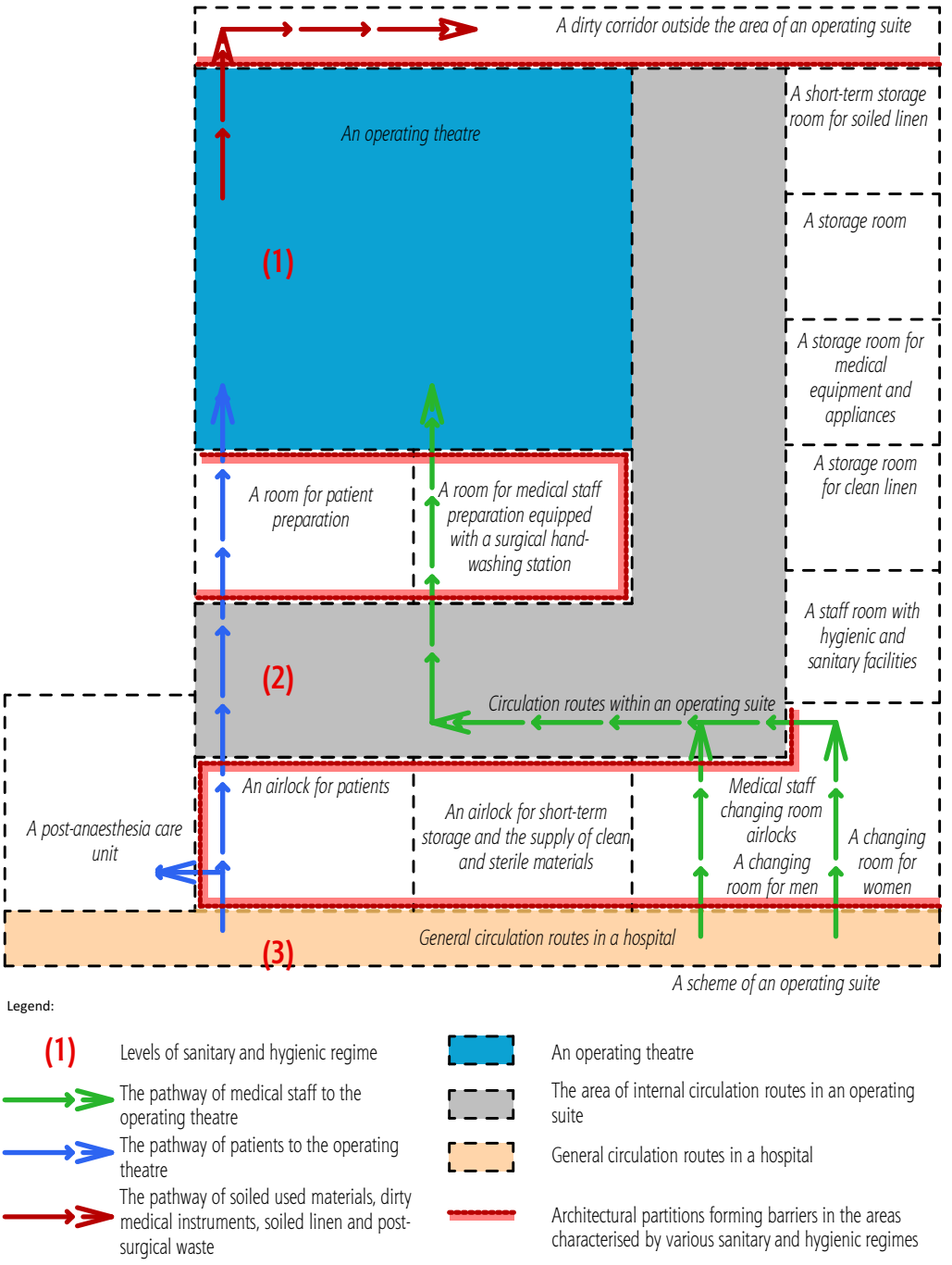



**Fig. 5.4.1** The layout of an operating suite presenting the barriers defined for the zones characterised by various hygienic regimes; analysed and designed by the Author

for cleaning and disinfection of operating tables and separate rooms for storing clean tables and for preparing clean tables for the use in the operating theatre. The necessity of interpreting the regulation each time it is going to be applied results in discrepancies in the expert opinions issued for similar arrangement systems and consequently for architectural solutions as well.

The other area of architectural solutions includes a group of activities involving process management, for example, by forcing the assumed circulation of users with the use of architectural partitions and elements of equipment.

The requirements stated in the regulation in the reference to an operating suite are as follows:

*The layout of the rooms in an operating suite makes it possible to meet the principles of separating medical personnel, patients, clean and soiled materials, dirty medical instruments, soiled linen and post-surgery waste. Supplying clean and sterile materials to the operating suite through a patient airlock is also acceptable(…). It is also possible to remove dirty medical instruments and dirty medical equipment, soiled linen and to dispose of the waste through the same way that is used for supplying clean and sterile materials, provided that sealed transport containers are used for that purpose* (Journal of Laws 2012, item 739, annex no. 1, item IX).

The above-mentioned regulations confirm the implementation of the principles for the circulation (process) management in the area of an operating suite through the implementation of the organisational requirements in the form of a rule of separating the circulation of users and materials. However, these guidelines do not provide complete answers referring to the processes that are not described in the regulations.

**Photograph 5.4.2** A decontamination station for mobile operating tables in the general circulation in an operating suite; photographed by the Author 2016

For instance, the process of waking patients from anaesthesia can be carried out in rooms arranged in different locations, which results in various ways of architectural design and consequently, with various approaches toward epidemiological safety (Janowicz 2017). Another example considered in the context of architectural solutions can be observed in the procedure of handling patients who should be isolated because of infection suspicion but who need surgery.

Undeniably, work process management and organisation of an operating suite are difficult tasks. The lack of guidelines may be interpreted as the legislator's trust in designers and managers of medical units. Following their professional experience, they should complete the requirements stated by the regulation with good design practice and adjust architectural solutions to individual needs. Such an attitude, however, results in different evaluation of epidemiological risk and other similar types of hazard. It also indicates that at least some medical units have applied architectural solutions that differ from optimal ones in terms of epidemiological safety.

The Author believes that it is necessary to strive for the unification of safety levels in various medical units by developing uniform design standards, with the consideration of scientific research and evidence.

Another group of architectural tools comprises functional and ergonomic activities undertaken in the field of space design. Unfortunately, the requirements stated by the legal regulations in the field referring to the application of the knowledge on ergonomics in architecture constitute a set of very general guidelines: *the shape and area of the rooms in a healthcare facility shall allow for proper arrangement, installation and use of medical equipment, appliances and devices that are indispensable for its proper functioning* (Journal of Laws 2012, item 739 § 16).

**Photograph 5.4.3** A sterilisation unit (the progressive flow of materials is applied as a tool reducing contamination); photographed by the Author, 2016

Despite the indication of the necessity of *proper* space design, the legal provisions do not specifically define the notion of *proper*. As a result, a number of doubts have appeared concerning the scope of the regulation. The Minister of Health does not define any conditions that should be met by designers who need to decide about the particular solutions to meet the requirements. As a result, there is a possibility to interpret the notion of *proper* in a variety of ways and to apply various methodologies to meet the requirements by assigning them with various values, depending on the context, needs and experts. In this way, the regulation deviates from the standardisation, unification and broad formulation of the guidelines for the solutions in the field of architectural standards of epidemiological safety. Specified by the legislator, the discussed legal regulations leave a relatively large space to apply the knowledge based on good design practice. In fact, each individual case of searching for the meaning of the *proper* term leads to random architectural solutions. As indicated by scientific research, this is an undesirable situation: *after the verification of their applicability, ergonomic solutions should be implemented into practice as general mandatory standards. Otherwise, a danger might occur, resulting from the differences in simultaneously used equipment and procedures (a frequent problem in intensive care and surgical medicine). The lack of standardisation and unification may result in undesirable incidents* (Pokorski and Pokorska 2017: 12).

Designing universal solutions dedicated to various groups of patients by assuming uniform solutions that are optimal for people, who differ physically, is extremely difficult. Assuming parameters of technological equipment and its ergonomic arrangement that results from human ergonomic needs still require scientific research that goes beyond architects' standard competences.

## 5.5 Legal basis for epidemiological risk assessment in a healthcare facility

Expert literature offers various definitions of risk. As it can be easily noted, risk has always been an element considered in activities and projects undertaken or abandoned by people (Tarczyński and Mojsiewicz 2001). Considering the mathematical aspect, it is related with the probability theory. According to *Słownik języka polskiego (Dictionary of the Polish Language),* risk can be understood as the possibility, the probability that something can go wrong (Ed. Szymczak 1981, vol. III: 155). It is also defined as *the possibility of a deviation of the actual result from the intended result. Hence, in economy it is most often treated as a possibility of a deviation from the expected value* (Rogowski and Michalczewski 2005: 17). Considering the epidemiological context, risk is described as the probability of an unfortunate incident. Risk management involves active analysis of events that may result in infections in patients, medical personnel and visitors. It also involves development and implementation of activities intended to eliminate or decrease the risk. Considering the managerial context, it also means monitoring and decreasing the risk to its acceptable levels by the management staff (Bulanda et al. 2016: 45).

Today, the elimination of epidemiological risk from the environment of medical facilities is impossible. Numerous microorganisms live in the human organism without causing any disease symptoms and forming its physiological flora. Healthcare-associated infections are often related to patients' own flora, which means they are endogenous infections (Wójkowska-Mach 2016). In medical facilities, the

management of epidemiological risk comes as the responsibility of hospital infection control teams (Journal of Laws 2010, no. 100, item 646 with later amendments). Hospital infection control teams are responsible for the surveillance of endogenous and exogenous infections. At present, it is not allowed to limit the surveillance only to epidemic situations related to exogenous infections transferred horizontally (Wójkowska-Mach 2016). In the field of epidemiological problems, the Polish law requires the performance of the analysis of hospital-acquired infections and alert factors (Journal of Laws 2008, no. 234, item 1570, with later amendments, art. 14.1). Unfortunately, legal regulations do not indicate any methodology to be applied in such an analysis and they do not define the way to determine the acceptable level or risk.

In the European Union member countries, a number of national regulations result directly from the transferring the EU directives into the national legal systems. Considering the responsibility of providing the analysis of sanitary and hygienic risk at workplaces imposed on medical personnel also results from the provisions of the framework Directive no. 89/391/EEC on the implementation of measures to improve the safety and health of employees at their workplace. The above-mentioned directive implements the elements of the methodology applied to evaluate the risk and the hierarchy of preventive measures. Still, it refers only to employees and does not consider problems related to other users of medical facilities. *Within the scope of their responsibilities, the employer should undertake any measures indispensable to provide safety and protection of their employees (…), based on the following general regulations: prevention of threats, assessment of threats that cannot be excluded, elimination of threat sources, adaptation of processes according to the individual needs (…), adjustment to technical advancement levels, replacement of dangerous activities with operations that are not dangerous or are less dangerous, proper development of a cohesive preventive policy (…), the priority of collective preventive measures over individual preventive measures, issuance of proper instructions to the personnel* (Council of Europe, Journal of Laws, L 183 of 29th June 1989, art. 6, section 2).

**Photograph 5.5** Elements of wall finishing at an operating theatre (an example of a surface characterised by an increased resistance to disinfection procedures); designed and photographed by the Author, 2016

In Poland, these regulations find their continuation in the Labour Code, according to which the employer assesses and documents the occupational risk related to work performed by the employees and applies indispensable preventive measures to minimise the risk (Journal of Laws 1974, no. 24. item 141 with later amendments, art. 226) and if there are any biological agents harmful to the human health in the work environment, the employer is responsible to design the work process in a way that allows employees to avoid the harmful biological agents or to minimise the transmittance of the harmful biological agents at the workplace, with the consideration of health protection of the employees who are exposed to such harmful agents because of their occupational duties (Journal of Laws 2005, no. 81, item 716 with later amendments § 7.4).

The discussed regulations confirm that regardless of the minimal requirements defined by the Minister of Health for medical facilities (Journal of Laws 2012, item 739), they should not cancel the necessity of risk evaluation and implementation of additional solutions in the field of safety. Unfortunately, considering the common nature of threats posed by microorganisms that live in the human environment, the general character of the legal provision does not allow for its rational application.

The evaluation of epidemiological risk can be the reason for the implementation of architectural solutions that are adjusted to the threat levels and that make it possible to pursue the relevant epidemiological safety policy. The evaluation of risk can be also used for designing architectural solutions, however in such a case, the evaluation methodology must be determined, along with the methods of assigning the adequate architectural solutions, with the use of tools related to the hermeticity of isolated rooms, medical process management and the solutions identified based on the analysis of infection transmission routes. Carried out in such a way, the analysis of epidemiological risk has the potential to provide general reformulation of the way in which the architectural space of medical facilities is designed. In the further part of the monograph, the potential of architectural solutions to minimise epidemiological risk posed by harmful biological agents in medical facilities is discussed (Figures 6.2.1.2 and 6.2.1.3), along with the design of spatial solutions applied in medical facilities in a way that allows for replacing dangerous activities with less dangerous operations (Figures 6.4.1 and 6.4.2).

## 5.6 Methods of epidemiological risk assessment in a healthcare facility

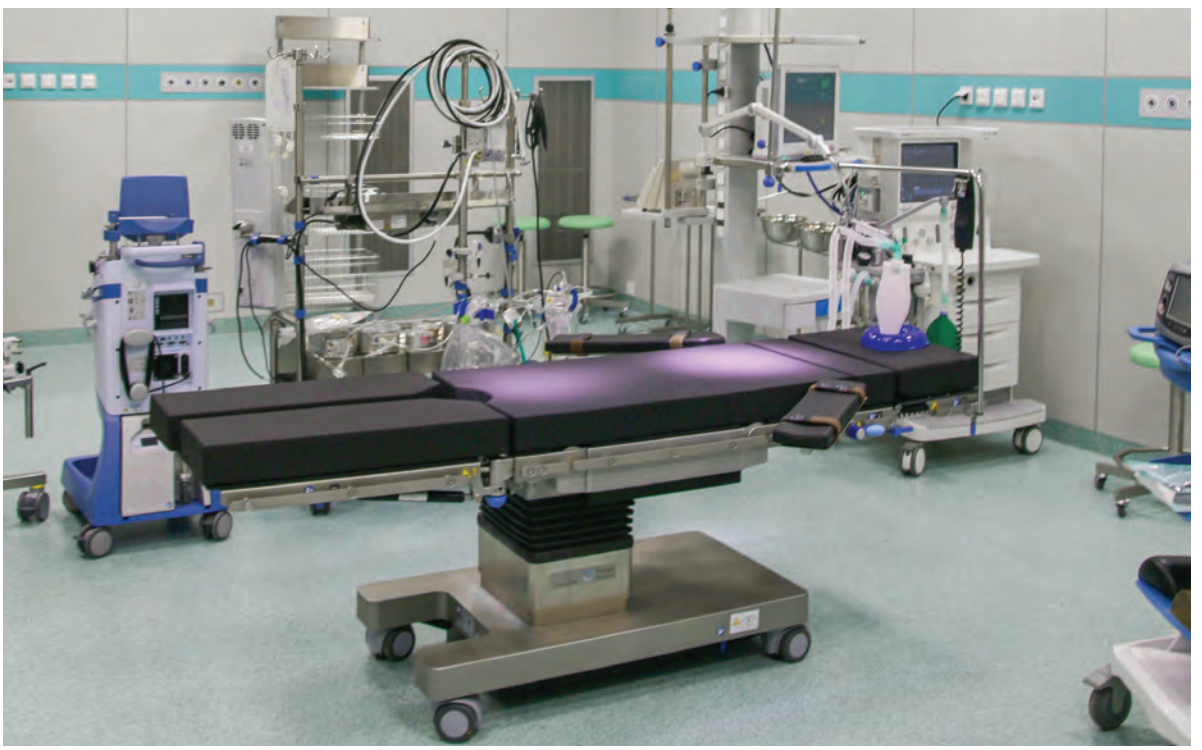
Hospital-acquired infections are of heterogeneous nature and they are vary over time. In a medical facility, their source can be its personnel, patients and its broadly understood environment. Patients constitute the elements of epidemiological risk themselves, in the context of a group of endogenous infections caused by the patients' own endogenous flora (Wróblewska 2016). The high level of complexity observed in the discussed problems does not foster any unambiguous definition of optimal architectural solutions necessary to be implemented in a medical facility.

The key element for the implementation of optimal architectural solutions in a medical facility is a reliable analysis of epidemiological risk. The problem related to the management of the probability of the occurrence of undesirable incidents is not specific to the medical sector only. Hence, it is possible to transfer the methodology for risk management from other areas. Such an attitude becomes even more

significant, due to the prevalence of the public healthcare units in the Polish system and investment projects carried out under the Act on Public Procurement that generates difficulties in the quality of design solutions (Stokwisz 2017).

One of the methodologies accepted for risk evaluation that can be applied is the implementation of the guidelines developed by units specialising in the optimisation of management processes, for instance, by the Standards Committee Project Management Institute (PMI), which has developed the methodology for risk management involving the following stages:

1) planning the process of risk management – developing the infrastructure and a risk management plan for the particular project;
2) identifying the risk – a clear description of events that might affect the implemented investment project;
3) classifying the risk;
4) measuring the risk;
5) planning the methods to respond to the risk – evaluating and assuming a strategy for risk neutralisation or risk prevention;
6) providing surveillance and control of the risk – implementing risk management methods and methods planned for the risk response (Rogowski and Michalczewski, in: Pichard 2005: 17).



**Photograph 5.6** An operating theatre (medical personnel can become an infection source for operated patients, when during a surgery operation there are several or – in some extreme cases – over a dozen people present); designed and photographed by the Author 2018

In some countries, risk evaluation methodologies have been developed that are specifically dedicated to the problem of hospital-acquired infections. According to the risk evaluation methods provided in the Australian guidelines for the prevention and control of healthcare-associated infections, there are five stages covering slightly different scopes of activities, namely:

1) identifying the context – identifying the basic risk parameters;
2) avoiding the risk – identifying whether there is a risk and if it possible to prevent it;
3) identifying the risk – a systematic and comprehensive process that should guarantee that no potential risks are excluded from the further analysis;
4) analysing the risk – carried out with the consideration of the risk sources, their consequences, the probability of the occurrence of such consequences and factors affecting the consequences and probability;
5) evaluating the risk - comparing the risk levels identified during the analysis to the previously assumed criteria of its evaluation and the analysis of the available possibilities to affect it through adequate actions;
6) minimising the risk – implementing the relevant management options in order to cope with the identified risk (*Australian Guidelines…*, 2010).

The European Commission provides another methodology for epidemiological risk management in the *Occupational Health and Safety Risks in the Healthcare Sector. A Guide to Prevention and Good Practice* (The European Commission 2011). The guide refers to the protection of medical personnel against various types of risk in medical facilities, including hospital-acquired infections, providing a detailed scheme of activities.

The scheme is dedicated to the counteraction of hospital-acquired infections in personnel. It introduces three types of preventive measures: technical (T), organisational (O), personal and individual (P). Considering the perspective of this monograph, the division presented by the European Commission is significant, because it indicates the role of technical measures, including architectural measures, as equal to other safety tools. Unfortunately, the document does not provide any specific information on the safe design of spatial solutions. A different approach toward epidemiological risk assessment is suggested by the Association of Hospital Epidemiology, the Polish Society of Hospital Infections, the Polish Association of Epidemiological Nurses and the Association of Committees and Hospital-acquired Infection Control Teams in Lesser Poland. These medical organisations indicate the need of implementing the system of personnel protection against infections acquired at work and against the transmission of infections from personnel to patients (Bulanda et al. 2016: 33). The system includes four stages, namely:

1) identifying the risk: it refers to the identification of activities posing risk to patients, personnel and visitors, for example, improper decontamination of equipment, improper disposal of sharp waste. It also refers to the identification of microorganisms causing infections, their virulence and transmission routes. The aim of the activities is to identify frequent problems that affect care provided to a large group of patients and also rare incidents that may cause serious health consequences. At this stage, the results of the surveillance and microbiological data are collected and systematised (e.g.: presence of drug-resistant microorganisms), including the risk of admitting patients with already acquired infectious diseases. The data is also obtained based on the observation of hospital practice, during the visits at hospital departments;

2) analysing the risk: in the situation when the risk has been identified, the evaluation of its frequency and health consequences is provided. The data obtained from the surveillance of infections and processes is used for this purpose. The suggested preventive actions are defined, along with their costs and intended outcomes;
3) controlling the risk: implementation of activities that eliminate the risk or decrease the probability of its occurrence to an acceptable level;
4) monitoring the risk: evaluation of the results after the implementation of actions through the monitoring of the hospital-acquired infections and comparison of the outcomes; the monitoring of processes and audits of hospital units. The evaluation of outcomes of the implemented corrective activities is carried out by providing feedback information to the interested parties, especially to the senior management staff of hospital units and managers of the particular departments (Damani 2016, in: Bulanda et al. 2016:44).

The systematics presented above is typical of the Polish system. It is of general nature and does not unequivocally indicate the role of technical preventive measures and environmental conditions. Considering the fact that hospital infection control teams lack in specialists from other non-medical areas, for example, technical sciences, the systematics allows them to manage epidemiological risk without the analysis of the potential offered by spatial solutions in hospital-acquired prevention. Therefore, considering the problem related to the clarity of the discussed problems, it is necessary to develop a model of epidemiological risk management with the use of architectural solutions with the reference to all the elements of medical procedures.

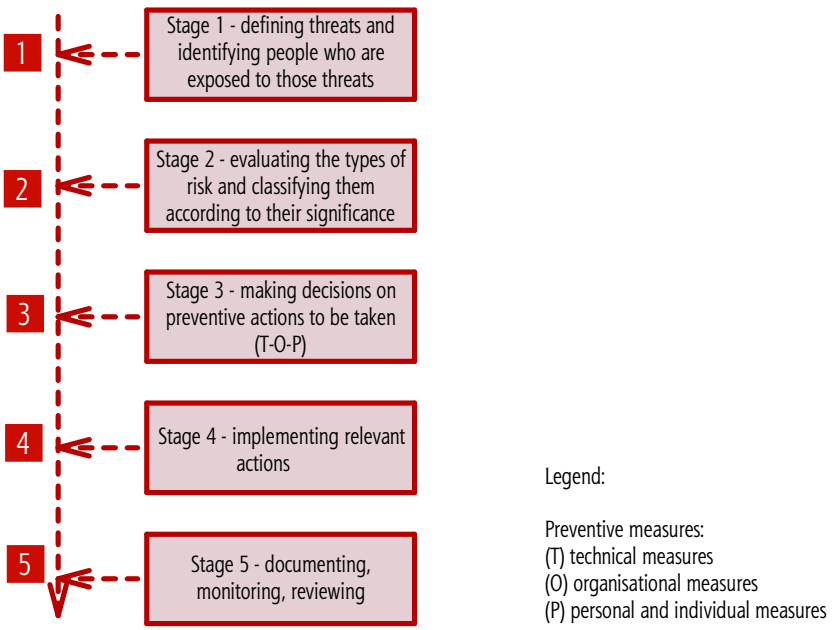



**Figure 5.6.1** The risk management scheme (The European Commission 2011: 30)

The model can be described in the six subsequent stages:

1) analysis of the operational conditions;
2) multi-aspect analysis of risk;
3) analysis of architectural elements eliminating or limiting the risk;
4) architectural organisation of space;
5) implementation of the procedures for using the facilities;
6) monitoring the effectiveness, analysis of the solutions, verification of the assumptions and tools, drawing conclusions that allow the interested parties to return to the (1) item and to repeat the analysis of the modified system.

The model can be presented in a graphical form, with the reference to the architectural tools (Figure 5.6.2).

As it can be observed, such a method of risk management is not a complete set of activities and it assumes continuous evaluation and improvement of the system, adjusting it to variable threats, the level of knowledge and available technologies, tools and possibilities to design space. Based on the analysis, such a permanent optimisation should result in a desired levels of using architectural solutions in order to minimise epidemiological risk. The discussed model assumes risk management with the participation of an interdisciplinary team and the outcome of the activities should result from the synergy of knowledge in the fields of architecture, management, medicine, medical technology, ergonomics, microbiology and epidemiology. The Author believes that the scope of knowledge indispensable to provide proper management of such a process is too broad to be implemented solely by physicians, who specialise in the field of medical microbiology and epidemiology. Architects also should not carry out such a process only by themselves, because they are usually not professionally prepared for a task of conducting an epidemiological inquiry, understood as detecting cases of a disease, etiological factors. Furthermore, they are not competent to identify the reasons, sources, reservoirs and mechanisms of the spread of infectious diseases and infections (Journal of Laws 2008, no. 234, item 1570 with later amendments). Defined in such a way, the process allows for the use of some management tools typical of industry in medical facilities, where – based on the defined processes – it is possible to analyse the places where the subsequent activities are performed, in terms of their ergonomics and the risk of error. In the case of medical facilities, defining the flows of materials, personnel and patients and places, where the subsequent activities are carried out, makes it possible to identify the risk and the potential transmission routes of infections. It paves the way for the optimisation of the process in terms of its safety, with the use of measures other than pharmacological ones. It should be also emphasized that the interdisciplinary team working on the implementation of the optimal functional system in accordance with the assumed model may integrate activities involving other (than epidemiological ones only) sanitary and hygienic threats. Hence, the elements included into the analysis can be the elements of radiological protection and the elements of protection against hazardous chemicals.

The types of risk threatening sanitary and hygienic safety are of heterogeneous nature. The problems related to hospital-acquired infections are of the complex character, which does not foster the application of one method of infection prevention that could be equally effective in all the areas. This fact imposes the necessity of developing a rational strategy for the activities undertaken on the basis of risk analysis and with the use of the available preventive tools. Hospital-acquired infections are the elements of a broader range of sanitary and hygienic hazards occurring in the human environment. It

is possible to list physical threats (for example, those that result from the presence of a very strong electromagnetic field), chemical threats (those that result from the presence of chemical agents harmful for human health), biological threats (those related to microorganisms, bacteria, viruses, moulds, fungi or algae). In some aspects, these types of hazard should be considered collectively, as an element of

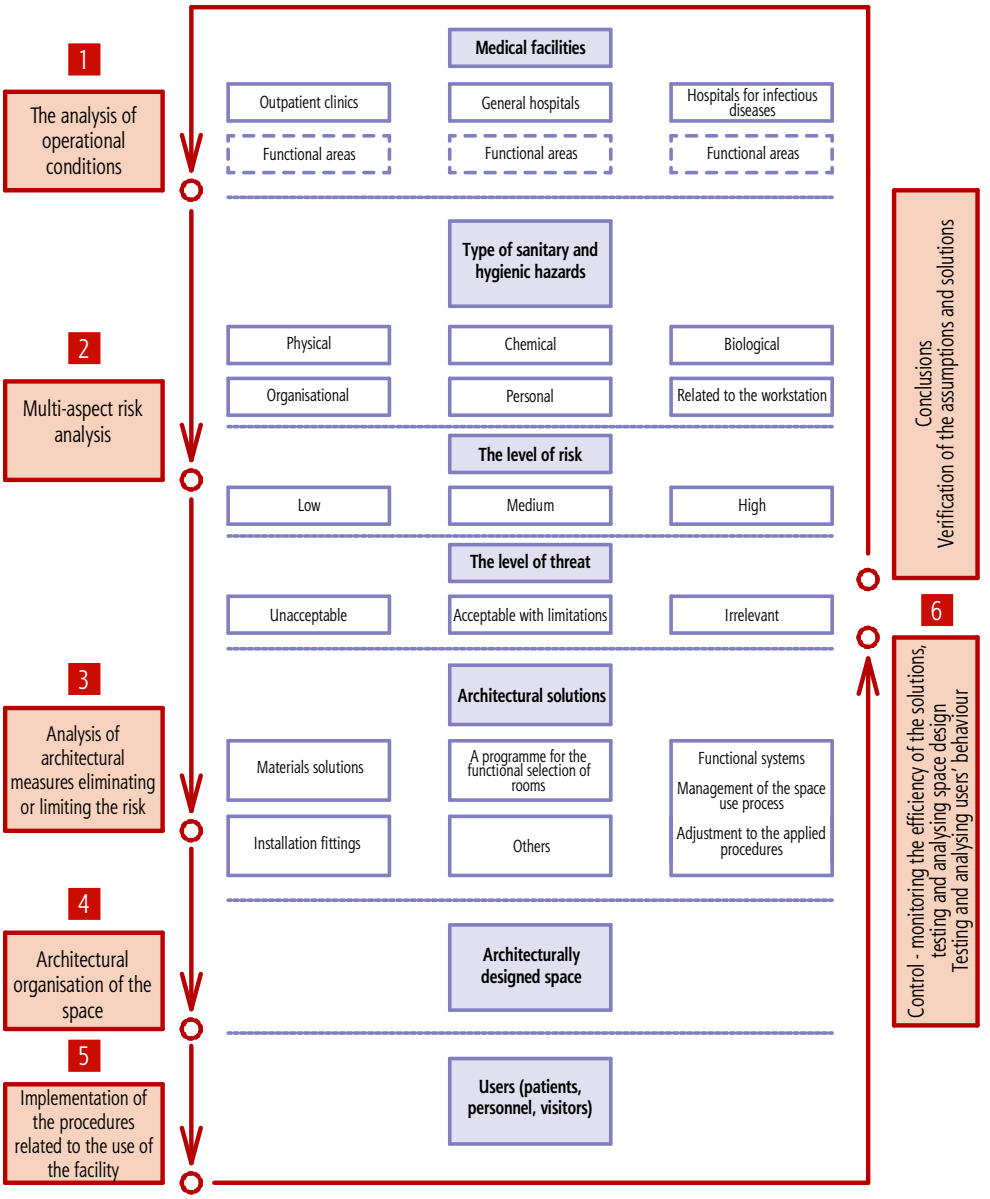
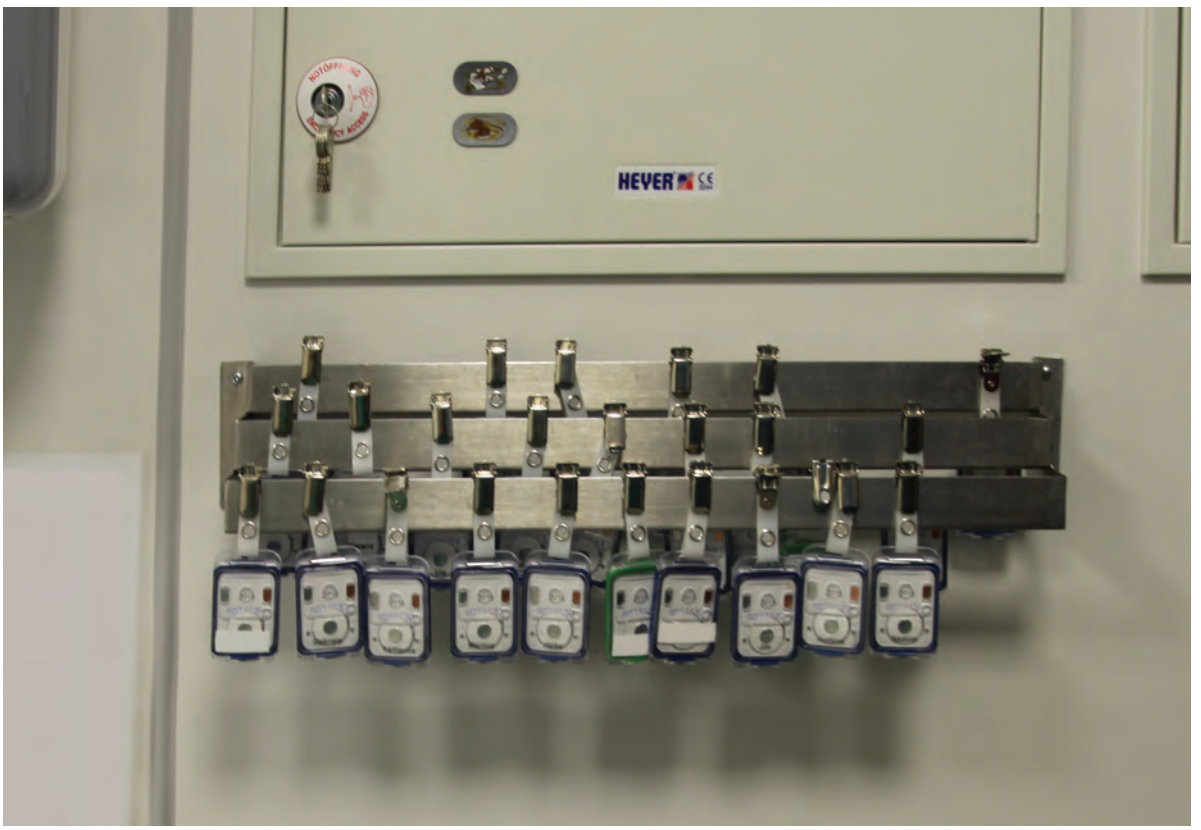



**Figure 5.6.2** A model of risk management in a medical facility with the use of architectural tools; elaborated by the Author

a broader safety policy. For instance, apart from reducing epidemiological hazard, gas decontamination of a room may pose additional threats to human health, such as poisoning with chemical substances. Such a situation proves that protecting human health becomes as a highly complex process and the advancement of knowledge and technology comes with the necessity of continuous adjustment of solutions that foster sanitary and hygienic safety to meet new challenges.

At the same time, it seems that medical units are not capable to independently and effectively develop standards for designing space adequate to the epidemiological risk. A situation that proves this hypothesis is the shortage of specialists in the fields of microbiology and epidemiology. In the Polish healthcare system, there is the lowest number of active physicians specialising in those fields per number of inhabitants. The diagnosis of the current threats in medical units is also more difficult. In Poland, the average number of microbiological tests per hospital bed is twice lower than in other EU countries (*The Report…* NIK 2018: 10).

Described above, the situation confirms the need of strengthening the significance of architectural scientific research in the field of infection prevention and including architects into interdisciplinary teams who analyse optimal standards applicable in the particular areas.



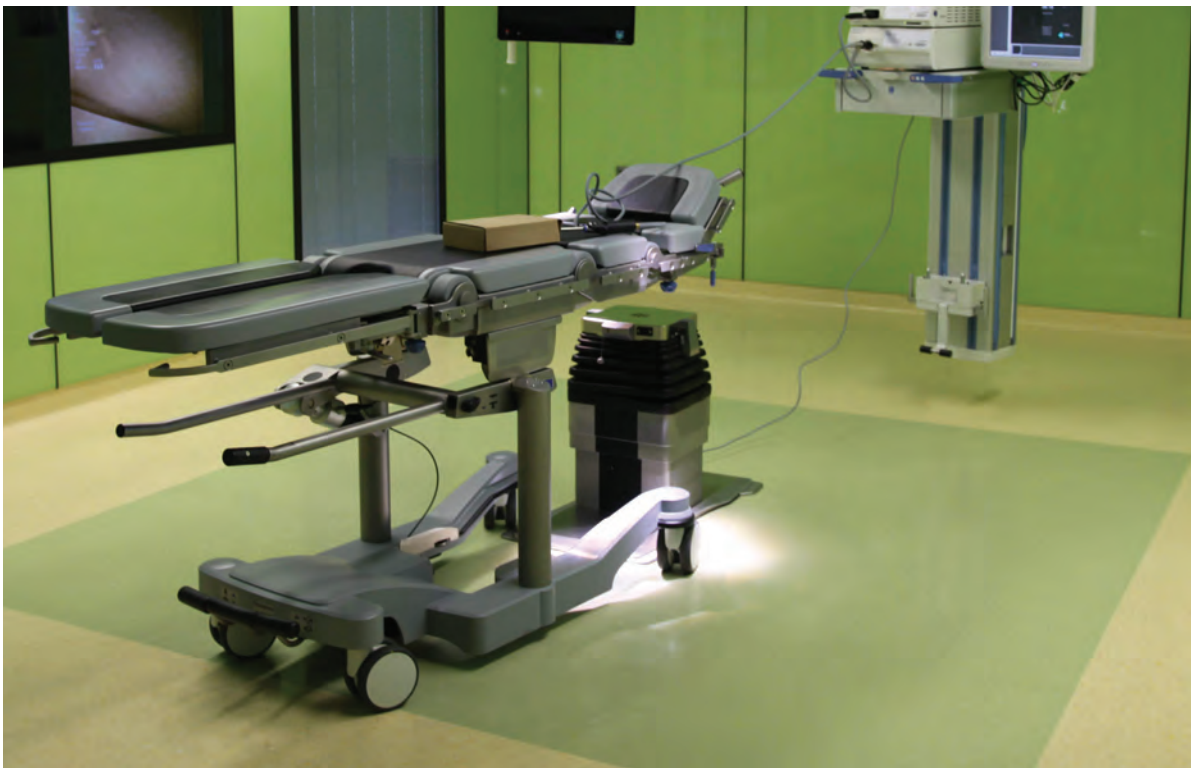

**Photograph 5.6.3** Radiation monitoring badges – assessment of radiological risk (depending on the type, it is possible to apply various tools facilitating its evaluation); photographed by the Author, 2012

# 6. Architecture as an auxiliary tool of epidemiological safety

According to one of the numerous definitions, architecture should be understood as *the art and skill of designing and arranging the space in real forms in order to satisfy material and spiritual needs of the human being* (Lenartowicz 2005: 12). Architecture is developed due to the synergy of concepts based on academic research and practical implementation. It offers a possibility to provide a theoretical analysis of the relations between design project solutions and phenomena observed in the designed space.

The monograph presents an attempt made at the analysis of those relations by discussing the problems of epidemiological safety in the environment of medical facilities. The identification of hazards and infection transmission routes allows for assigning them with particular architectural solutions, which - in relation to organisational activities - reduce the spread and transmission of pathogens. Discussed in the monograph, the practical examples undergo theoretical analysis in order to determine the scope and the character of interdependencies observed between the spatial solutions and the process of hospital-acquired infection control and to indicate problems related to the unused potential of architectural solutions.

The environment of a hospital building is a complex structure that requires continuous multi-aspect research, analysis and control. There are numerous medical and diagnostic procedures carried out within hospital environment. They are supported by an ergonomic layout of rooms equipped with



**Photograph 6.0** A mobile operating table and a stationary operating table, permanently installed within an operating theatre (the use of mobile and stationary elements of medical equipment allows for the performance of various decontamination procedures); photographed by the Author, 2016

the advanced technical infrastructure. Providing safety to the users of a medical facility through the implementation of relevant architectural solutions depends on three aspects, namely: environmental conditions (the quality of air, water, natural lighting, acoustics), properly designed spatial layouts and the quality and rationality of the selected furnishing and finishing materials (Joseph and Rashid 2007). These two latter aspects perform a highly significant role in the process of minimising the risk of hospital-acquired infections through the implementation of optimal architectural solutions. The contemporary scientific research confirms the hypothesis stating that the role of the building environment is fundamentally significant to the process of minimising and controlling the level of hospital-acquired infections. Architectural solutions and design decisions come as the key elements at the stage of constructing a medical facility oriented toward epidemiological safety (Lacanna 2014).

## 6.1 Infection sources in medical facilities

A hazard posed by pathogenic microorganisms may have various origins. In epidemiology, there are several basic sources and reservoirs of key significance in the context of infection transmission observed in the environment of medical facilities. The sources include users of medical facilities, patients, medical personnel, medical instruments and equipment, interior surfaces that medical facility users may have contact with, room cleaning and disinfection equipment, medical waste, used equipment and disposable materials, air (Maniewska 1999). On the basis of the potential sources of infections and infectious diseases identified above, it is possible to indicate places of their occurrence. This allows the analysis of epidemiological risk to cover the problem of architectural solutions that can directly or indirectly reduce the occurrence of nosocomial infections. In order to develop such an impact model, it is possible to use a scheme of medical technology components (Tomanek 2015: 32), as presented in Figure 6.1.1.

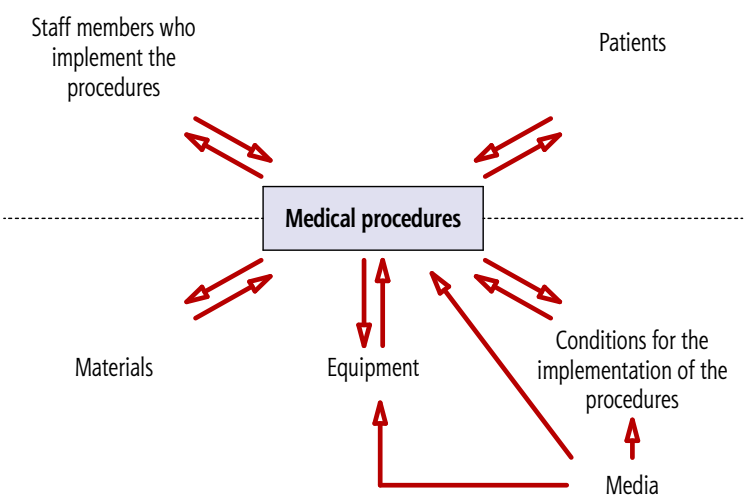



**Figure 6.1.1** A scheme presenting the components of medical technology (Tomanek 2015: 32)

In relation to medical procedures, the scheme presents interactions that determine infection transmission (personnel, patients, equipment, environment) and allows the Author to present the mechanism of infection spreading within a medical facility.

The above-mentioned interactions allow for assigning architectural solutions to the particular levels and character of epidemiological risk. It can be done in a simplified way, with the use of a basic classification of rooms in a medical facility, with the consideration of the epidemiological hazard levels. In specialist literature, there are four basic levels of infection risk identified in the particular zones of a medical facility:

1) low risk that applies to administrative and technical maintenance zones;
2) medium risk that is identified for zones where the highest flows of users are observed, namely, for the internal circulation of a hospital, waiting rooms and diagnostic rooms;
3) high risk that applies to hospital wards and medical treatment rooms;
4) very high risk that applies to other spatial layouts, including operating suites, intensive care units and palliative care units (Hoban 2012).

In terms of hospital-acquired infection risk, the role of architectural solutions is to classify design solutions adequately to the particular levels of risk. It should be implemented on the basis of the analysis of the levels of risk, transmission routes and rationality of spatial solutions suggested for the identified relations and groups (personnel, patients, equipment, environment), as presented in the following graphical scheme (Figure 6.1.2.).

Architecture of medical facilities should be designed to provide their safe use to all the users (personnel, patients, visitors). The scheme presented below indicates striving towards the implementation of functional layouts that reduce the possibilities of spreading infections and allows the undertaken activities to be evaluated in terms of their rationality and efficiency. The discussed solutions should undergo continuous evaluation and verification. Defined in such a way, the research problem still represents a large area that requires multi-aspect evaluation of architecture, epidemiology, ergonomics and management. Hence, the suggestion is made to develop design solutions in interdisciplinary scientific research teams incorporating specialists who work in various fields (Janowicz 2018). Considering the vast scope of the problem and the individual character of design solutions, the monograph refers to several selected examples of architectural solutions analysed in terms of the discussed question. Based on the examples, this part of the monograph is to confirm the hypothesis stating that the current legal regulations on the prevention of infections in medical facilities in Poland do not fully use the potential of architecture. There are numerous solutions that may rationally affect epidemiological safety in medical facilities. However, they are not required by any legal regulations and, considering their non-standard character, they are rarely implemented in medical facilities. Presenting the original design solutions in the subsequent sub-chapters is aimed at discussing the problem in more details and at confirming the hypotheses stated in the monograph. The impact exerted by the design solutions on epidemiological safety is presented with a consideration of a classification depending on the pathogen sources and pathogen transmission routes, with the reference to the potential of architecture to lower epidemiological risk through adequate design solutions. However, the discussed examples do not cover the entire research problem. Their task is to present a broad scope of the current unused potential of architecture in the field of preventing hospital-acquired infections.

The first part of the analysis refers to the spatial layouts of the most important zones where patients are located. The second part refers to the spatial solutions that may reduce transmission through medical personnel's hands and clothing. The third part of the analysis refers to the impact exerted by the selection of technological lines, flows of equipment and selection of materials on the epidemiological safety of a hospital. The fourth part refers to the design of the medical facility environment. The fifth part of the analysis presents the possibilities of architectural solutions to affect the behaviour of medical facility users with informative activities and marketing measures.

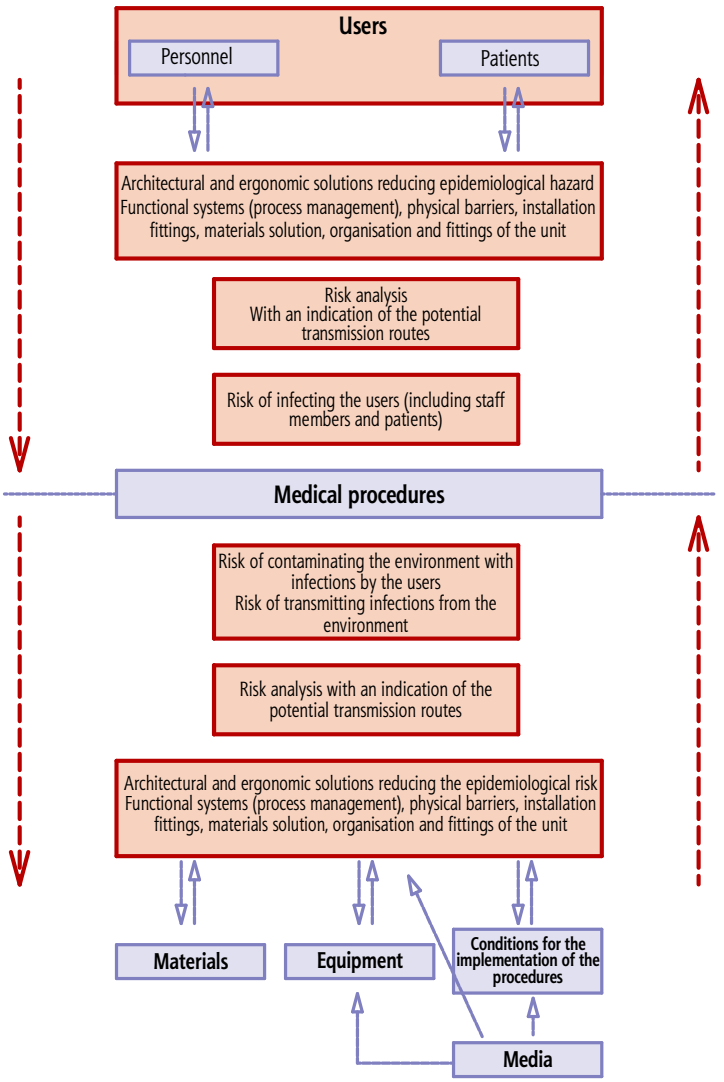



**Figure 6.1.2** An extended scheme of the medical technology components (Tomanek 2015:32), with the process of assigning architectural solutions according to the analysis of the risk levels; elaborated by the Author

## 6.2 Patients as infection sources

Medical facilities are characterised with different populations of users, who differ in terms of their health condition. Among people who are present at medical units, the largest group consists of patients who need medical assistance.

Considering patients who stay in a medical facility as potential infection sources allows the Author to present the potential of architecture to reduce the level of nosocomial infections. It can be observed on the examples of various hospital organisational units. For the requirements of the monograph, architectural solutions are discussed on four examples, in the reference to various categories of patients during the hospitalisation process:

1) patients requiring immediate medical assistance;
2) isolated patients;
3) patients staying in very high infection risk areas;
4) patients staying in nursing areas.

**Photograph 6.2** A separate area in an observation room (an example of additional solutions that go beyond the current legal regulations on epidemiological safety); photographed by the Author, 2016

The spatial and functional layouts of the areas where patients who require immediate medical assistance are admitted, are analysed on the example of an operational scheme of a hospital emergency department. This is an area that since the very moment of the patient admission is characterised by high uncertainty in terms of the potential epidemiological risk. Moreover, the procedures of microbiological diagnostics are usually long-term processes and they do not allow for a clear assessment of the patient's health condition at the moment of their admission to hospital. It means that patients who are carriers of pathogenic or infectious microorganisms can get to the medical unit through its emergency department and become the potential infection sources there. Hence, the procedures and architectural solutions that prevent broad contamination of the environment, transmission of microorganisms onto other patients, visitors and medical personnel, become more significant. In the monograph, a scheme of the patient flows in the area of an emergency department and in other spatial layouts of a medical facility is analysed. There are also several examples of the solutions, in which the preliminary qualification process allows for the identification of the particular individuals suspected of being a source of potential epidemiological risk. In such a situation, according to the Polish regulations, those patients are usually isolated, therefore, the current requirements pertaining to patient isolation are also verified, with the indication of the unused potential of architecture in the field of separating patients.

The second area discussed in the monograph involves the requirements stated for isolation rooms. The problem is presented in the context of some broader use of isolation rooms in medical facilities, with the consideration of the potential of architecture that can be used for organising various levels and types of isolation and for modifying currently existing solutions.

The potential of architecture to reduce infection transmission in the zones of high HAI risk is discussed on the example of the requirements that must be met by anaesthesiology and intensive care units. Hospitalised in these areas, patients are characterised by lowered immunity and they usually require numerous invasive medical procedures and broad-spectrum drugs. Medical care provided to those patients should be focused on their safe stay at hospital, with a minimal possibility of acquiring infections caused by microorganisms occurring in the hospital environment. In Polish legal regulations, these areas are provided with particularly succinct guidelines in the reference to the design of the discussed units. Therefore, the results of the research studies on the current spatial and functional layouts of anaesthesiology and intensive care units are also presented. Considering the fact that in Poland the level of hospital-acquired infections in the above-mentioned medical units is exceptionally high, the solutions resulting from the analysis of the transmission routes are also discussed. These solutions allow for rational modification of the existing architectural solutions applied in intensive care units.

The fourth example discussing patients as infection sources is an architectural solution applied in patient rooms at nursing units. Many patients with various diseases who stay in common rooms pose the risk of infection transmission. It specifically refers to nursing units, diagnostic and medical treatment areas. The accommodation type offered during the patient's stay at hospital comes as an important factor contributing to the transmission of pathogens: patients can be located in single-bed or multi-bed rooms. The spatial layout of a patient room is analysed with the consideration of the current scientific research studies on infection transmission within multi-bed patient rooms.

## 6.2.1 Patients requiring immediate medical assistance – the analysis of the functional layout of a hospital emergency department

One of the key elements of the epidemiological safety provided in a medical facility is the procedure of isolating patients, who are suspected of infections acquired from other users, in rooms isolated from the main spatial layout of that medical unit. However, in the Polish system, a decision about isolating patients who have acquired an infection is often made at the later stage of their hospitalisation process. The place of patients' first classification in a hospital facility is the admission room or the emergency

**Photograph 6.2.1.1** An operating theatre – a view from the patient preparation room (in other countries, the entrance to an operating theatre may require passing through additional preparation rooms); photographed by the Author 2018

room. In these areas, medical personnel decide on further medical procedures, including possible hospitalisation and its location. It is relatively easy to prove that the lack of any barriers to the spread of infectious pathogens may result in the contamination of the entire environment. In medical facilities, patients are present in numerous areas, among which they can move freely. Hence, they can contaminate all those zones. As presented in Figure 6.2.1.2, the scheme of the routes followed by the patients and personnel assumes the presence of a patient who is treated in four basic functional hospital areas, namely:

1) preliminary diagnostics area;
2) specific diagnostics area (imaging and laboratory);
3) medical treatment area;
4) non-surgical area, observation, convalescence, rehabilitation (Tomanek 2015).

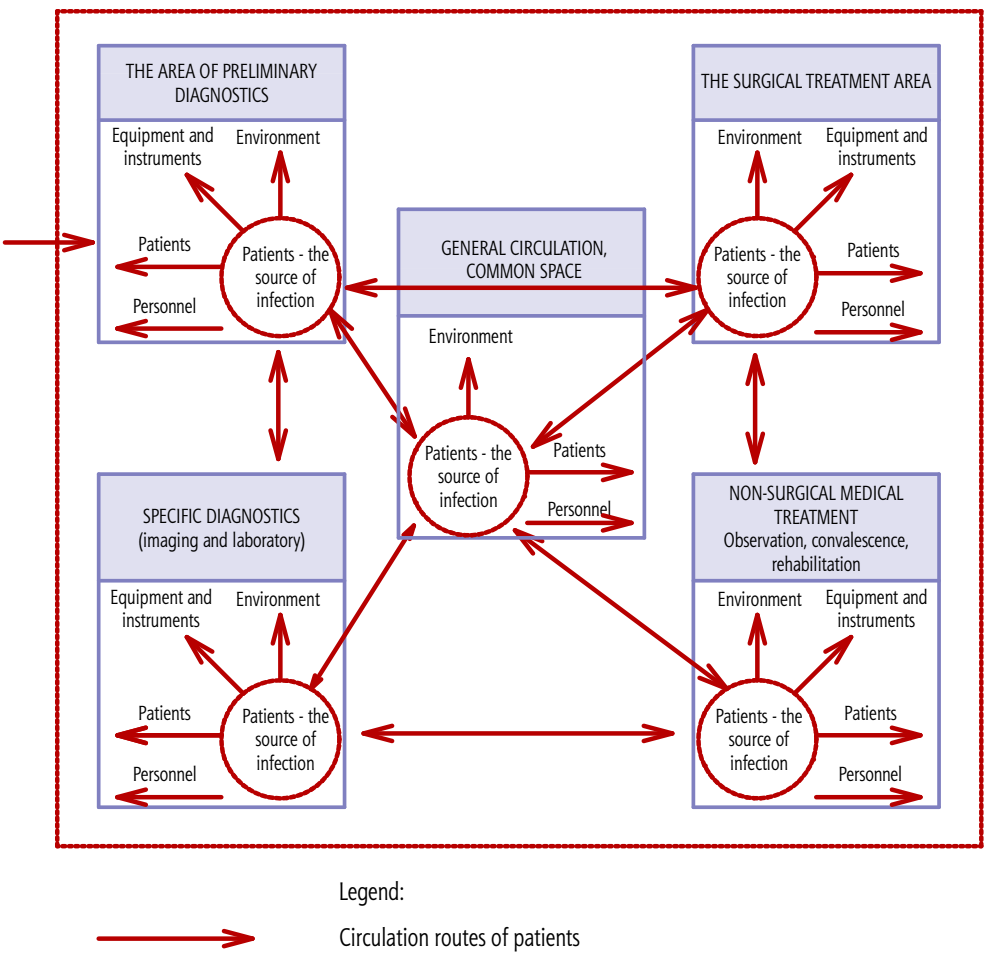



**Figure 6.2.1.2** An extended scheme of the patient route (Tomanek 2015: 58) with the directions of pathogen transmission by infectious patients; elaborated by the Author

In the case of an infectious patient, the above-mentioned patient route indicates that this person has been present in numerous areas of the medical unit. In accordance with the data provided by the Supreme Audit Office, in Poland the time of obtaining the results of microbiological analysis required to confirm medical diagnosis is up to several days. Depending on the amounts of the cultured bacteria, the culture test results with antibiograms (marking the antimicrobial susceptibility) are obtained within 2 up to 5 days and for the diagnosis involving anaerobic bacteria – up to 7 days. The culture test results without antibiograms and the results of quick tests on the presence of bacteria and viruses of epidemiological significance in clinical sample material (tests for *Clostridium difficile, Noroviruses, Rota- and Adenoviruses, Campylobacter*) are obtained within 24 hours (*The Report…* NIK 2018: 39). Hence, it is possible to assume that in the current system, infectious patients may uncontrollably move around various hospital areas.

Within 24 hours, patients who require immediate medical assistance, admitted to hospital at the emergency room, can move around all four hospital areas, as presented in Figure 6.2.1.2. This relations can be analysed in an epidemiological aspect, through the verification of the effects after the infectious patient has been admitted and allowed to move around the hospital areas, as indicated in the scheme. It is also possible to indicate the potential lines of further infection transmission. As described above, the routes followed by infectious patients in a hospital unit allow for the analysis of the potential infection transmission within a medical unit. In each of those areas, infectious patients are potential sources of infection to other patients, personnel, equipment and hospital environment (Figure 6.2.1.3). The analysis discloses a hazard generated by uncontrolled admission of infectious patients into the hospital environment. While moving around the areas, infectious patients may infect the environment in all four functional hospital areas, along with the generally accessible areas, where they may have contact with other people. Through the performance of medical procedures, such patients have also contact with medical personnel, equipment and other patients and as a result, epidemiological risk is increased. Such a broad potential scope of spreading infections is highly dangerous in medical units, and it definitely requires some rationally selected solutions.

As confirmed by scientific research, even if organisational activities have been implemented, the admission of infectious patients increases the risk of further cases of infections. *The pollution of the inanimate environment of patients becomes a significant reservoir of microorganisms posing HAI risk increased by 73% on average if patients who were previously located in the same room had MRSA (…). Numerous scientific research studies indicate that these microorganisms can survive in the environment despite the fact that cleaning and disinfection processes have been considerably improved* (Vickery 2012: 53). According to Figure 6.2.1.3, if the surface has been contaminated, its efficient disinfection in a large area and in a short time becomes an exceptionally difficult task. Assuming the standard cleaning procedures, according to the basic hygienic scheme, some surfaces undergo such procedures once a week or once a month (Grochowska 2011) – Figure 6.4.2. Unfortunately, *Staphylococci,* as well as other gram-positive cocci, can survive on non-disinfected surfaces even up to several months (Denys 2012), forming reservoirs of microorganisms. In order to prevent the above-mentioned hazards, hospitals should implement safety procedures. Considering patients who are admitted to a hospital based on a schedule, prevention should involve a properly implemented diagnostic process. It should be implemented, among other elements, through the analysis of the patient's medical history and medical diagnosis supported by microbiological tests. Considering patients admitted to a hospital by its emergency

department, architectural solutions become especially significant in the area where patients requiring immediate medical assistance are admitted.

The spatial layout of a hospital emergency department is the subject discussed in numerous contemporary publications in the field of hospital infection control. The first guidelines on architectural solutions were based on the conclusions drawn from the incidents related to the increased epidemiological hazards that took place at the beginning of the 21st century: bio-terrorist attacks with the use of anthrax in the United States of America, the occurrence of the severe acute respiratory syndrome (the SARS virus) reported in hospitals in Asia, Canada and the United States in 2003 and the pandemic caused by the influenza A/H5N1 virus in 2009. The analysis of those incidents indicated a high coefficient of transmitting those pathogens at emergency departments. Indicated at that time, a number of shortcomings in the hospital practice and infrastructure resulted in the fact that a lot of hospitals reorganised their emergency departments with the implementation of architectural solutions, next to other organisational procedures (Chen et al. 2004; Borgundvaag et al. 2004).

A hospital emergency department is one of the main areas where patients are admitted to the spatial layout of a hospital. While entering this space, patients might be potential carriers of pathogens causing highly infectious diseases (HIDs) that can be easily transmitted from one person onto another, causing life-threatening diseases, posing serious threats in healthcare facilities and human communities and requiring special control measures (Fusco et al. 2012). Patients can be infected symptomatically or asymptomatically with pathogenic microorganisms, such as influenza viruses, rotaviruses, tuberculosis and other antibiotics-resistant microorganisms, such as methicillin-resistant Staphylococcus aureus or *Klebsiella pneumoniae* strains resistant to carbapenems. They may also become infection sources resulting in epidemics of diseases, such as influenza A/H5N1 or measles.

It should be assumed that hospital emergency departments are the strategic areas in the management of infection transmission – they constitute the initial nodes, where patients are introduced to the complicated spatial layout of a hospital. The system of flows in such an object can be analysed with the use of simulation modelling and process mapping. Today, methods and tools applied in management are transferred and adapted to other fields, e.g.: the industrial sector. The examples of implementing methods applied in management in medical facilities are discussed in specialist literature. Among other methods, it is possible to mention the Lean Six Sigma method in the process of optimisation and operational management of a hospital emergency department (Shiver and Eitel 2012). One of the tasks performed by the system is to plan the flows of patients, medical personnel, medical equipment, medical waste and to test various incident scenarios on a model. Obtained in such a way, the data is analysed in the context of a clinical programme. This approach toward the simulation and modelling in the field of healthcare combines three key processes: clinical, architectural and engineering activities (Ibid.: 128).

Architectural design provides a possibility to manage patient flows in medical facilities, allowing for the implementation of safety procedures. This type of solutions is implemented in various countries. Considering the experience of the SARS infections in 2003, in Singapore, hospital admission zones have been provided with centres for the management of infection carriers and infectious patients. Patients are verified in terms of previous travels, fever and other symptoms. If they answer positively to any factor indicating the suspicion of infection risk, patients are directed to a separate area. The reason for such actions is the identification of high risk patients as quickly as possible (Lateef

2009). Intended for fast detection of potentially infectious patients and reduction of infections, similar principles have been implemented in Dutch hospitals, with the consideration of the assumed scenario. Since 2001, the Netherlands pursue the *Search and Destroy* policy in hospital infection control, in relation to the programme of reducing the transmission of methicillin-resistant *Staphylococcus aureus* strains (MRSA). The programme involves actions undertaken to isolate and treat infectious patients and carriers and even to close down the entire hospital departments. Following this policy in hospital facilities has already resulted in decreased levels of MRSA infections and has eventually brought considerable savings (van Rijen and Kluytmans 2009). Similar procedures are followed in Ireland, where the Department for Health and Children recommends screening patients at MRSA increased risk, assuming the isolation of such patients, starting from the moment of the confirmation of negative test results and elimination of any identified MRSA. However, the effectiveness of this programme has not been confirmed yet (Higgins et al. 2010).

Architectural solutions applied in hospital emergency departments have recently become a popular topic in the research analysis, where they are considered as strategical points in a potential epidemic crisis. Under the framework of the European Network for Highly Infectious Diseases (EuroNHID) in 2009, the data was collected in 41 hospital emergency departments located in 14 European countries. One of the analysed aspects was the number of isolation rooms located directly within the structures of the hospital emergency departments. The results of the research indicated that isolation rooms were available in 34 medical facilities (accounting for 82.9% of the analysed facilities). However, only 19 of them were equipped with airlocks and in 15 hospitals isolation rooms were provided with a separate entrance doors. The differences in the elements of hospital furnishing was also observed in terms of mechanical ventilation in the analysed isolation rooms: in 17 hospital facilities negative pressure was applied and in 12 hospitals HEPA filters were installed. Only 6 medical facilities (accounting for 14.6%) were equipped with isolation rooms designed with the consideration of all the discussed elements in the area of their emergency departments (Fusco et al. 2012).

In 2013, the Canadian epidemiological safety services (in French: *Comité sur les infections nosocomiales du Québec*) issued some guidelines on the infection prevention and control measures in emergency departments (*Infection Prevention…*, 2013). Among the recommendations included in this document, there are several ones that directly refer to the architectural design of the medical space. The authors of the document emphasize the need of incorporating the spatial structure of hospital wards and their equipment into the scope of technical inspection, as it should be the priority during the construction of new emergency departments or modernisation of the existing ones. They pertain to the protection of employees through the construction of physical barriers at the admission centres, the use of high desks and glass partitions, providing separate stations for admission of infectious patients and separate toilets dedicated to medical personnel only.

Patients admitted to hospital emergency departments should be located at individual separate stations. Multi-bed rooms dedicated to patients with various types of trauma and requiring resuscitation should be divided into stations separated with rigid partitions made of materials that are easy to clean and to disinfect. Today, curtains and textile screens are not recommended because the process of their decontamination is more difficult. The research carried out at one of American hospital emergency departments indicated that 42% of hospital curtains were contaminated with vancomycin-resistant *Enterococci*, 22% were contaminated with methicillin-resistant *Staphylococcus aureus* and 4% - with

*Clostridium difficile*. Hence, it was confirmed that hospital curtains become reservoirs of healthcare-associated pathogens (Trillis et al. 2008). They are potential sources of spreading pathogenic microorganisms because of their frequent contact with patients and personnel. Consequently, new materials have been searched for and applied, including glass partitions with antimicrobial properties (Schweizer 2012).

Discussed above, the examples and analysis prove that architectural solutions facilitating management are of auxiliary and supporting nature to organisational activities. The architecture of medical facilities should allow for efficient implementation of preventive actions. The scientific research studies confirm that cohesive multi-aspect activities undertaken in the field of reducing hospital-acquired infections produce positive results (Tabori and Dettenkofer 2018).

In Polish hospitals, as in any other European countries, similar problems can be observed, however, the procedure standards and architectural solutions do not always follow the experience of other countries. In 2017 in Poland, nearly 4.8 million people received medical assistance at hospital admission wards and hospital emergency departments, on an outpatient basis (GUS 2018: 1). It should be assumed that among patients admitted to a hospital emergency department, there will be patients infected with pathogenic microorganisms and that there has not been any diagnostics carried out to classify them properly. Empirical isolation should be implemented in the area of hospital emergency departments, considering the fact that the clinical picture can be unobvious.

Empirical isolation is applied to patients who are suspected of infections with pathogenic microorganisms, based on the information provided by medical personnel, medical interview and physical examination, without microbiological confirmation, who require contact, droplet or respiratory isolation. The isolation is continued until the negative test results are confirmed or to the moment when the applied antibiotics eliminate infections (Ozorowski et al. 2017: 16). In terms of architecture, empirical isolation requires prior preparations made to the area where it is going to take place. Organisational solutions in the field of epidemiological safety should be adequately supported by properly designed space for patients in the disease incubation period, patients who are suspected to be carriers or diagnosed with infectious diseases and followed the procedures of emergency admission. As a result of safety analysis, it is possible to construct and analyse impact scenarios and maps of impact exerted on the safety of medical facility users. Architecture has the ability to affect the routes followed by users (patients, personnel and visitors) and their behaviour. One of the tools applied to develop such a strategy is the event matrix that includes planning locations where the particular activities and calculations are going to be carried out (Janowicz 2012).

Such a scenario allows for reliable management of epidemiological risk, considering activities aimed at the elimination and reduction of hazards through the combination of organisational and spatial actions. The analysis of relations between architectural solutions and procedures of the medical facility use should be the basis of the system for preventing hospital-acquired infections.

One of the aspects related to safety management in the field of hospital emergency departments is the analysis of the routes followed by potentially infectious patients. At the stage of a preliminary design, some locations are selected within the particular medical facility that are considered significant in terms of the sanitary safety of the building. Next, referring to the clinical knowledge and applying adequate architectural solutions, the routes for patients are designed within the hospital department and then within the entire medical unit. Considering the analysis of rare or unscheduled events, they

can lead to the development and analysis of emergency/contingency plans. In this way, spatial solutions are not limited to the implementation of one possible variant of the procedures to be followed. They provide a possibility of the occurrence of various needs and implementation of different anti-epidemic strategies. If it is necessary to implement emergency procedures, they are ready for negative scenarios (related to the calculation and atypical, rare or particularly dangerous events). Developed in such a way and approved, the plans become a basis for the design of the architectural space of a hospital emergency department and for the implementation of operational procedures within the medical unit.

The functional and spatial layout of a hospital emergency department includes the following areas: medical segregation, registration and admission, resuscitation and surgical treatment, initial intensive care, urgent care, observation, consultation, administrative and maintenance areas, a base area for emergency response teams if they are included in the structure of the department. Considering the epidemiological aspect, the regulations on the principles for designing the area of hospital emergency departments do not state any requirements of a separate isolation room and of a separate route for potentially infectious patients (Journal of Laws 2011, no. 237, item 1420 with later amendments).

If there are not any organisational and architectural protective measures applied, patients may uncontrollably infect the environment of a medical facility and its other users (Figure 6.2.1.2). Users of a hospital emergency department are often immunocompromised patients, elderly people who constitute a group particularly susceptible to infections. This situation contributes to an increased risk of transmitting infections onto other patients and medical personnel. An additional problem is caused by the growing overcrowding of hospital emergency departments. As a result, the numbers of users in common hospital areas become higher and there are delays in the implementation of the procedures. The specific character of the problems currently observed in hospital emergency departments and the increased numbers of patients indicate that the necessity of carrying out a detailed and multi-aspect architectural analysis is well justified. Such an analysis should be aimed at finding optimal solutions to epidemiological problems related to the design of the discussed areas. It should be also noted that the frequency of hospital-acquired infections is not significantly lowered due to the structural improvement only. The expected results in the reduction of nosocomial infections can be achieved through a cohesive multi-aspect strategy combined with the proper organisation and management of human resources, hygiene and environment (Tabori and Dettenkofer 2018). Planning should result in a situation when working processes are well thought through, coordinated and efficient. It should facilitate the implementation of hygienic standards into the routine clinical procedures. A tool for such designing is simulation modelling and planning which allow for collecting information on the system and, as a result, for achieving the ability to manage the change, namely: the possibility to compare different variants based on the data. In the process of change management, planning allows for the development of modified spatial layouts and their multi-aspect comparison.

Figure 6.2.1.3 presents a functional scheme of a hospital emergency department, where spatial solutions that allow for management of potentially infectious patients have not been implemented. It can be compared to the scheme where architectural and organisational tools for separating the flows of patients in order to reduce infection transmission have been applied (Figure 6.2.1.4).

The comparison of both models allows for collecting a large amount of data on the infected surfaces, the numbers of potential contacts with other users, technical information, such as, the length of the route to be followed by medical personnel to perform their duties. The comparative analysis of the

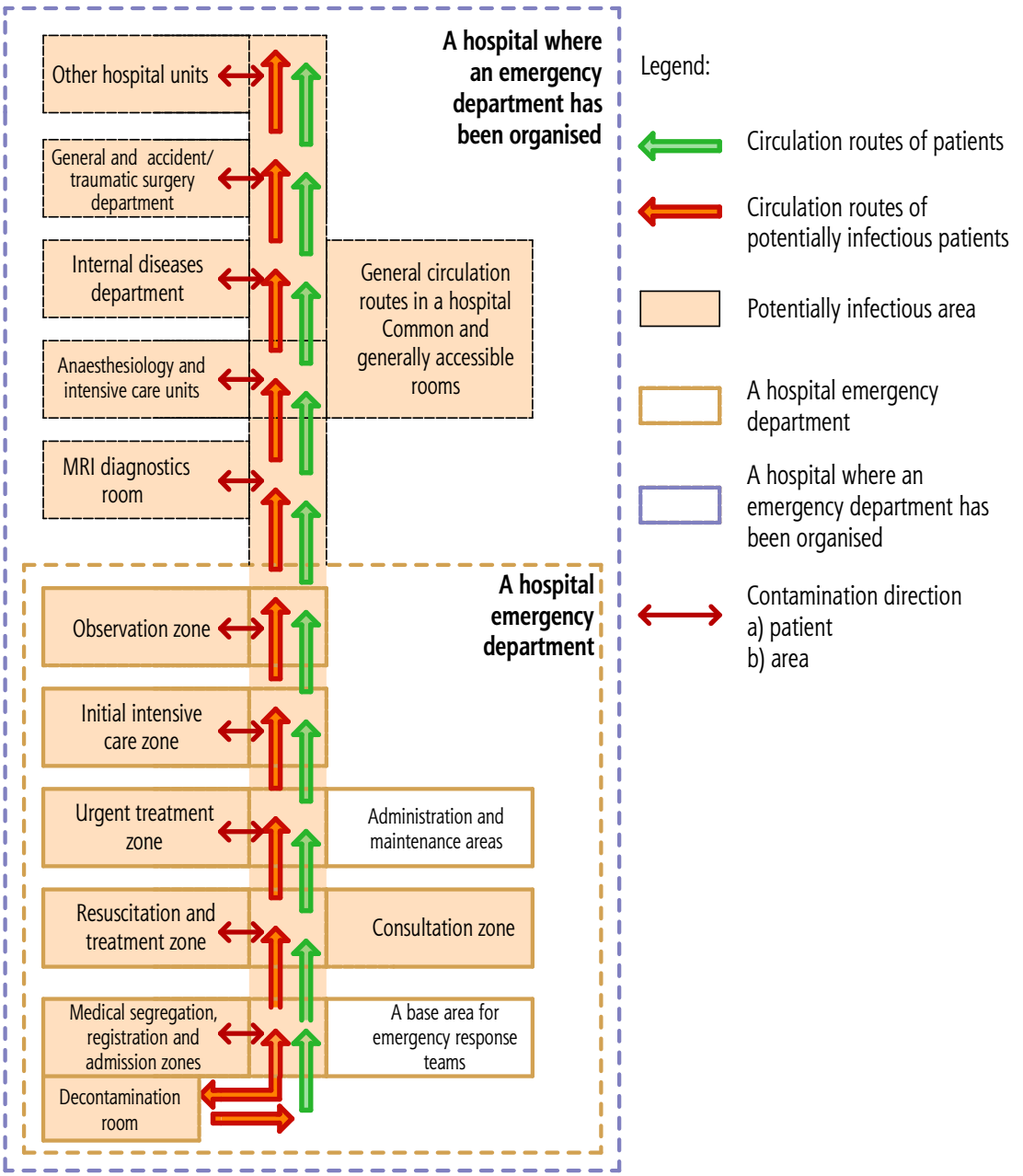



**Figure 6.2.1.3** A schematic route of patients in a hospital where spatial elements allowing management of separating potentially infectious patients have not been implemented; elaborated by the Author

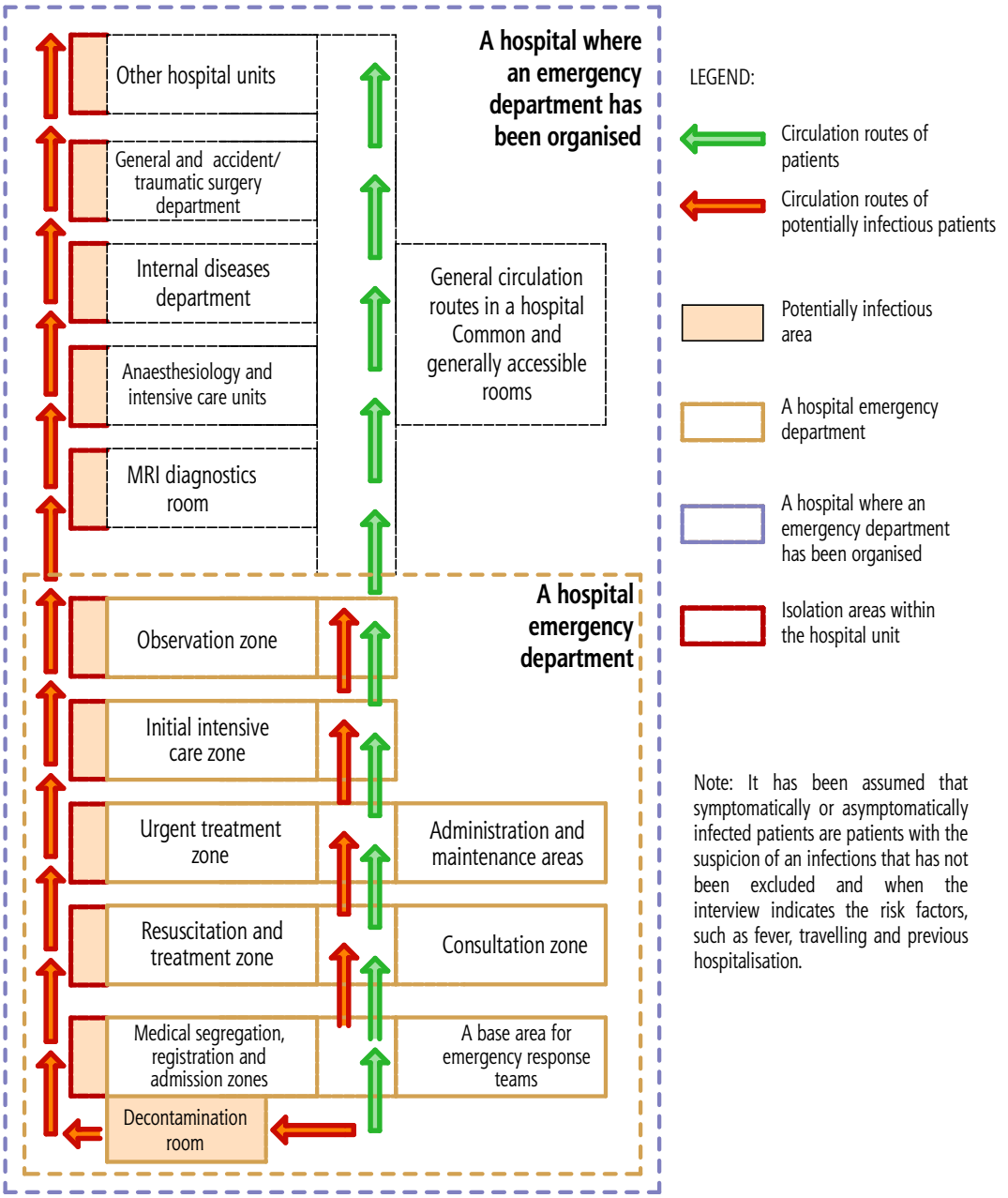



**Figure 6.2.1.4** A schematic route of patients in a hospital where architectural and organisational tools for management of flows of potentially infectious patients have been implemented; elaborated by the Author

functional models presented in Figure 6.2.1.3 and Figure 6.2.1.4 allows for a reliable quantifiable theoretical evaluation of the solutions. In process management, the ultimate evaluation of the changes is possible after their implementation (Tytyk 2016). However, a preliminary assessment of both schemes suggests that there is a possibility of reducing contaminated surfaces and contact with other users even by approximately 80%. Such an estimation indicates the potential of architecture to improve safety within the discussed space in a rational, however, non-standard way in relation to the regulations currently applicable in Poland.

The current regulations applicable in Poland refer to the problems related to infections in the area of hospital emergency departments to a very little extent. The management of the process in which potentially infectious patients are admitted to a medical facility is represented by a requirement of room decontamination. It refers to a separate space or a station within which pathogenic agents, including biological ones on patients' bodies, are deactivated. The procedure of decontamination involves washing the patient's body before diagnostics and medical treatment. Undertaken for the benefit of decontaminated patients, other patients, visitors and medical personnel, the procedure is aimed at reducing epidemiological risks in all the areas. As identified by the medical personnel, the need for decontamination results from the possibility of infecting the patient, their clothes, skin, appendages, etc. A decontamination station must be arranged within the area of medical segregation, registration and admission or – as a temporary solution – at a place that is accessible directly from the outside of the facility building or located as closely as possible to the entrance for patients and to the driveway dedicated to specialist vehicles of medical transport, leading to the department (Journal of Laws 2011 no. 237, item 1420 with later amendments).

In Poland, the implementation of a decontamination station to the structure of a hospital emergency department results from the current legal regulations and is related not only to the preparation of patients to medical procedures but also to the prevention of infections and infectious diseases. However, in Poland, apart from indicating the need of providing a decontamination station, the relevant legal regulations are not followed by any guidelines on further procedures that should be undertaken towards such patients. As a result, a decontamination station rarely becomes an element of a larger functional system of patient separation. If there is not any isolation room functionally connected with it, the possibilities of direct separation of patients after their decontamination process are limited, although it is necessary if decontamination has been performed because of the epidemiological reasons. In Poland, the current regulations do not refer to the management of circulation of patients leaving decontamination stations, despite the fact that the methods applied to organise such flows of patients are known and discussed in specialist literature (Lateef 2009). It means that after the process of decontamination, patients should be moved to an isolated area and their circulation around other areas of the hospital emergency department should be restricted to the absolute minimum. The contemporary scientific research recommends that there should be at least one isolation room with mechanical ventilation and an air pressure cascade provided in order to isolate patients with a clinical picture of an infection caused by a disease transmitted by the respiratory tract, such as tuberculosis, measles, smallpox, severe diseases of the respiratory tract (Chen et al. 2004). The example of an expanded functional system is presented in Figure 6.2.1.5., showing the solutions that are not required by the current legal regulations, such as an entrance to the decontamination station leading directly from the outside of the building, a connection of the decontamination station with the areas of medical segregation, registration and admission and isolation.

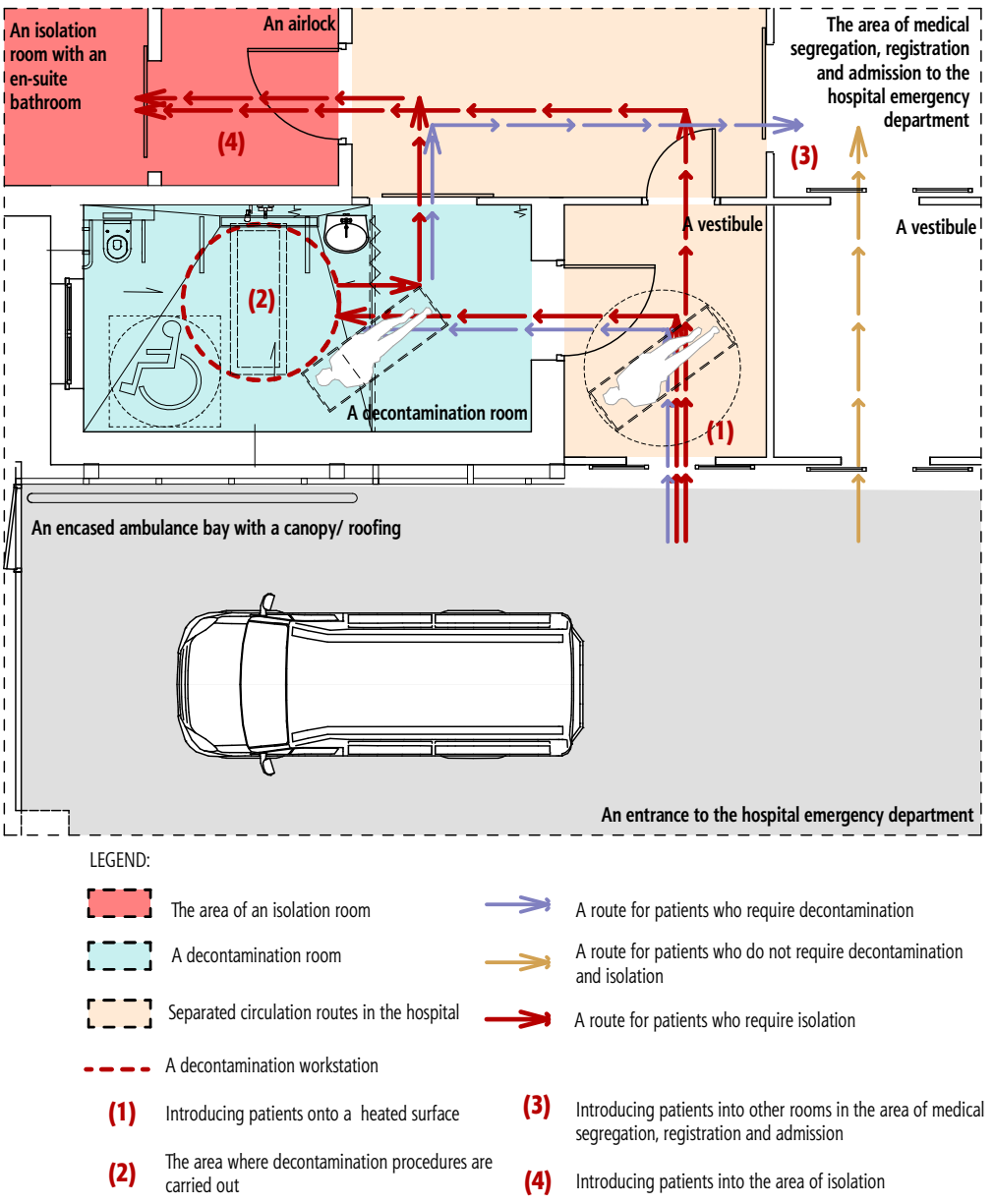
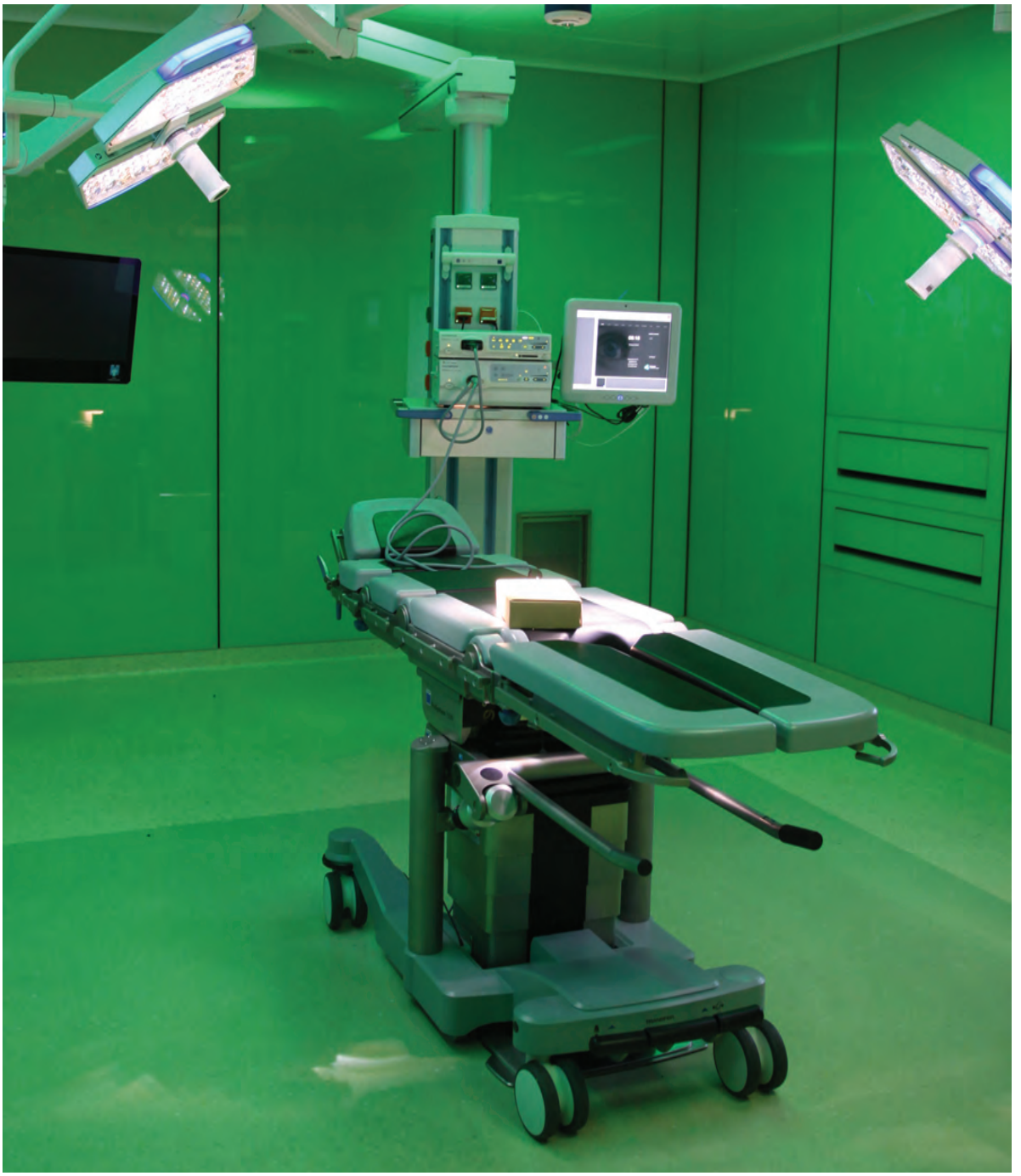



**Figure 6.2.1.5** An example of designing a decontamination station at a hospital emergency department; elaborated by the Author



**Photograph 6.2.1.2** An operating theatre – a view from the patient preparation room (in other countries, the entrance to an operating theatre may require passing through additional preparation rooms); photographed by the Author 2018

As discussed previously, the defined architectural areas of patient isolation and the example of the design of a hospital emergency department confirm the architectural ability of organising the space in a way that reduces introduction of infectious pathogens into the medical facility. The analysis of the flows of patients with increased risk allows for the reduction of potentially infected areas and for better management of epidemiological risk. The discussed analysis indicates the need of implementing additional design solutions that are not mentioned in the current legal regulations into architectural projects. It also proves that in Poland there is a need for implementing legal modifications or for developing nationwide design standards in the field of the principles defining the operation of medical facilities in terms of epidemiological hazards. The development of such standards should particularly refer to hospital emergency departments, as it should positively affect the level of epidemiological safety through the unification of safety standards applied by medical units.

The identified need for a considerable contribution of good design practice in the proper architectural design of the hospital emergency departments and deviations from experience-based practice of other countries confirm the fact that in Poland there is also a need for an increased role of architecture in the field of preventing hospital-acquired infections. It also indicates the necessity of providing in-depth scientific research on the theory of architecture in the field of designing medical facilities.

## 6.2.2 Isolated patients – the architecture of an isolation unit

Isolating infected patients has been applied to control spreading infectious diseases for a long time. The current solution of locating the patient in an isolated room has been used since the time of the hygienic and sanitary guidelines suggested by Florence Nightingale (Fleischer 2009). Since the 1960s, separating some patients has been the procedure commonly applied in hospital facilities. Initially, it was intended to provide protective isolation of heavily immunocompromised patients and later to prevent cross-contamination of patients and medical personnel and transmission of drug-resistant bacteria, mainly Staphylococcus aureus strains (Morgan et al. 2009). The scientific research studies on the transmission routes of tuberculosis bacilli from patients to patients and from patients to medical personnel have been also well documented (Pearson et al. 1992).

At present, isolation and limited contact also come as basic tools intended to decrease the spread of pathogenic agents, particularly within a medical facility. There are numerous examples of implementing this method under the form of architecturally organised units. The basic spatial requirements defined for such units are commonly known.

In numerous countries, including Poland, a solution similar to the one defined by the American Institute of Architects (*Guidelines…,* 2006) has been adopted. An airborne infection isolation room (AIIR) is a single room dedicated to care provided to patients with a suspected or confirmed infectious disease transmitted by air. The AIIR is provided with negative pressure in relation to the airlock (the air flows under the door into the room) and is directly extracted from the room outside the building or it is circulated through a HEPA filter before being reintroduced into the room (*Centers for…,* 2007).

In Ireland, the minimal number of respiratory isolation rooms in newly constructed hospitals of the national level is defined as one room per 150 hospital beds, in regional hospitals and hospitals of

**Photograph 6.2.2** Automatically opening door (a solution that reduces a possibility of contaminating medical personnel's hands); photographed by the Author, 2015

a higher status - one room for 75 beds. Newly-constructed hospital emergency departments should be provided with at least one isolation room (*Infection Prevention…*, 2008).

In 1996, in the United States of America, the Centers for Disease Control and Prevention (CDC), an agency of the federal government, formulated some guidelines based on two safety levels:

- 1st level refers to basic safety measures recommended for all hospitalised patients who do not have to be isolated in separate rooms. It includes the proper hand hygiene immediately before and after the contact with the patient and the use of individual protective measures;
- 2nd level refers to isolation depending on infection transmission routes; it applies to patients with documented infections or colonisation with infectious microorganisms divided into the following groups:
  - transmitted by droplet and airborne-droplet routes; isolation is applied to patients with suspected or confirmed infections, such as measles (a disease transmitted by droplet and airborne-droplet routes); droplet isolation;
  - transmitted by airborne-dust routes; respiratory isolation;
  - transmitted by contact routes; contact isolation (Fleischer 2009; Bauman et al. 2014).

Furthermore, specialist literature also lists protective isolation recommended to immunocompromised patients in order to protect them against microorganisms occurring in the hospital environment – in the context of architectural solutions, this aspect is discussed in the next chapter of the monograph.

In 2007, the Australian agency, the Victorian Advisory Committee on Infection Control issued a list of the hermeticity classification for designing isolation rooms (*Guidelines for…*, 2007):

- Class S refers to standard isolation providing basic isolation conditions to the patient, considering the possibility of transmitting infections by contact or droplet routes. The key features of the Class S isolation rooms are: a self-closing door, a washbasin and an individual bathroom. Isolation rooms of this type are recommended to all nursing departments.
- Class N refers to isolation rooms where additional solutions have been applied, particularly including mechanical ventilation and negative pressure. They are provided to reduce transmitting infections by air routes. They are dedicated to the hospitalisation of patients with suspected infections transmitted by droplet routes, such as smallpox and measles. The functional layout of units with isolation rooms usually includes a patient room provided with the access to an individual bathroom and an airlock separating the unit from the hospital circulation. Washbasins activated without hand contact are installed in the patient room and in the airlock. The required difference in pressure between the rooms is not less than 15 Pa and the required frequency of air exchange is 12 cycles per hour. It is recommended to use isolation rooms of this type at hospital emergency departments, intensive care units, paediatrics and neonatology departments.
- Class P refers to isolation rooms with positive pressure in relation to the environmental pressure to reduce the risk of transmitting infections on susceptible patients by air routes. Isolation rooms of this type are provided in some medical facilities to isolate immunocompromised patients after transplantations. Class P isolation rooms are considered as protective isolation units.

In Poland, the guidelines published in *Zalecenia izolacji chorych w trakcie hospitalizacji* (*The Guidelines on Isolation of Hospitalised Patients* 2017) by the Polish Association of Epidemiological Nurses indicate locating patients based on a decision depending on the evaluation of risk of transmitting potential pathogenic agents. If possible, patients who may pose the risk of transmitting microorganisms should be hospitalised in isolated rooms. The decision about locating the patient in an isolated room should be made with the consideration of the following factors:

- transmission routes of confirmed or suspected infections;
- risk of transmission;
- risk of complications resulting from the occurrence of hospital-acquired infections in other patients in the same rooms;
- availability of single rooms (Ozorowski et al. 2017: 31)

The Polish legal regulations do not differentiate isolation rooms. They are described as rooms dedicated to the isolation of a patient or a group of patients with an infectious disease, or a person or a group of people with a suspected infectious disease, in order to prevent transmission of pathogenic biological agents onto other people (Journal of Laws 2012, item 739 art.1, section 1, sub-section 2). The guidelines provided by the Minister of Health describe only one type of rooms: *A hospital isolation room that consists of:*

- *a patient room;*
- *a hygienic and sanitary facility accessible from the patient room, equipped with a) a washbasin with a tap activated without hand contact and, additionally, with a disinfectant dispenser activated without hand contact, a container with disposable towels, a container for soiled towels; b) a shower with isolation room at the anaesthesiology and intensive care units; c) a washer-disinfector for hospital bedpans and urinals if they are reusable items; d) a device for decontamination and disposal of single-use soiled pads, installed in the way that eliminates any possible risk for the patient – if disposable bedpans and urinals are used;*
- *an airlock with a washbasin and medical gowns situated between the patient isolation room and general circulation pathways* (Journal of Laws 2012, item 739, art. 21.1).

Some additional guidelines can be found in *Zalecenia izolacji chorych w trakcie hospitalizacji* (*The Recommendations on the Isolation of Hospitalised Patients* 2017) issued by the Association of Hospital Epidemiology and the Polish Association of Epidemiological Nurses. The publication indicates the needs referring to the rooms with the air exchange (from 6 up to 12 cycles per hour) and the direct extraction of air outside. If it is impossible, the air should be circulated through HEPA filters. The air pressure should be monitored in order to control negative pressure in the isolation room. The door of the isolation room must be closed and opened only if there is a necessity to move equipment or medical personnel need to enter or exit the room (Ozorowski et al. 2017). These solutions are similar to the ones developed by the American Institute of Architects for air-isolated rooms.

Hence, the minimal requirements for the architectural solution to be applied in the isolated areas, which are also the areas of increased epidemiological risk, are defined and basically refer to three rooms. In those rooms, architectural and organisational measures are required to reduce the possibility of transmitting infections. Still, the recommendations do not provide any description of the ways applied to verify those solutions in terms of their proper functioning. Furthermore, the current regulations indicate the need of hospital isolation rooms only in paediatrics and infectious disease depart-

ments. Medical communities also postulate changes to the current regulations, indicating the need to provide adequate conditions for the isolation of patients who require it, with the consideration of transmission routes of microorganisms and biology of etiological factors of infections (Bulanda et al. 2016: 33).

Indicating the need of providing isolation rooms, the Polish legal regulations do not define any requirements regarding their hermeticity. Considering the rational character of undertaken activities, assuming a similar level of protection against infectious agents of the second hazard group, *the spreading of which is unlikely in a human population,* and infectious agents of the fourth hazard group, *which cause serious diseases in humans, are dangerous for employees and the spreading of which is very likely in a human population. Usually, there are not any efficient preventive and medical treatment methods to combat them* (Journal of Laws 2005, no. 81, item 716, annex no. 1) comes as a solution that is inadequate to the growing need for preventive isolation in various hospital areas. It seems that architectural and organisational solutions related to isolation should be more commonly applied and adjusted to the types of hazard. An attempt at averaging them is not only irrational but also dangerous. Using inadequate safety measures as a protection against agents of the low category can be considered economically irrational, however, applying lower safety measures in isolation of hospitalised patients of the third and fourth hazard group generates unjustified risk. Adopting uniform architectural and organisational standards in the procedures in the situation of the identified low and high risk may negatively affect the proper qualification of epidemiological hazards by medical personnel, who should adjust their organisational activities to the level of risk.

Figure 6.2.2.1 presents an example of an architectural solution for an isolation unit, in accordance with the Polish legal regulations. It allows the reader to observe the functional and spatial solutions in the context of intended effects, namely: counteracting infection transmission. As presented in the design scheme, the solutions foster reduction of infection transmission through the functional system described by the Minister of Health (2012). Such isolation allows for reducing infection transmission even when infectious pathogens are transmitted by droplet routes. It refers to microorganisms whose parts of the diameter above 5 μm are emitted during speaking, coughing, sneezing and during medical procedures performed on the patient's respiratory tract (Fleischer 2009: 207). The applied architectural solutions contribute to epidemiological safety through the separation of rooms with constructional partitions, limited access of unauthorised persons, mechanical ventilation that provides the possibility of managing the potentially contaminated air through the control of its flow from the clean area to the contaminated area. In that way, the risk of contaminating the environment outside the defined isolation zone is reduced (Figure 6.2.2.1 – the red area). The solution reduces the risk of infections transmitted through indirect contact with the carrier. The airlock dedicated to medical personnel allows employees entering the isolation room to use additional measures of individual protection, reducing the possibility of transmission through direct and indirect contact. The regulations referring to the minimal architectural solutions do not specify the use of ergonomic and technological elements regarding the use of protective medical gowns, despite the fact that the presence of an infectious patient is always assumed in an isolation room. The proper performance of the procedures related to the use of protective medical gowns becomes more difficult and there is a risk of contaminating employees' personal clothes.

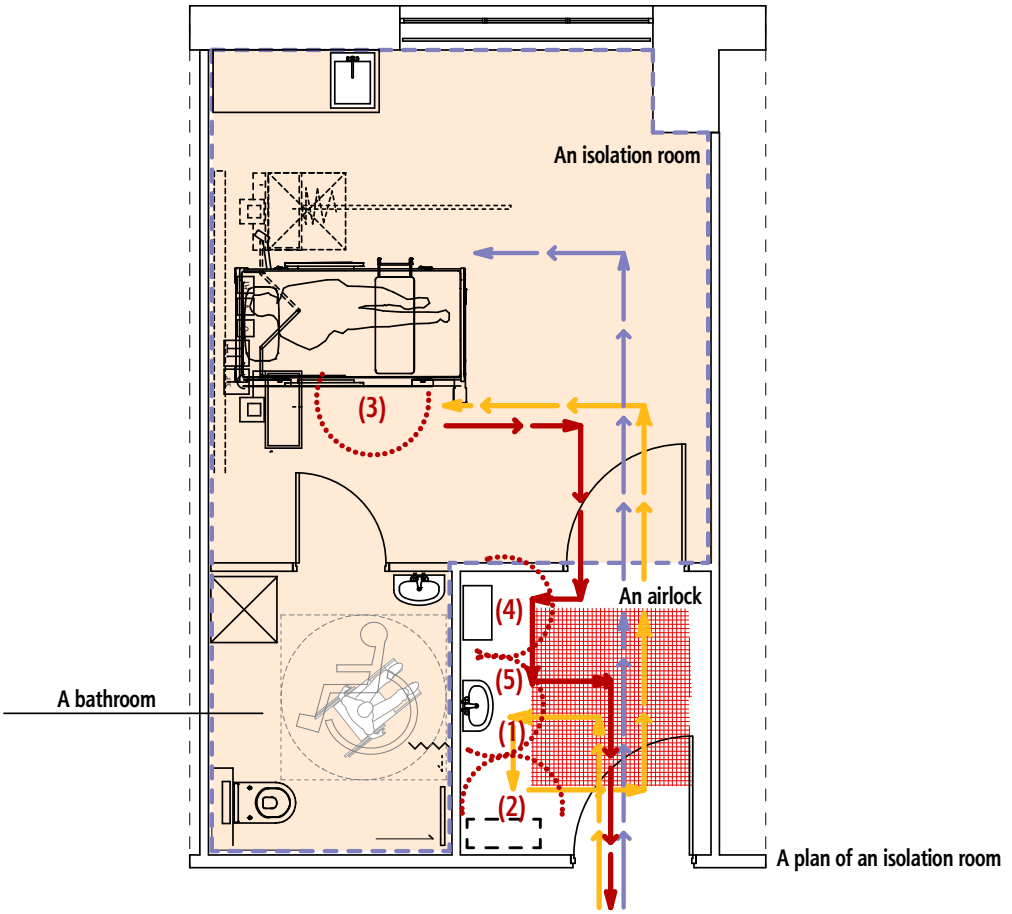



**Figure 6.2.2.1** A patient isolation unit – in accordance with the requirements stated in the Ordinance of the Minister of Health of 26th June 2012 on the specific requirements for the facilities and equipment of entities providing healthcare services; elaborated by the Author

Presented in Figure 6.2.2.1, the example of an isolation unit does not come as a closed set of architectural solutions that can be implemented to improve safety. The need for providing isolation itself allows us to assume that a patient who is staying in such a unit is a potential source of infection. This, in turn, allows us to compare the safety standards typical of other organisational hospital units. By comparing the ways used by medical personnel to enter an isolation room and to enter an operating suite, it is possible to notice that in both these areas protective medical gowns are changed, however, the approach toward the risk of contaminating clean clothes by soiled garments is different in each case. The changing room unit preceding an operating suite consists of a number of rooms, including a dirty changing room (where medical staff leave their personal clothes), a bathroom, a clean changing room (where medical staff put on protective medical gowns) and a return changing room. This solution is aimed not only at providing the possibility of changing clothes in separate rooms but – first of all – at reducing their contamination (Figure 6.2.2.2). A comparison of the above-mentioned standards may indicate that the solutions characterised with the lower safety levels are implemented in a situation of an increased risk. It also confirms the fact that the requirements stated by the current regulations are not uniform in the context of a specified risk. The contemporary scientific research clearly indicates the necessity of providing in-depth studies on architectural design of isolation rooms, their furnishing and ventilation methods (Hyttinen 2011).

Figure 6.2.2.2 presents a hospital isolation room where a patient is isolated with the spatial layout going beyond the requirements specified in the legal regulations. The airlock separating the isolation room is organised within one room. However, its dirty and clean parts are clearly defined and, therefore, the possibility of contaminating personnel's clothes is reduced. It should be emphasized that the discussed theoretical solution complies with the requirements of the legal regulations indicating the need for providing an entrance airlock. However, in order to achieve that aim, the functional solutions similar to those presented in Figure 6.3.2.3 are applied. The architectural solution is also complemented with an observation room. To maintain the high level of hermeticity, isolated patients should remain under the surveillance of medical personnel. However, the necessity of entering the isolated area can be limited. The use of electronic communication means and an observation window reduces the necessity of entering the isolation room.

The legal regulations in Poland do not clearly define the need for providing isolation rooms in numerous organisational hospital units. It means that the implementation of architectural solutions that increase epidemiological safety through the possibility of isolating some patients largely results from the arbitrary decisions made by managers of medical facilities and not from the legal regulations. In some cases, this situation may negatively affect the safety level of the entire medical unit. Indeed, it is possible to observe discrepancies in the design and organisation of medical facilities in this respect. It is also possible to observe a problem related to hospital infrastructure, namely: too few isolation rooms (Bulanda et al. 2016).

Medical units are not able to eliminate nosocomial infections, but they should strive for reducing their transmission. In practice, it should mean the implementation of architectural solutions that provide the possibilities of isolating patients at each stage of their medical treatment. Considering the need for reducing the epidemiological risk and the time needed to perform microbiological diagnostic tests deciding about the character of the hazard, it is possible to state that an isolation room or isolation rooms should be provided in all organisational hospital units, where patients without their confirmed

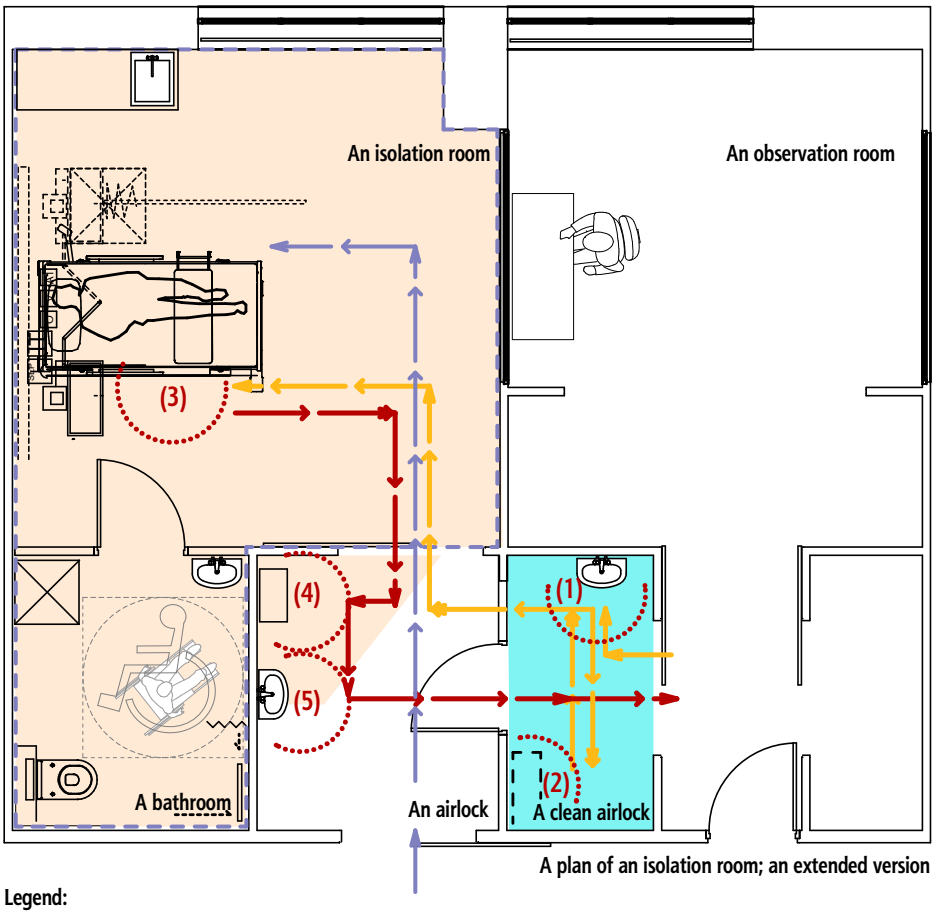



**Figure 6.2.2.2** A hospital isolation room – a variant going beyond the legal requirements applicable in Poland; elaborated by the Author

medical diagnosis are going to be located. The architectural design of that space allows safety procedures to be implemented and infection transmission to be reduced. It can be achieved based on the isolation scheme presented in Figure 6.2.1.4. Limiting spatial measures of isolating patients by medical facilities may result from the costs related to the preparation of the constructional structure of a hospital. It should be also emphasized that such an approach increases epidemiological risk through additional surfaces that can be potentially contaminated, exposing medical personnel and other patients to the transmission of infections. A proper architectural solution for patient isolation rooms comes as one of the basic tools applied to protect the area of a medical facility against the spread of infections. In an organisational context, isolation means limited possibilities of moving patients with a suspected infection or colonised with pathogenic microorganisms and infectious patients around the medical facility. It also provides a possibility of implementing additional measures to protect medical personnel against transmission of infections.

The analysis presented above confirms the significance of architectural solutions for isolation of potentially infectious patients in Poland. It also confirms the potential of design solutions that can be used for increasing the level of safety in medical facilities.

## 6.2.3 Patients in the areas of high infection risk – architectural solutions applied in the area of anaesthesiology and intensive care units

The number of infections, undesirable events and epidemic outbreaks in the environment of healthcare facilities is particularly important in intensive care units, where patients are exposed to an increased risk related to their stay at hospital (Rothschild et al. 2005).

The hospital space comes as a particular type of hazard to human health, especially to immunocompromised patients. Patients included in the hazard group are, among others, elderly patients, patients with open skin wounds, patients after invasive surgical treatment and patients with chronic diseases.

Hospital areas that require special attention during the surveillance of hospital-acquired infection risk are anaesthesiology and intensive care units (ICUs), also referred to as critical care units (CCUs). Within the hospital structure, these units are responsible for providing healthcare in the field of anaesthesiology, intensive care, resuscitation, pain treatment regardless of its cause and sedation. In comparison to other organisational hospital units, the share of the occurrence of nosocomial infections is the largest at intensive care units.

While staying at an intensive care unit, patients with severe clinical conditions, who require monitoring of their vital functions, supporting their respiratory and circulatory systems, being in need of additional nursing procedures, for example, related to the prevention of bedsores, become more susceptible to hospital-acquired infections. Moreover, most of these patients are treated with antibiotics. The problem increases with the spread of multidrug-resistant microorganisms that make medical treatment more difficult and often ineffective. In accordance with most international scientific research, the level of infected patients reaches 20-30% (Teltsch et al. 2011; Vickery et al. 2012).

According to the data presented in the report issued by the Supreme Audit Office in Poland, the level of nosocomial infections within the inspected hospital facilities at the anaesthesiology and intensive care units reached 33.11% in 2015, 35.29% in 2016 and 37.97% in the first half of 2017, with the consideration of the general level of hospital-acquired infections. The authors of the report emphasize the fact that the numbers stated in the collected data are most probably lower than the actual numbers. This fact results from the defective nature of the reporting system. (*The Report…* NIK 2018). Nevertheless, the data presented in the report leads to the conclusion that in Polish hospital anaesthesiology and intensive care units the occurrence of hospital-acquired infections reaches the above-average levels. This situation may suggest the deficiency in organisational and architectural activities undertaken in the field of preventing nosocomial infections in those areas.

In Poland, the current regulations pertaining to the architectural design of anaesthesiology and intensive care units are difficult to find. Some specific guidelines on the design of those hospital units are not included in the provisions of the most important act on the architectural design of medical facilities, namely: the Ordinance of the Minister of Health of 26th June 2012, on specific requirements for facilities and equipment used by entities providing healthcare services (Journal of Laws 2012, item 739). However, those provisions are confined to a few succinct sentences of little significance to the proper design of such hospital units, for example: *an isolation unit includes (…) a hygienic and sanitary*


**Photograph 6.2.3** Terminal units for medical gas pipeline systems (technical infrastructure may become a hospital-acquired infection source); photographed by the Author, 2016

*room (…) equipped with (…) a shower with the exclusion of an isolated room at the anaesthesiology and intensive care unit* (Ibid., art. 21). Some more information is provided in the regulations dedicated directly to the organisation of anaesthesiology and intensive care units, namely, in the Ordinance of the Minister of Health of 26th June 2012, on the organisational healthcare standards in the field of anaesthesiology and intensive care (Journal of Laws 2016, item 2218), where the following provision is stated: *an anaesthesiology and intensive care unit and a paediatric anaesthesiology and intensive care unit shall be provided with an isolation room accessible from the circulation pathways in the department, with an airlock for hand washing, changing clothes and storing isolation materials* (Ibid., art. 5). The above-mentioned legal act also provides recommendations for the design of patient rooms at an anaesthesiology and intensive care unit, stating the minimal areas dedicated to hospitalisation provided within the unit. The minimal area of a single-bed patient room is at least 18.0 $m^2$ and for a multi-bed patient room it is at least 16.0 $m^2$ for each bed (Ibid., annex no. 1). The discussed regulations come as very general guidelines, especially when considering regulations applicable in other countries in Europe or North America.

In Poland, the postulates for the implementation of architectural solutions increasing epidemiological safety in anaesthesiology and intensive care units are presented in independent scientific publications, where the following recommendations can found:

- designing new intensive care units; renovation and modernisation of the currently operating units should be carried out with the consideration of their share in transmission of pathogenic microorganisms and consulted with specialists working in the field of hospital-acquired infections;
- the risk of crossing clean and dirty pathways should be reduced;
- developing the methods for cleaning and disinfecting the unit and its particular areas, with the consideration of the differences is the process of decontamination of the patients' stations during their hospitalisation and after their discharge from hospital;
- locating hand washing stations in the places facilitating the proper hand hygiene before and after the contact with patients and their environment;
- providing a contact isolation room at an intensive care unit (A1); providing a respiratory isolation room depends on the risk analysis pertaining to the hospitalisation of patients with infections transmitted by respiratory routes (A1);
- disinfecting environment with the use of hydrogen peroxide steam in units with epidemic or highly endemic occurrence of infections of *C. difficile* aetiology;
- storing decontaminated medical equipment in the conditions that prevent its recontamination (Hryniewicz et al. 2013);

and also:

- providing an adequate area to each patient, namely: not less than 16 $m^2$ per bed to allow medical personnel to move freely during the performance of their professional duties and to improve ergonomics;
- dedicating patient rooms equipped with airlocks and, if possible, with negative pressure and HEPA filters for air-dust isolation, considering the need for isolating some patients;

- providing changing rooms to medical personnel, with a possibility of segregating hospital gowns and private clothes; providing a large storage area for removing some equipment from the patient rooms and an area for its preliminary preparation for central sterilisation;
- providing hand hygiene stations for visitors;
- providing hand disinfectant dispensers located within a convenient distance from washbasins, however not in their immediate vicinity, considering the risk of creating bioaerosols (Misiewska-Kaczur 2016).

The postulates presented above refer to the architectural design of the space. They define the user's needs, however in the context of the actual needs, they seem to be insufficient and ambiguous. The recommendation to reduce the crossing of dirty and clean pathways in the facilities does not actually define the design principles for the area that is critical in terms of infection transmission, namely: the principles for organising the circulation of medical personnel and patients on patient beds in intensive care units. The provision referring to airlocks with negative pressure and HEPA filters does not explain why HEPA filters should be installed exclusively in the airlock. Furthermore, it does not specify the air purity class after the air passes through HEPA filters in an intensive care unit. The postulate of providing 16 $m^2$ per bed in a patient room (also indicated in the current regulations) does not necessarily contribute to the increased distance between patients' beds, which is crucial in terms of the organisation of work and transmission of infections between patients (Figure 6.2.3.1).

The contemporary scientific research confirms the efficiency of architectural barriers in the prevention of hospital-acquired infections in the area of intensive care units. Most guidelines for the design of anaesthesiology and intensive care units have recently recommended planning isolation units as single-bed rooms or separate boxes in multi-bed rooms. Referring to the example of an infection with drug-resistant *Staphylococcus aureus* and to the analysis or risk and infection control measures, it has been indicated that these solutions are auxiliary factors in preventing cross-contamination with pathogenic microorganisms (Bracco et al. 2007; Berry 2013).

Similar conclusions may be drawn from the scientific research carried out in Canada on the effects of changes to the organisation of intensive care units from the spatial and functional layout based on multi-bed patient rooms to the structure based on single-bed rooms. A 14-bed intensive care unit with six single-bed rooms was compared to a unit composed of a six-bed and a two-bed bay rooms. The research study indicated a decrease in infections caused by *Clostridium difficile* by 43% and in infections caused by *Staphylococcus aureus* - by 47% (Teltsch et al. 2011; Pennington and Isles 2013). Moreover, the length of patients' stay at the hospital intensive care unit was noticeably shortened by 10% (Teltsch et al. 2011).

An increased share of hospital-acquired infections in the area of anaesthesiology and intensive care units in Poland (NIK 2018) indicates deficiencies in the area of architectural and organisational activities. The above-mentioned scientific research studies confirm the efficiency of single-bed patient rooms in reducing infection transmission. In Poland, considering the limitations in the field of the discussed problems, the modernisation of the existing facilities in order to adjust them to such standards may turn out to be a long and expensive process, while architectural solutions applied to reduce infection transmission can be implemented relatively easily, modernising the existing intensive care units only to a slight extent.

This thesis can be illustrated with an example of changes suggested for the implementation in an intensive care unit in order to reduce epidemiological risk. The design solutions are based on the analysis of infection transmission routes. Figure 6.2.3.1 presents a typical layout of an intensive care unit with marking the droplet transmission routes for infection spreading. It indicates that despite the provisions of the minimal area of 16m$^2$ per patient bed, the solution does not guarantee an increased level of safety. Figure 6.2.3.2 presents a similar area, where the distance between patient beds is increased and additional partitions are implemented to clearly define the space that can be potentially contaminated by the patient. This solution allows for the separation of the areas dedicated to hand washing stations and distribution of protective medical gowns and medical gloves, next to the entrance to the patient room. Such a layout allows medical personnel to carry out medical procedures with hand disinfection before each contact with the patient, in accordance with the recommendations issued by the World Health

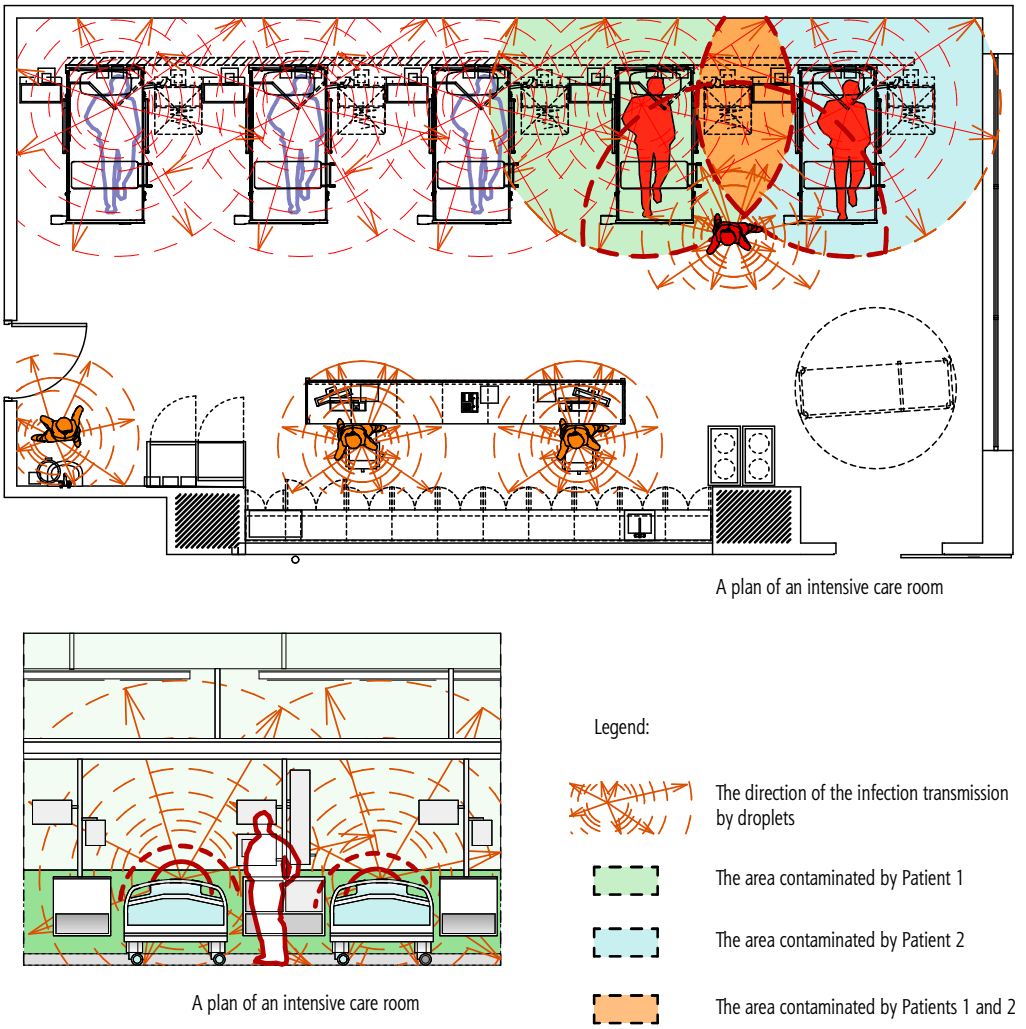
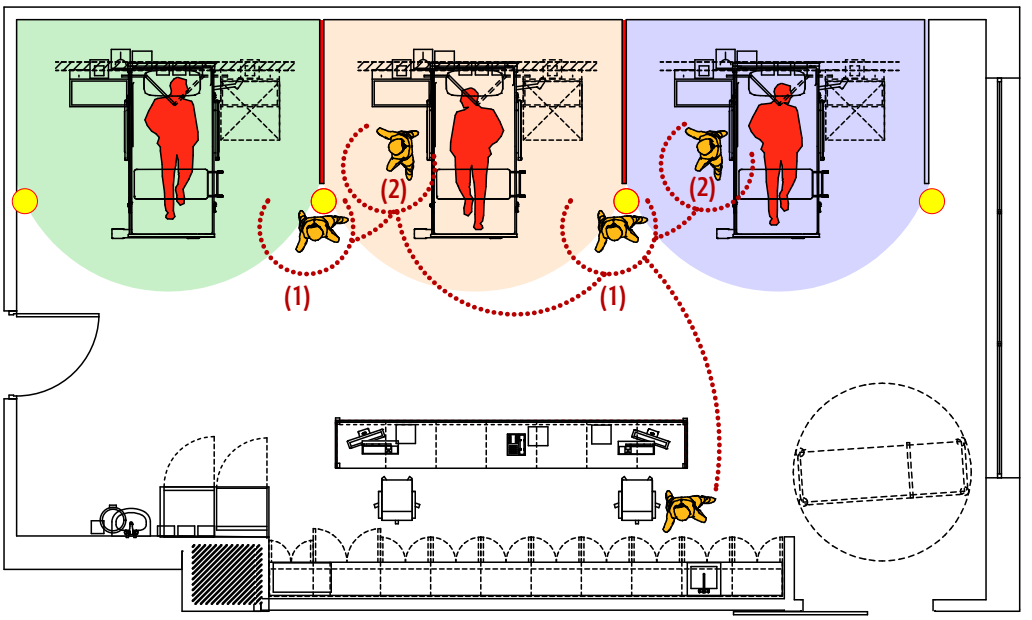
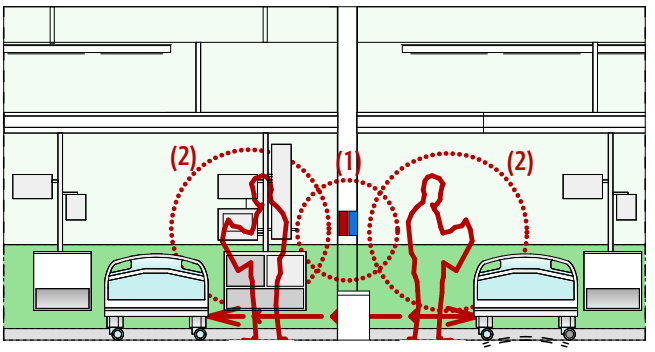



**Figure 6.2.3.1** An intensive care unit – a typical layout; elaborated by the Author




A plan of an intensive care room

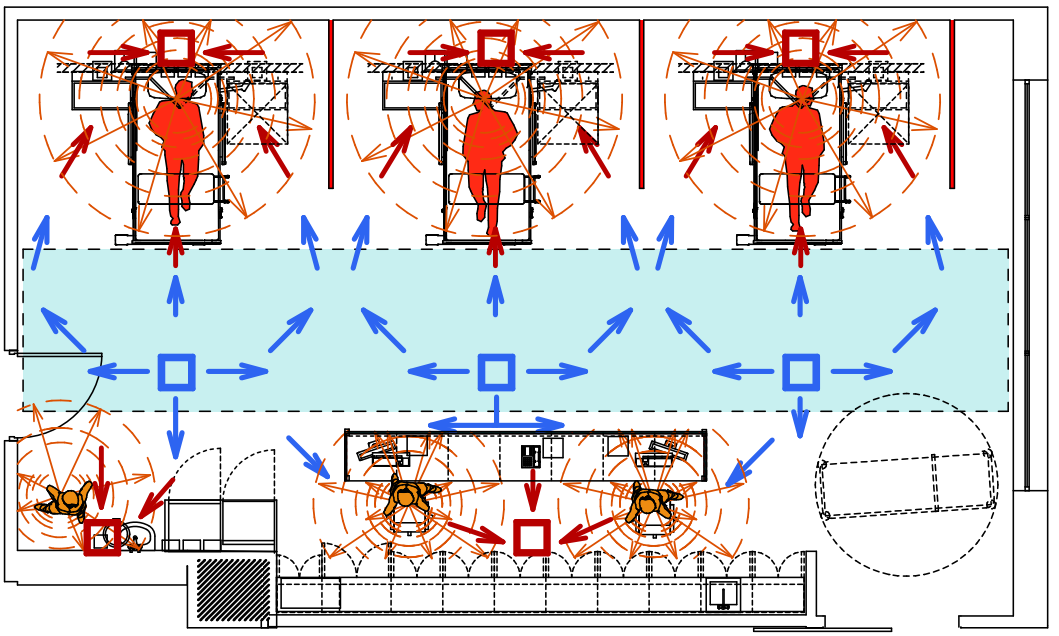



A cross-section of an intensive care room

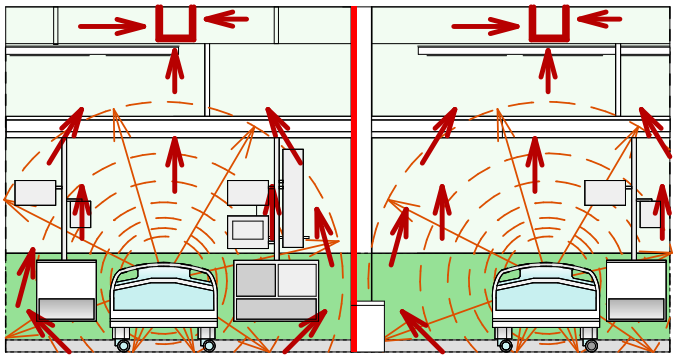
Legend:

- The area contaminated by Patient 1
- The area contaminated by Patient 2
- The area contaminated by Patient 3
- The route of personnel members during the hand washing procedures before and after the contact with the patients – in accordance with the World Health Organization
- (1) A hand washing station
- (2) A place of the contact with patients
- A station with disinfectant and disposable protective equipment

**Figure 6.2.3.2** An intensive care unit – a modified layout with partitions reducing the spread of infections by droplet transmission routes and with hand disinfection stations; elaborated by the Author



A plan of an intensive care room



A cross-section of an intensive care room

Legend:

An exhaust anemostat – removing dirty air

An air supply diffuser – supplying clean air

The direction of the air flow

The direction of the infection transmission by droplets

The clean air buffer zone

A partition made of washable materials that can be disinfected, which is built up to the ceiling to force the direction of the air flow

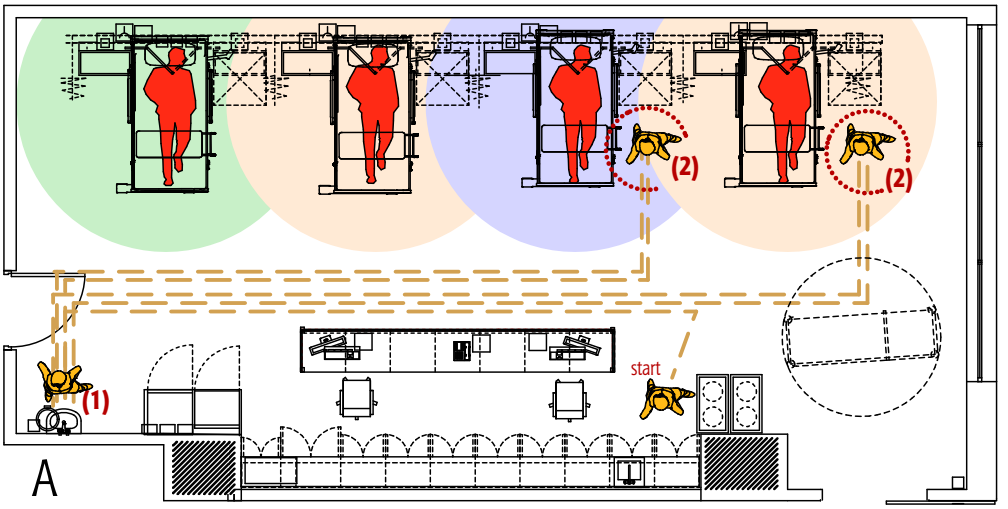
**Figure 6.2.3.3** An intensive care unit – a modified layout with the air flow management system; elaborated by the Author

Organization and with less effort on medical personnel's part. Figure 6.2.3.4 presents a possibility to manage not only air purity through the installation of HEPA filters but also the air flow directions within the area of the unit through exhaust anemostats (air valves) located directly above the patient bed. In this way, the possibility of transmitting infections between patients is limited. The installation of the air supply diffusers in the central part of the unit creates a barrier that reduces migration of the air with bioaerosols among the defined areas. Figure 6.2.3.3 presents a modified layout of exhaust anemostats and air supply diffusers in the system of mechanical ventilation. In this solution, the elements indispensable for air flow management are applied, which – when implemented – contribute to the reduction of infection transmission among patients. Figure 6.2.3.5 also presents a scheme of modifications based on the guidelines developed by the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (in German: Bundesinstitutes für Bau-, Stadt- und Raumforschung – BBSR), where it is recommended to implement individual boxes in intensive care rooms, regardless of other isolation rooms, in the areas of anaesthesiology and intensive care units (Sunder et al. 2018).

As presented above, the analysis confirms the potential of architectural solutions to reduce infection transmission within the area of anaesthesiology and intensive care units. It also indicates the need for more scientific research to be carried out in the field pertaining to the theory of architecture and epidemiology oriented toward the description of optimal solutions, with the consideration of the conditions in Poland. In terms of spatial, epidemiological and economic aspects, the layouts that implement the achievements of modern knowledge and state-of-the-art technology specifically adjusted to Polish conditions should constitute the standards to be followed in the entire country. Searching for such solutions is important because of difficulties observed in the elimination of environmental antibiotic-resistant bacterial strains that occur in the area of anaesthesiology and intensive care units, where the high level of nosocomial infections is reported. The combination of the high administration of antibiotics and environmental biofilms in the area of anaesthesiology and intensive care units may form a mechanism through which an increased genetic exchange among the bacterial strains occurring in biofilms takes place, resulting in the survival of environmental antibiotic-resistant bacteria, despite the improved disinfection procedures (Vickery 2012: 54).

Hence, in Poland it is possible to observe a lot of unused potential offered by architecture and the analysis of relevant legal regulations discloses their ambiguous nature. On one hand, managers of medical facilities are obligated to undertake actions preventing the transmission of infections and infectious diseases (Journal of Laws 2008, no. 234, item 1570 with later amendments, art. 11, section 1), but on the other hand, the deficient guidelines in the field of the architectural design of medical facilities result in a situation, where it is very easy to present the compliance of the solutions applied in the area of anaesthesiology and intensive care units with the minimal standards, even when there have been excessive levels of hospital-acquired infections reported in the particular unit. Therefore, such a situation does not foster the implementation of additional architectural solutions, next to those required by the legal regulations. The reluctance felt by managers of medical facilities toward the increase in safety standards with the use of the discussed tools may result from the lack of information or knowledge or it may also be related to the circumspect attitude of medical entities toward allocating additional funds for the actions that are not required by law.

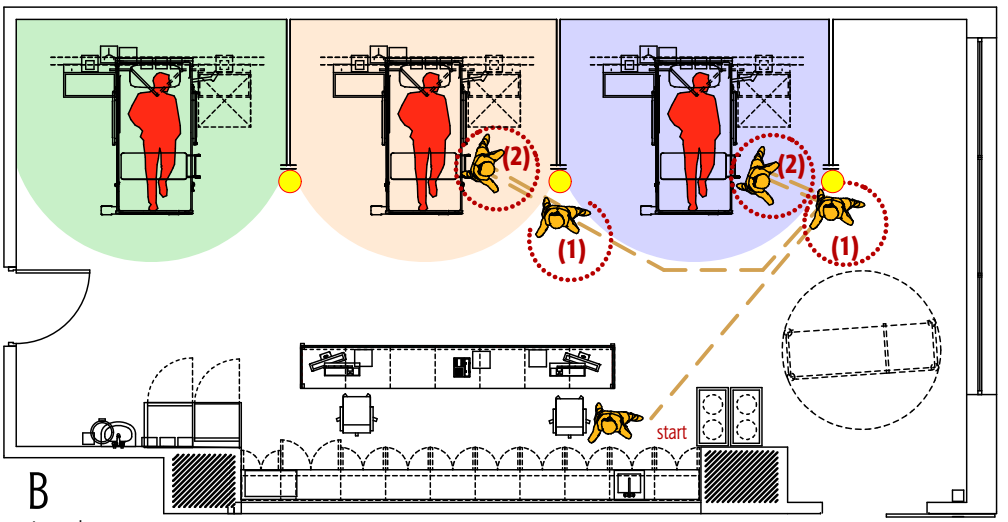
In Poland, there is a deficiency of legal requirements in the field of architectural solutions dedicated to anaesthesiology and intensive care units. Indicated in the current legal regulations, the guidelines




Legend:

A plan of an intensive care room; version A with one hand washing station

The route of medical personnel during the hand washing procedure before and after the contact with patients, in accordance with the recommendations provided by the World Health Organization, on the example A about 61 m.




Legend:

A plan of an intensive care room; version A with one hand washing station

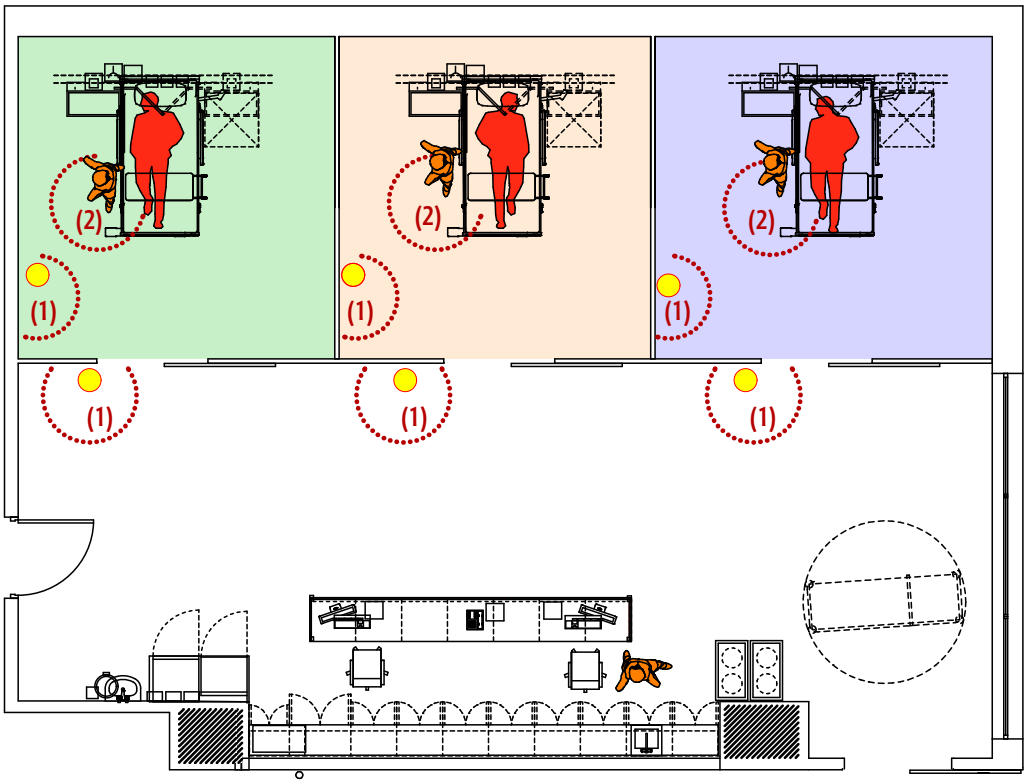
The route of medical personnel during the hand washing procedure before and after the contact with patients, in accordance with the recommendations provided by the World Health Organization, on the example B about 12.4 m.

(1) A hand washing station

(2) A place of the contact with patients

**Figure 6.2.3.4** A comparison of the circulation paths of medical personnel during the hand washing procedures before and after the contact with the patient in an intensive care unit;
A - a typical layout;
B - a modified layout, where medical personnel's effort is reduced and the risk of human error is lowered; elaborated by the Author

pertaining to the spatial design of anaesthesiology and intensive care units should be considered as insufficient. Among other reasons for excessive numbers of hospital-acquired infections reported in the area of anaesthesiology and intensive care units, an insufficient level of minimal requirements in the field of architectural solutions must be also mentioned.

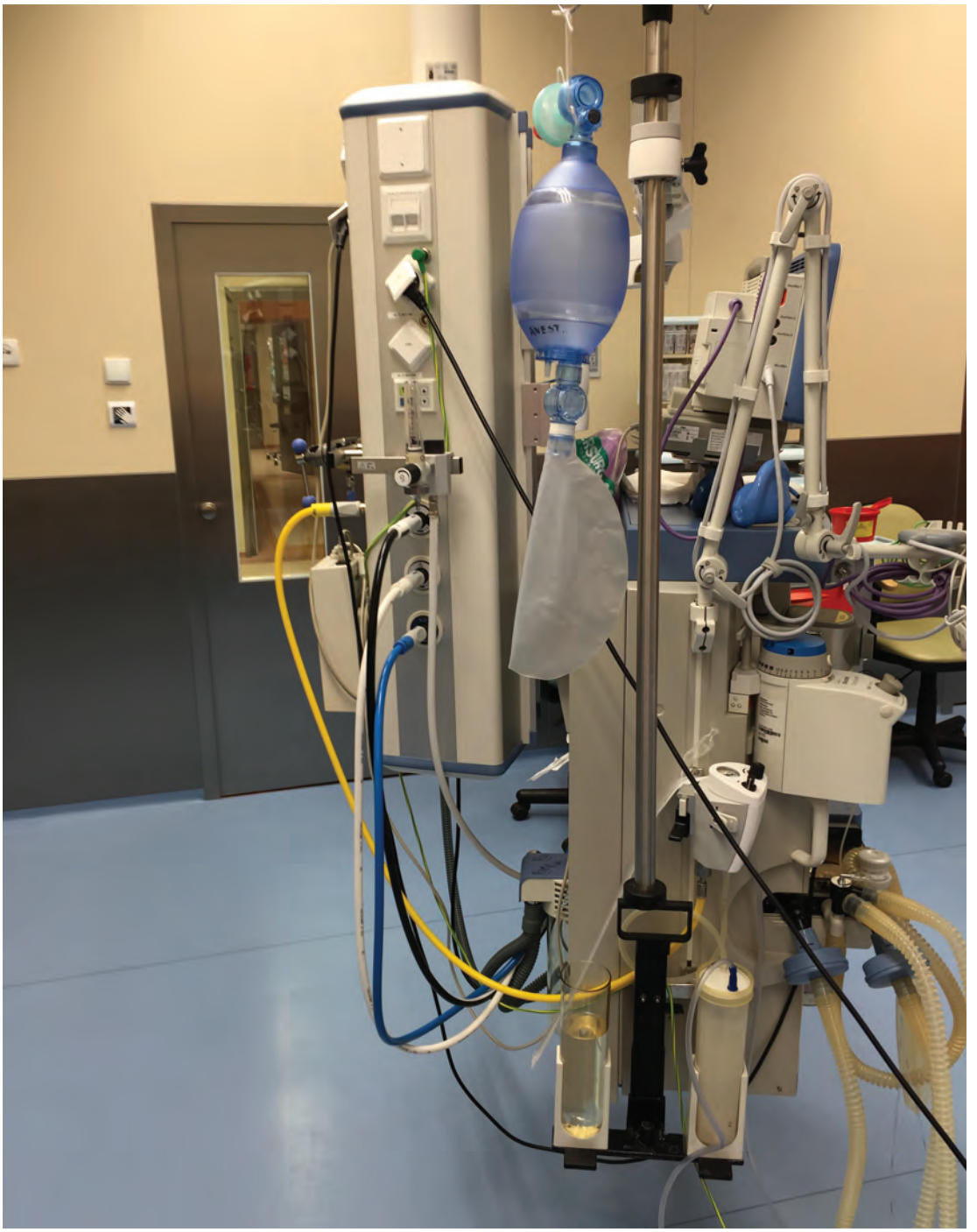



A plan of an intensive care room

Legend:

- The area contaminated by Patient 1
- The area contaminated by Patient 2
- The area contaminated by Patient 3
- A station with disinfectant and disposable protective equipment
- (1) A hand washing station
- (2) A place of the contact with patients

**Figure 6.2.3.5** An intensive care unit – a modified layout with single-bed boxes recommended by, among others, the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (in German: Bundesinstitutes für Bau-, Stadt- und Raumforschung – BBSR); elaborated by the Author



**Photograph 6.2.3.6** The equipment in an operating theatre (a possibility of suspending some elements on a column facilitates disinfection of the floor); photographed by the Author, 2016

## 6.2.4 Patients in the area of nursing departments – a design of a bed unit/patient room

In the hospital architecture of the first half of the 20th century, the prevailing standards allowed multi-bed patient rooms, where the number of beds could be up to twenty per room. Individual single-bed rooms with bathrooms were available only to a small group of patients who paid for such individual hospital accommodation. In the second half of the 20th century, new spatial layouts were implemented, assuming a gradual decrease in the number of patients hospitalised in multi-bed rooms. The latest trends in architectural design of medical facilities followed for several decades indicate that single-bed hospital accommodation has been prevailing in newly designed closed medical facilities. Carried out for over a decade, scientific research studies in the field of hospital-acquired infection control have emphasized epidemiological aspects in the analysed problems to clearly indicate the advantages of designing single-bed patient rooms. It is commonly considered that single-bed patient rooms facilitate better infection control and to provide better conditions to patient isolation, which allows for more efficient prevention in the field of infection control (Detsky and Etchells 2008). Some analysis confirms

**Photograph 6.2.4** A post-surgical treatment room (the design of the room without any permanent partitions between patient beds makes it difficult to organise hand hygiene stations at each patient station); designed and photographed by the Author, 2018

the fact that higher risk of hospital-acquired infections was reported in patients hospitalised in two-bed rooms than in those ones hospitalised in single-bed rooms (Munier-Marion et al. 2016). This thesis has been confirmed mainly on the basis of the results obtained from the intensive care units. Adopting that assumption for nursing departments is still being discussed and the scientific research carried out in this field is being updated on an on-going basis (Berry 2013).

The need for achieving the prevalence of the single-bed room model in hospitals results not only from epidemiological reasons. In the public discourse, which becomes intensified on the occasions when decisions must be made on increasing the number of single-bed rooms in relation to multi-bed rooms, the arguments focused on the economic advisability of such a solution and the well-being of individually hospitalised patients have been prevailing. Commonly referred to, the arguments indicating single-bed rooms as the optimal way of patient hospitalisation also draw our attention to the advantages of that solution, as it allows for respecting patients' need for privacy and human dignity and for providing them with confidentiality when medical information is being discussed or delivered. Patients do not have to feel embarrassed with reactions of their own bodies and, undoubtedly, it is easier to struggle with the problems related to the course of the disease without the company of any third parties (Berry 2013; Pennington and Isles 2013).

An argument often referred to in discussions on the number of single-bed rooms planned for a hospital unit is the problem pertaining to the characteristics of hospital acoustics. Some international scientific research has indicated that the levels of noise in hospitals are definitely too high and they exceed the volume specified in the guidelines issued by the World Health Organization. The factors contributing to such a situation in medical facilities include the specific character of work performed there: hastiness, loud voice communication, clatter of mobile medical equipment and mobile beds during the transportation of patients. Additionally, the noise is increased by the use of hard cladding in constructional partitions applied for interior design, as it can strongly amplify sounds (Ulrich 2006). This specific type of clamour is also a problem in multi-bed rooms. Therefore, a lot of patients prefer staying alone in an isolation room as it guarantees peaceful sleep (Madeo 2001). While analysing that question, some scientific research studies pose a hypothesis that a silent hospital can be created through its properly designed physical environment – not only through some changes in medical personnel's behaviour or the hospital organisational culture. Moreover, single-bed rooms provide more space to the patient and a possibility to add more furniture for visitors, to provide more privacy in contacts with other patients and family, along with more flexibility in visit schedules. They also make it easier for the families to become involved in nursing hospitalised patients (Urlich 2006; Pennington 2013).

Opponents of the idea fostering the increased number of single-bed rooms in nursing departments emphasize some negative effects of individual hospitalisation of patients, especially considering their well-being. The most frequently mentioned disadvantage is the mental state of isolated patients affected by stress and anxiety caused by hospitalisation in isolation. Some reports on that problem appeared shortly after the protective isolation was introduced as a common instrument of hospital-acquired infection control (Morgan et al. 2009). Scientists who have analysed the problem emphasize not only the psychological effects of staying alone in isolation but also a possibility of decreased control over the patient. As a result, the healthcare quality might be lowered. A review of the recent specialist literature also indicates several additional aspects related to the negative impact of individual hospitalisation of patients, namely: less contact between medical personnel and patients, delay in the implementation of

proper diagnostic and medical treatment procedures, susceptibility to depression and patients' lower satisfaction from the healthcare they are provided with (Morgan 2009; Barrat 2011; Ozorowski et al. 2017).

Despite the confirmed high risk of mental strain resulting from forced isolation or hospitalisation in an individual room, most contemporary scientific studies recommend resigning from hospital multi-bed rooms and implementing practice that can mitigate negative effects of isolation. It includes facilitating social interaction, frequent contact between medical personnel and patients, implementing strategies aimed at preventing depression, allowing patients to obtain some self-control in their isolated environment. The provision of timely and adequate information on the implemented diagnostic and medical treatment procedures, along with the sense of being provided with the right amount of nursing care, medical assistance and access to the current treatment – all these elements are of fundamental significance to isolated patients' mental well-being (Baratt et al. 2011). As indicated by some scientific research surveys carried out among oncological patients, hospital environment and medical procedures are highly stressful. The support provided to patients should be of multi-aspect nature: informative, instrumental, substantive and emotional (Bernad et al. 2008). The opinion that patients who stay in multi-bed rooms provide social support to each other to reduce stress is contradictory to the evidence that sharing the rooms with one or more patients is the main stressor in most cases (Ulrich 2006). Carried out in this field, the scientific research also specifies some guidelines pertaining directly to the architectural design of isolation and individual rooms. In order to lower patients' sense of being isolated from the external environment, such rooms should have windows in the walls separating them from the circulation in the unit to provide eye-contact with what is going on outside (Oldman 1998). Single-bed rooms can be also provided with some elements of furnishing that can allow patients to perform some simple activities, such as watching TV, listening to the radio or reading a book (MacKellaig 1987).

In the context of the problems discussed in this monograph, the aspect related to the impact or the single-bed room architecture contributing to the efficient prevention of nosocomial infections is highly important. Scientists have not reached any consensus in this field either. Opponents of the common implementation of single-bed rooms in hospitals refer to the problem pertaining to the reliability of the methodology applied during the research surveys that have indicated a decrease in the number of hospital-acquired infections reported in the case of single-bed hospital accommodation. This is due to some disruptive elements associated with the overall hospital environment. Hence, the subsequent difficulties arise in controlling the samples and interpreting the results (van de Glind et al. 2007). A similar opinion was presented in 2013 (Pennington 2013), indicating contradictory results on the frequency of the occurrence of nosocomial infections in single-bed and multi-bed patient rooms. Some research has not directly indicated any significant differences, whereas other research studies have proved that single-bed rooms contribute to a decrease in the risk of hospital-acquired infections. Despite the reservations about the methodology applied to perform such an analysis, a review of articles carried out between 31st December 1990 and 31st December 2015 by a scientific team under the leadership of Andrea Stiller (2016) indicates that more and more contemporary scientific studies prove that single-bed patient rooms come as an important means of infection control. Preventing transmission of pathogenic agents from one patient to another results from the fact that the transmission cannot occur directly from other patients staying in the same room and, furthermore, its indirect

character is also reduced, for example, through the hands of medical personnel who take care of other patients. Adopting the architectural design of a hospital with a prevailing number of single-bed patient rooms and easily accessible dispensers of disinfecting agents in the vicinity of patient beds is beneficial for infection control. It also provides useful elements to a multi-dimensional strategy for reducing healthcare-associated infections.

However, it is necessary to continue adequately planned multi-centre scientific research, because the results obtained from single centres are limited by an error related to the size of the sample and simplifications resulting from the analysis of one individual case only (Morgan et al. 2009).

Regardless of the currently performed scientific analysis on the negative and positive experience of patient isolation, it should be noted that the contemporary discourse on the possibilities to eliminate multi-bed rooms from hospitals has already brought about some spatial effects. The share of single-bed rooms in the functional and spatial hospital systems has been systematically increased. Some publications indicate that there is a need for implementing only single-bed rooms in nursing departments. In numerous countries in Europe and North America, a consensus has been reached that single-bed rooms in hospitals are important elements in the process of preventing and controlling hospital-acquired infections (Pennington 2013). The scientific research, including some analysis commissioned by the American Institute of Architects and the Institute Facility Guidelines, has documented a beneficial relation between single-bed patient rooms and a decrease in the occurrence of hospital-acquired infections and an improvement in the performance of medical procedures. The recommendations are presented in the publications issued by those institutions on the design and construction of hospitals and healthcare facilities (*Guidelines for…*, 2006).

Designing single-bed patient rooms decreases the risk of transmitting pathogens among patients by air and cross-contamination routes. It is believed that single-bed rooms facilitate better practice in infection control and allow for better protection of patients against hospital infectious agents (Detsky and Etchells 2008). Single-bed rooms also allow medical personnel to carry out efficient disinfection after discharging one patient and before admitting another one. Although hospitalisation in single-bed rooms has been usually considered a privilege and treated as private hospital accommodation, scientific evidence indicates a need for increasing their number in hospitals, so that all infectious patients or patients particularly susceptible to infections could be treated in single-bed rooms (Brouqui 2016).

An interesting summary of the above-presented analysis is a table presenting advantages and disadvantages of hospitalisation provided in single-rooms. It has been elaborated in Ireland and published in *Infection Prevention and Control of Building Guidelines for Acute Hospitals in Ireland. Strategy for the control of Antimicrobial Resistance* (2008). The table is presented in Figure 6.2.4.1. Architectural solutions applied in patient rooms located in the area of hospital nursing departments are the subject of numerous contemporary scientific research studies and analysis. One of their main aims is to develop spatial solutions that will directly contribute to a decrease in the level of hospital-acquired infections. The search for such solutions also refers to the shape and furnishing of patient rooms and to the number of patients hospitalised in one room.

Architectural spatial solutions applied in medical facilities dedicated to patients' stay are of various nature. A patient room can be provided with an en-suite bathroom or there might be a need for using a common sanitary unit shared with other patients. Another solution may provide a washbasin or a disinfectant dispenser.

| Thematic aspect of the assessment | Issues | Single-bed room | Multi-bed room |
|---|---|---|---|
| Costs | Operating costs | decreased | inconclusive |
| | Initial capital costs | increased | decreased |
| | Length of hospitalisation | decreased | increased |
| | Medical errors and their costs | decreased | increased |
| Hospital infection prevention and control | Occurrency rates of nosocomial infections | decreased | not addressed |
| | Patient transfers | decreased | increased |
| | Length of the patient's stay | decreased | increased |
| | Infections in patients with burns | decreased | not addressed |
| | Transmission of infections with Hepatitis C virus between patients | decreased | not addressed |
| | Hospital-acquired diarrhoea | decreased | increased |
| Accidents threatening patients' health | Fall in patients requiring intensive supervision | increased | decreased |
| | Falls in elderly patients | increased | increased |
| | Bathroom access accidents | not addressed | increased |
| | Sense of privacy | increased | decreased |
| Therapeutic impact of hospital design | Amount of pain medication | inconclusive | inconclusive |
| | Patient consultations with physicians | inconclusive | inconclusive |
| | Patients' preferences for room design | inconclusive | inconclusive |
| | Noise level | decreased | increased |
| | Sleep disturbance level | decreased | increased |
| | Patients' satisfaction level | increased | decreased |
| | Patient control | increased | decreased |
| | Crowding | decreased | increased |
| | Stress reduction through music | increased | decreased |

**Figure 6.2.4.1** A summary of the review of contemporary research comparing advantages and disadvantages of patient hospitalisation in single-bed and multi-bed rooms [in: *Infection Prevention...*, (2008)]

The assumed intensity of using the particular space affects the level of epidemiological risk. It results directly from a situation where the close distance to other patients who spread infectious microorganisms and the presence of such pathogens on the furnishing elements increase the possibility of infections (Zieliński 2009: 15). Some scientific research studies indicate that the risk of hospital-acquired infections caused by the transmission of microorganisms among immunocompromised patients is higher for patients hospitalised in multi-bed rooms, in comparison to those accommodated in single-bed rooms. Hence, it proves that multi-bed rooms contribute to an increase in infection incidence (Munier-Marion 2016).

In a situation where several patients are hospitalised in one room, there is a risk of infections transmitted by various routes. The analysis of a droplet transmission route indicates that the spatial elements contributing to the spread of infections are: a small distance between patients' beds and ventilation characterised by a low rate of air exchange that manages the air flow in a typical way – from the window toward the door. It facilitates the transmission of infections between patients staying closer to the window onto patients staying further from the window.

Due to the fact that sanitary facilities are shared by a larger number of patients in multi-bed rooms, the risk of infections transmitted by this particular route can be observed there. In order to be efficient, bathroom disinfection procedures should be carried out each time the bathroom is used by a patient. In practice, considering the necessary workload, such an organisational solution is very difficult to execute and not observed in hospitals. The need for disinfecting a bathroom shared by several patients is analysed by the scientific research studies on the level of the *C. difficile* bacteria load in the bioaerosols created during toilet flushing that increase air pollution. It was proved by the cultures from the bathroom surface, tested with an assumption of an open (uncovered) toilet seat during the flushing procedure (Best et al. 2012). Hence, after the contamination of the surface, a possibility of transmitting infections of the next user appears.

Considering hospital epidemiological control, the space of patient hospitalisation is one of the most important areas in medical facilities. Figure 6.2.4.2 presents a scheme of a typical patient room with the infection transmission routes between hospitalised patients additionally marked.

Architectural solutions may contribute to the reduction of infection transmission by increasing a distance between patients beds in nursing departments. Today, the relevant Polish legal regulations do not specify that distance precisely. The specifications on the designing of such distances can be found in specialist literature. In numerous research studies carried out in hospital departments, the safe minimal distance between patient beds of ≤ 1 m is defined as a significant factor of risk related to diseases transmitted by droplet routes (Stiller et al. 2016). The referential parameters of the distance between patient beds are specified between 1.20 m and 1.50 m and the distance between the wall and the patient bed is recommended as up to 1 m (Tabori and Dettenkofer 2018).

The legal regulations currently applicable in Poland do not provide any guidelines on the size and arrangement methods for multi-bed patient rooms. The Ordinance of the Minister of Health of 26th June 2012 on the specific requirements for the facilities and equipment of entities providing healthcare services does not specify any particular parameters, providing only some general statements: a patient bed shall be accessible from its three sides, including its two longer sides; the distance between beds shall provide free access to the patients; the width of a patient room shall provide the possibility of removing the bed (Journal of Laws 2012, item 739 art. 3, section 18-20 ).

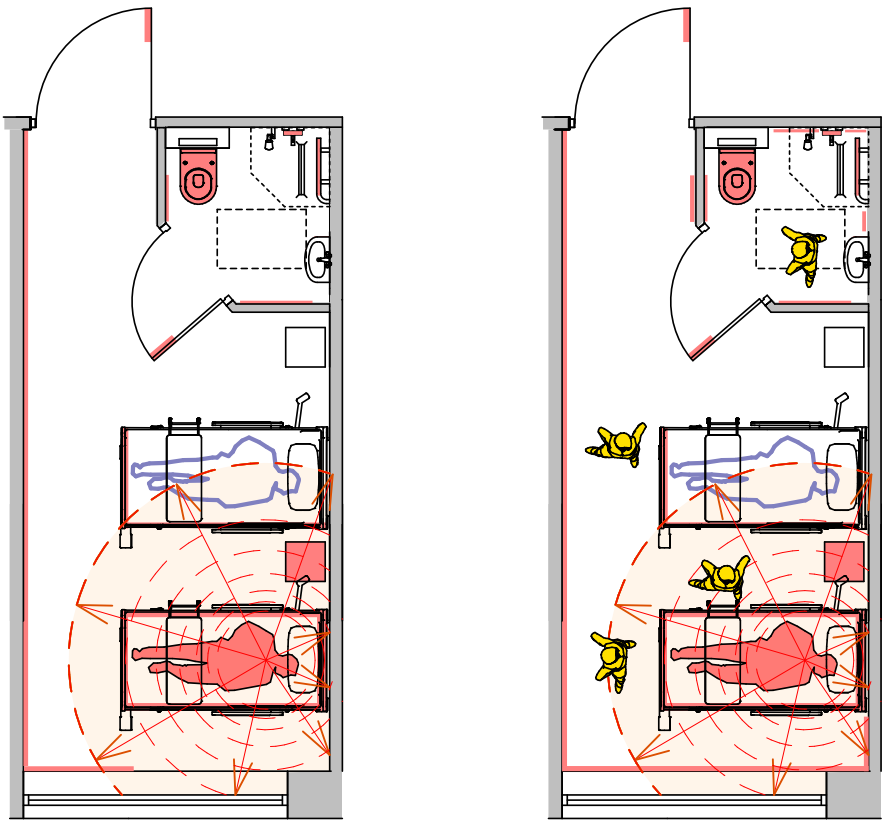



**Figure 6.2.4.2** Visualisation of the potential transmission directions:
A - between patients;
B - between patients and visitors, on the example of a multi-bed patient room;
analysed and designed by the Author

In accordance with the repealed ordinance of the Minister of Health of 2011, the maximal number of patients hospitalised in a multi-bed room was specified as 5 (art. 3, section 18) and it required the distance of 70 cm between patient beds and the distance of 80 cm between the wall and the patient bed. It also specified the required minimal area of a patient room, respectively: for a department with a uniform spatial layout (including paediatrics sub-units for older children) it was 18 $m^2$ for a two-bed patient room and at least 6 $m^2$ per each bed in a multi-bed room designed for 3 up to 5 patient beds.

In most European countries, such spatial regulations are provided in consolidated publications on the recommended programmes of hospital-acquired infection prevention. In Ireland, the guidelines included in *Infection Prevention and Control of Building Guidelines for Acute Hospitals in Ireland* implement a number of rules to be followed by architectural solutions applied in patient rooms, for example:

- the number of patient beds in a multi-bed room should not be more than 3;
- patient rooms must be provided with en-suite showers and toilets and their design should allow for reconfiguration in case of any changes to medical technology;
- the minimal floor surface dedicated to each patient bed should be 19 $m^2$, and the area of a single-bed room with an en-suite bathroom with a shower should not be smaller than 25 $m^2$;
- single-bed rooms should be designed to facilitate optimal care provided to patients, to provide them with comfort and to allow for adequate space for visitors (*Infection Prevention…*, 2008).

Today, it is possible to observe the development of new recommendations on increasing the number of single-bed patient rooms, however, their share in the structure of nursing departments is different. In newly designed hospital buildings in the Irish healthcare system, it is assumed that intensive care units will be constructed exclusively on the basis of single-bed rooms and their number in other nursing departments will be at least 50% of all the patient rooms. Similar guidelines are applicable in England. In France, it is recommended to increase the number of single-bed patient rooms, however, their number in relation to the intended multi-bed patient rooms has not been officially specified (Pennington and Isles 2013). In Germany, the Commission for Hospital Hygiene and Infection Control (in German: *Kommission für Krankenhaushygiene und Infektionsprävention* – KRINKO) recommends designing at least 10-20% of single-bed patient rooms in newly constructed or modernised nursing departments (Stiller et al. 2016).

In 2008, referring to the dignity of patients and striving for a decrease in the number of hospital-acquired infections, the Scottish government decided that the architectural programme developed for new hospital facilities should aim at 100% of single-bed patient rooms in their spatial layouts (S*ingle Room…*, 2008). Five years later, the analysis of Scottish hospital facilities indicated that 26 hospitals were constructed or modernised meeting the requirement of patient hospitalisation carried out exclusively in single-bed patient rooms (Ford 2013).

As presented above, the examples prove that despite the fact that some design solutions are relatively easy to be implemented in medical facilities, they do not always become a standard. It may result from the character of the current legal regulations and costs incurred during their implementation. Medical circles generally agree that the close presence of patients spreading infectious pathogens and the presence of microorganisms on furnishing elements increase the probability of infections (Zieliński 2009: 15). Nevertheless, in Poland, according to the currently applicable regulations, patients are hospitalised in multi-bed rooms even in infectious diseases and probationary departments. This information is publicly accessible, a lot of hospital facilities publish information about hospitalisation

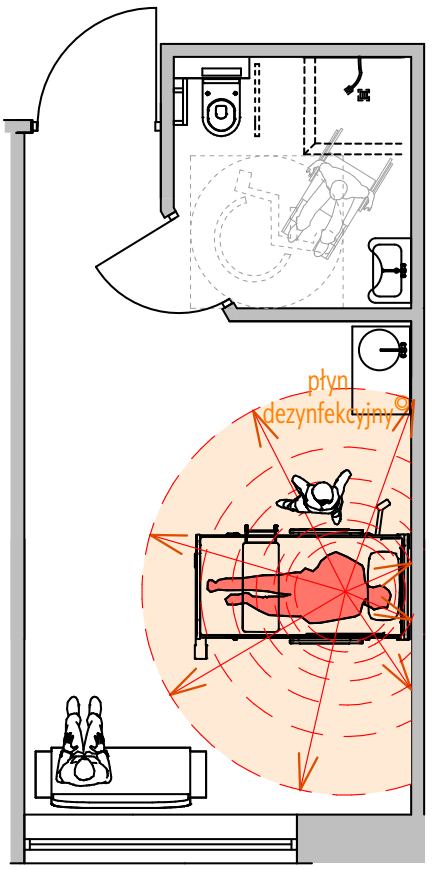
Architectural solutions reducing infection transmission

(1) Reducing transmission between patients:

By contact and by droplets though: single-bed rooms; restricting the mobility of patients (a single room with an en-suite bathroom is provided to satisfy patients' basic needs); reducing the number of surfaces that can be potentially contaminated and accessible to other patients; eliminating common toilets accessible to many patients

(2) Reducing transmission between patients and visitors through an increased area of the patient room and providing adequate space for visitors

(3) Supporting the proper course of medical and nursing procedures by providing hand washing and disinfecting stations in the vicinity of the patient bed to reduce the distance that must be covered during the proper hand hygiene procedure.




A plan of a single-bed room with an en-suite bathroom

Legend:

The direction of infection transmission by droplets

**Figure 6.2.4.3** An example of reducing the risk of infection transmission between patients and patients and visitors in a single-bed room; analysed and designed by the Author


**Photograph 6.2.4.4** The curtains between patient stations (an example of a conflict between the need for privacy and epidemiological safety; curtains can become hospital-acquired infection sources); photographed by the Author, 2019

conditions they offer on their official websites. For example, on its official website, the administration of Provincial Polyclinic Hospital in Konin informs that the hospital provides care in its infectious diseases and probationary department with a paediatric infectious diseases sub-unit in two four-bed rooms, one three-bed room, three single-bed rooms and one two-bed room. The hospital also provides hospitalisation of adult patients in five single-bed rooms, one two-bed room and three four-bed rooms (szpital-konin.pl, accessed 12.01.2019). Hence, it is possible to observe that the standard in the above-mentioned hospital assumes multi-bed rooms even in the area where patients are monitored in terms of infectious diseases and in the area dedicated to patients with infectious diseases. The example proves that there is a lot of space for a change in architectural standards applied in healthcare facilities in Poland.

Defined in the regulations issued by the Polish Minister of Health, the minimal requirements stated for architectural solutions do not impose any obligation to organise single-bed rooms and isolation rooms in hospital nursing departments. The only exceptions are made for paediatric units, where there must be an isolation room provided and for infectious diseases departments, where three isolation rooms must be provided (Journal of Laws 2012, item 739). Hence, the legal requirements deviate from the recommendations resulting from the contemporary international scientific research studies. In 2015, the share of single-bed rooms in the general number of all patient rooms was 13.9. At the same time, in other European countries, this parameter was 49.4 (Ozorowski et al. 2017: 4). Hence, it is possible to state that in Poland the level of the minimal requirements defined for architectural solutions applied in nursing departments needs verification.

## 6.3 Personnel as a source of nosocomial infections

Hospital-acquired infections can be directly or indirectly transmitted by personnel. The direct transmission route is followed when staff members contact patients and infections are transmitted from an infected staff member, or a staff member who is a carrier, onto a person who is susceptible to infections (Loveridge 2012). The preventive means applied against this type of transmission are incorporated into the Polish legal system. People employed at medical facilities who perform duties that pose a threat of transmitting infections or infectious diseases onto other people are subject to mandatory periodic tests for sanitary and hygienic purposes (Journal of Law 2008, no. 234, item 1570). In this way, it is possible to organisationally reduce the number of employees who can become the source of infections.

Staff members can also become a source of infections, transmitting microorganisms in an indirect way. The problem stems from the ability of some pathogens to survive outside the human organism for a period of time long enough to infect another susceptible host (Loveridge 2012). While analysing the risk posed by medical personnel as the source of nosocomial infections in a review of specialist literature, it is possible to find some clear indications of elements crucial for transmission of pathogens by employees. According to contemporary epidemiologists, hands and medical gowns are the main sources of infections (Denys 2012: 20). Architectural solutions may contribute to the reduction of indirect transmission by fostering some particular organisational activities. Such activities are analysed in the further part of the monograph, on the example of developing functional layouts that facilitate organisational activities: the frequency of hand washing and hand disinfection and the management of medical gown cleanliness.

**Photograph 6.3** The Author wearing protective medical gowns (the use of protective medical gowns requires an analysis of procedures, separation and adequate equipment for changing rooms); photographed by the Author 2016

## 6.3.1 Impact of architectural solutions on the personnel's hand hygiene

The proper hand hygiene is one of the fundamental elements that affect infection transmission. The problem is emphasized by the World Health Organization that brings up the significance of hand hygiene but also the permanent character of implementing, educating and supervising the right behaviour in hospital staff (WHO 2009). Modern microbiology provides evidence that there is a relation between the level of hand hygiene and the occurrence of hospital-acquired infections in patients, confirming not only the aetiology of infections but also providing information about the level of similarity in microorganisms and their relation to a particular source (Wójkowska-Mach 2016). According to the Polish Association of Epidemiological Nurses, the process of pathogen transmission by contaminated hands can be divided into four stages of transmitting infections, namely:

- the patient as a source of infection – pathogenic microorganisms are present on the patient's skin and on the surfaces in the patient's immediate vicinity;
- hospital personnel's hands become transmission vectors – microorganisms are transmitted onto a staff member's hands during the medical examination of patients or nursing procedures. Improper hand hygiene results in the contamination of medical personnel's hands;
- hospital personnel's contaminated hands transmit microorganisms onto other patients or items that later on have contact with other patients (Ochocka 2017).

Hand hygiene is not just a possibility to clean them. Contemporary microbiological research studies prove higher efficiency in hospital-acquired infection control when hand disinfection is applied instead of hand washing (Wójkowska-Mach 2016). In the context of architectural solutions, it means that it is necessary to design not only hand washing stations with washbasins, but also hand disinfection stations.

A solution that reduces hand contamination is also the use of individual protection measures. Disposable gloves not only protect medical staff members but also prevent the risk of transmitting biological agents by hands, however, only when they are used in a correct way. Still, despite all the procedures followed in the right way, infection transmission is possible, for example, in a situation when staff members fail to dispose of contaminated protective gloves before they take care of another patient or move to another area to perform their professional duties. The use of protective gloves does not exempt anyone from hand hygiene procedures.


**Photograph 6.3.1** A hand disinfection station (following 5 moments for hand hygiene should apply to all the users of medical facilities); photographed by the Author, 2018

According to the World Health Organization, it is necessary to follow the rule recommending five moments for hand washing in medical facilities. Hospital personnel must wash and disinfect their hands each time they are in the following situations:

1) before touching patients;
2) before performing clean/aseptic procedures;
3) after the exposure to the body fluids;
4) after touching patients;
5) after touching patients' surroundings (WHO 2009).

Following hygienic procedures should apply to all the users of hospital space. In Poland, the inspections carried out by the Supreme Audit Office in 2018 revealed a number of deficiencies in the field of proper organisation of epidemiological safety in medical facilities, however, there were not any cases of negligence reported as far as hand washing and disinfection stations were concerned: *the requirements in the field of providing medical facilities with liquid soap and disinfectant dispensers have been fully met (Informacja o wynikach kontroli (Information on the Inspection Results…)* NIK 2018: 32).

As discussed in the further part of the monograph, the excellent inspection results do not mean that protection is provided in all the medical units with the same effectiveness. The current Polish regulations pertain to the necessity of providing hand washing and disinfection stations in particular rooms, however, without indicating the need for correlating the number and location of hand disinfection stations with medical technologies and five hand washing moments identified by the WHO (Figure 6.3.1.4). As a result, the potential of architectural and organisational solutions in the prevention of hospital-acquired infections is not fully used.

The insufficient level of hygiene among medical personnel becomes a problem that consists of numerous factors, including architectural solutions as well. It is considered that the insufficient hand hygiene is caused by: uncomfortable location of disinfectant dispensers and/or washbasins, excessive workload often related with the staff shortage, dermatological problems (skin irritation) and cultural background questions, such as the lack of behavioural patterns and forgetting about mandatory procedures (Wójkowska-Mach 2016: 87). The proper design of medical facility space contributes to the comfort of using hand washing and disinfection stations and decreases effort required to perform indispensable procedures in the correct way. Following the rules of hand hygiene decreases if washbasins and disinfectant dispensers are located too far from medical personnel's workstations or from their pathways they use to perform their duties at work. The correct procedure of hand disinfection comes as one of the most efficient methods of infection control (Pittet et al. 2000; Kampf et al. 2009; Stiller et al. 2016). The proper routines are related with the process of educating medical staff members. However, the scientific research studies indicate that even some intensive educational or training courses seem to result only in a periodic increase in the level of hand hygiene (Dubbert et al. 1990; Dorsey et al. 1996). At present, it is commonly known that following the rules of hygiene is of fundamental significance to epidemiological safety and adequate architectural solutions can positively affect the probability of medical staff members' correct behaviour (Lacanna 2014). There are strong indications that locating hand disinfection stations in the vicinity of medical personnel's pathways, in visible spots and in the vicinity of places where they perform their caring duties, leads to a permanent increase in the hand hygiene (Ulrich 2006).

The analysis of design solutions allows for assigning values to the selected elements of hygienic procedures, such as, for example, the circulation paths that must be followed by medical personnel while performing their duties. This makes it possible to estimate the workload performed by medical staff. The following figures present the analysis of medical personnel's circulation paths during the procedures of hand hygiene before and after touching the patient, with the comparison of typical design solutions and a modified solution that is aimed at reducing medical personnel's circulation paths.

Figure 6.3.1.1 presents a layout of a typical multi-bed patient room constructed in accordance with the legal regulations currently applicable in Poland, on the example of a two-bed patient room in the Michałkowski Specialist Hospital in Katowice (in: Tomanek 2015). The scheme is compared to a modified layout aimed at improved ergonomics during the procedures of hand decontamination, with an additional disinfection station. The example presents a possibility to reduce medical personnel's paths by about 40%.

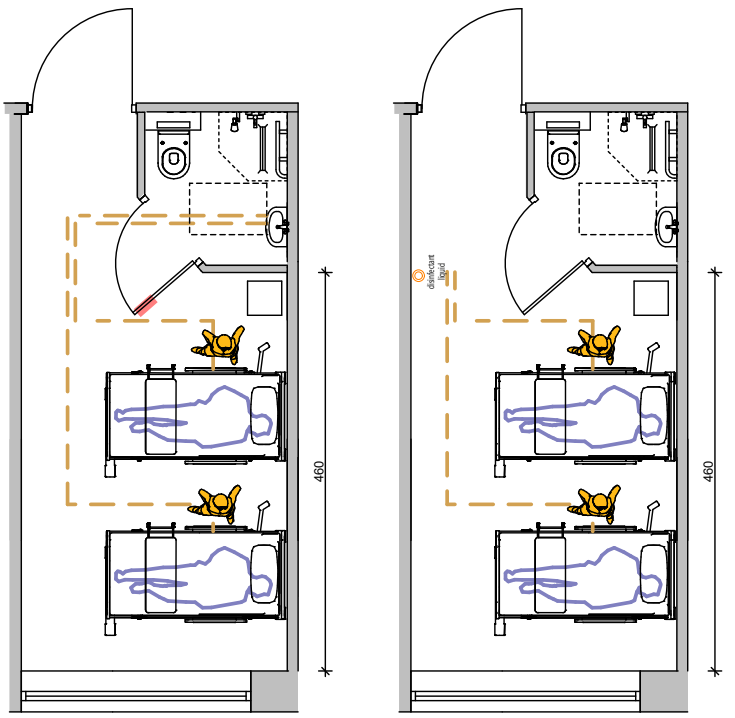
Typical to the Polish healthcare system, a patient room does not allow for revealing the entire potential that results from the change in the attitude toward the designing of a functional layout. Figure 6.3.1.2 presents a single-bed room adjusted to handling disabled patients. Based on such a solutions, a comparison of medical personnel's paths to reach the hand hygiene station located in the bathroom are presented. This solution is acceptable and described in the current regulations (Journal of Laws 2012, item 739), with a spatial solution locating the hand hygiene station in the patient room, in the immediate vicinity of the patient.

This example indicates that providing an additional hand hygiene station contributes to the reduction of the paths that must be followed by medical staff members to perform a set of complex activities. The architectural change affects medical personnel efforts, decreasing their paths by approximately 80%, from 12.5 m down to 2.4 m. The analysis confirms that architectural solutions affect the workload that must be performed by medical personnel during medical treatment and caring procedures. The optimal organisation of the room and a decrease in workload facilitate both the compliance with the procedures and the decrease in the risk of undesirable behaviour caused by the fatigue of medical staff members.

Providing disinfectant dispensers to patient rooms in hospital nursing departments is a solution that does not require incurring high financial costs and it can be indeed a factor contributing to the compliance with the correct hand hygiene procedures. Architectural solutions may positively affect the reliable functioning of the barrier to infection transmission, namely: medical personnel's clean hands. The holistic approach toward patients' safety should cover all the elements that affect epidemiological risk, including ergonomic solutions as well (Carayon et al. 2006).

The spatial solution in which hand washing and disinfection stations are located in a non-functional way contributes to an increased risk of infections transmitted by medical personnel's hands. At the same time, the disadvantages of this solution remain invisible during inspections that test the compliance of patient room furnishing with the provisions of the legal regulations, because the only inspected element is the fact of providing hand washing and disinfection stations, regardless of their architectural and ergonomic aspects.

The problems related to the location of hand washing and disinfection stations are important not only in nursing departments. They can be also observed in relation to some particular medical procedures. Figure 6.3.1.4 presents an example of a design of a magnetic resonance imaging (MRI) room.




A plan of a patient room version A

A plan of a patient room version B

A The distance that must be covered by medical staff members to follow hand disinfection procedures before and after the contact with patients; for the layout of approximately 13 m.

B The distance that must be covered by medical staff members during the hand disinfection procedures before and after the contact with patients; for the layout of approximately 8 m.

Legend:

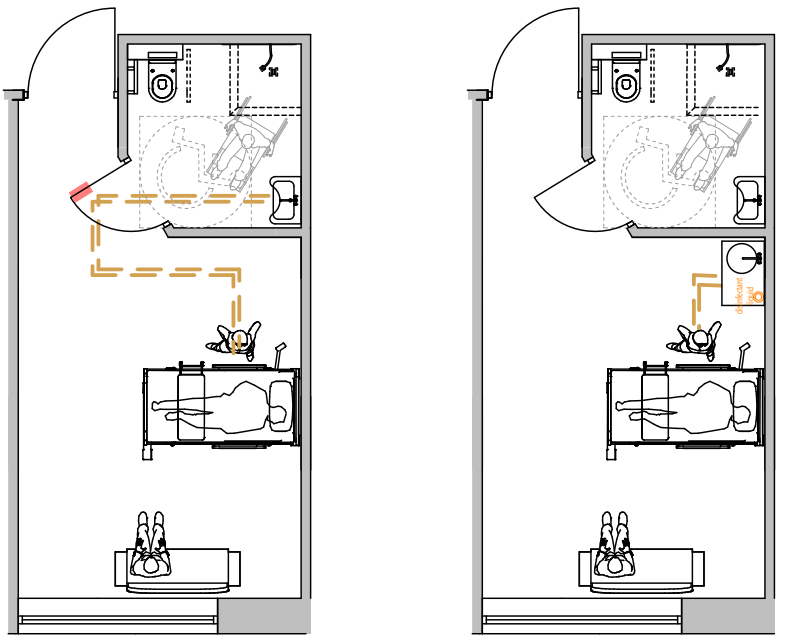
The route of medical staff members covered during the hand hygiene procedures before and after the contact with patients, in accordance with the recommendations provided by the World Health Organization

A door handle as a potentially contaminated surface

An architectural solution for a two-bed room based on the design of patient rooms in the Michałkowski Specialist Hospital in Katowice (Tomanek 2015)

**Figure 6.3.1.1.** The analysis of medical personnel's paths followed during the hand hygiene procedures before and after the contact with patients, on the example of a layout of a typical two-bed patient room (Tomanek 2015)
A - a typical location of hand hygiene station – in an en-suite bathroom adjacent to the patient room;
B - a modified layout with an additional hand hygiene station;
analysed by the Author

The room is used for imaging diagnostics. An MRI machine uses strong magnetic fields to provide images of tissues, body organs and blood circulation flows. The currently applicable regulations impose particular requirements on diagnostics rooms, including separate hand washing and disinfec-



A plan of a patient room version A

A plan of a patient room version B

A The distance that must be covered by medical staff members during the hand disinfection procedures before and after the contact with patients; for the layout of approximately 12.5 m.

B The distance that must be covered by medical staff members during the hand disinfection procedures before and after the contact with patients; for the layout of approximately 2.4 m.

Legend:

The route of medical staff members covered during the hand hygiene procedures before and after the contact with patients, in accordance with the recommendations provided by the World Health Organization

A door handle as a potentially contaminated surface

jednoosobowy pokój modelowy z organizają miejsca dla odwiedzajacych. Projekt i analiza autor.

**Figure 6.3.1.2** The analysis of medical personnel's paths followed during the hand hygiene procedures before and after the contact with patients, on the example of a layout of a typical single-bed patient room;
A - a typical location of hand hygiene station – in an en-suite bathroom adjacent to the patient room;
B - a modified layout with an additional hand hygiene station;
analysed and designed by the Author

tion stations, however there is not such a requirement formulated for MRI rooms: the rooms where diagnostics or medical treatment procedures are carried out, with an exception of MRI rooms, must be equipped with: 1) at least one washbasin with taps supplying hot and cold water; 2) a liquid soap dispenser; 3) a disinfecting agent dispenser; 4) a container with clean disposable towels and a container for used disposable towels (Journal of Laws 2012, item 739, art. 36, section 1). As a result, MRI rooms, where during the procedures involving contrast application the continuity of tissues is disrupted, the

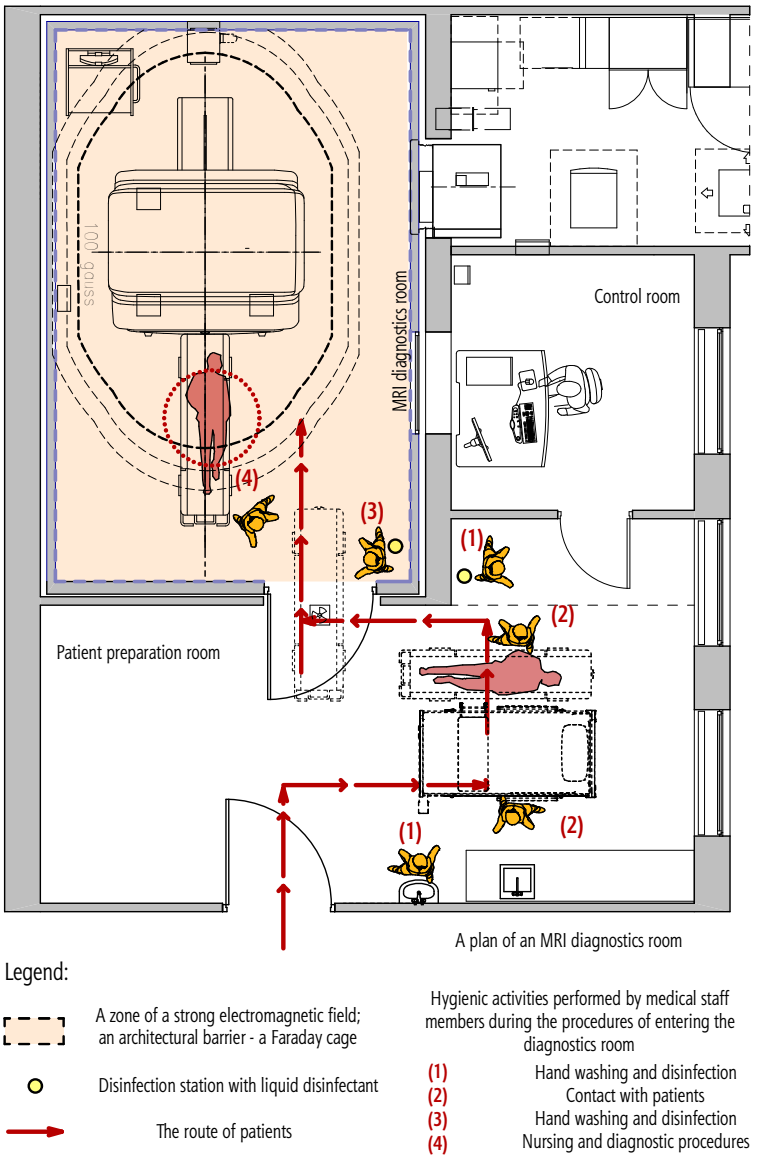
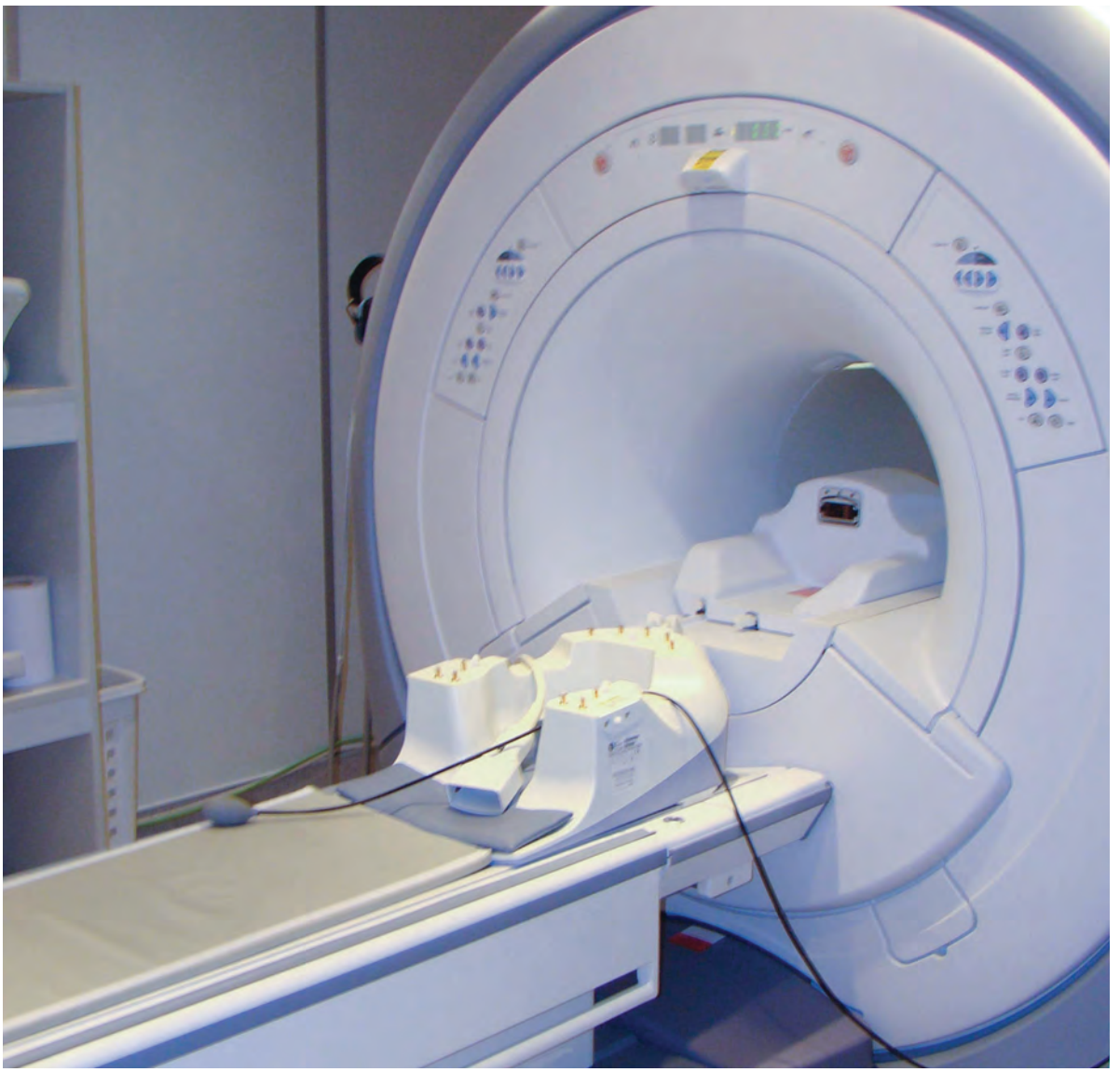



**Figure 6.3.1.3** The design of an MRI room with the technology scheme and hand hygiene stations; analysed and designed by the Author

legal basis for providing a hand washing and disinfection station does not exist. The justification for this exception is the presence of high electromagnetic fields in MRI rooms. Due to this fact, the possibilities of installing a washbasin with metal elements are limited and the area outside the room must be secured through the implementation of safety screens in the form of a Faraday cage. As presented in Figure 6.3.1.3, the discussed requirements stated by the legal regulations are inadequate to the needs and technical possibilities.



**Photograph 6.3.1.4** A magnetic resonance imaging room (the use of the testing table by many patients poses an increased risk of infection transmission); designed and photographed by the Author 2016

The architectural layout of an MRI room has been analysed by superimposing medical procedures onto the MRI plan. Displayed in such a way, the paths of patients and medical personnel during the diagnostic tests allow for indicating the location and moments to perform hand hygiene procedures, in accordance with the recommendations issued by the WHO. In the analysed room, there are three such locations. Considering the restrictions resulting from the presence of the electromagnetic field, a location for disinfectant dispenser is designed in the place where the MRI machine works; there are also two disinfection stations and one hand washing station in the patient preparation room. The implementation of several hand hygiene stations in one room is aimed not only at facilitating necessary procedures but also at shortening the circulation paths followed by medical personnel, in order to foster correct behavioural patterns in the context of epidemiological prevention.

This solution goes significantly beyond the above-mentioned requirements stated by the legal regulations, as it implements non-standard architectural solutions. However, it allows for the performance of medical procedures in accordance with the recommendations on hand hygiene issued by the World Health Organization.

**Photograph 6.3.1.5** Elbow-operated taps (an example of hygienic equipment that can be operated in a hand-contactless way); photographed by the Author, 2016

As presented above, the analysis provides the evidence that in Poland there is a lot of architectural potential that can be used for improving epidemiological safety in medical facilities, through the implementation of non-standard solutions that go beyond currently applicable legal regulations. The discussed examples indicate the need for scientific research and verification of the current legal regulations. In accordance with the National Consultant for Epidemiological Nursing, pathogen transmission by medical personnel's contaminated hands is the main reason for hospital-acquired infections (Ochocka 2017). It is also confirmed by the common opinion of the Association of Hospital Epidemiology, the Polish Society of Hospital Infections, the Polish Association of Epidemiological Nurses and the Association of Committees and Hospital-acquired Infection Control Teams in Lesser Poland, which indicates the need for the adequate design of medical facility space in terms of ergonomics, especially the *proper access to the equipment indispensable for efficient hospital infection control, for example, access to hand disinfection dispensers* (Bulanda et al. 2016: 13). Equipping workstations with washbasins and disinfectant dispensers is one of the elements the location of which in medical facility space requires analysing its functional, ergonomic, sanitary and hygienic conditions. Discussed in this part, the relations between architectural solutions and technological processes contribute to epidemiological safety. Affecting the quality and comfort of work performed by medical personnel in a positive way, they indirectly reduce transmitting infections by medical staff members' hands. This dependency proves the significance of architectural activities undertaken in the field of preventing hospital-acquired infections.

## 6.3.2 Architectural solutions in the high risk areas on the example of changing room units

While circulating among various functional areas of a hospital, medical staff members have contact with reservoirs of different microorganisms that can be transmitted among those areas. Transmitting infections by medical personnel's contaminated clothes comes as another indirect infection transmission route. Architectural solutions that reduce possibilities of such infection transmission can be of various nature, however, they are related to the implementation of requirements involving the use of medical protective gowns.

A place where it is relatively easy to observe the relations between the assumed epidemiological regimes referring to the use of medical protective gowns and architectural solutions, is a changing room unit located next to an operating suite. This is an area where medical personnel prepare themselves to enter the zone of an increased sanitary and hygienic regime. It is also an area where additional requirements on architectural solutions are applicable regarding the reduction of infection transmission, including the rules on the use of protective medical garments. The basic task of a changing room unit leading to an operating theatre is the protection against the transmission of infections through vectors such as medical personnel's clothes or hands.

In Poland, it is required by legal regulations to provide a unit composed of changing rooms and airlocks through which medical personnel members enter the area of an operating theatre (Journal of Laws 2012, item 739). The implementation of restrictions to the circulation in the area of an operating theatre in clothes that are worn in generally accessible hospital parts comes as an element of that

**Photograph 6.3.2** Storage of medical protective gowns (the use of reusable protective gowns requires separation of clean and contaminated items); photographed by the Author 2016

system. The architectural layout of a changing room unit may appear to be a simple design question, however, its design principles have not been clearly defined in the currently applicable legal regulations. The Guidelines of the Minister of Health (Ibid.) state that such units must be provided, but they do not list their components and optimal architectural solutions to be applied. Therefore, the guidelines that are followed in the reference to that hospital areas are the general regulations in the field of occupational safety and hygiene issued by the Minister of Labour and Social Policy (Journal of Laws 1997, no. 129, item 844, annex no. 3), although they are dedicated to a larger group of employees, who work in industrial sectors and services other than provided in the medical sector (Figure 6.3.2.1). The discussed regulation does not fully solve functional problems in the area of medical facilities, because it does not consider specific hazards occurring in the operating theatre zones that must be prevented by those sanitary units.

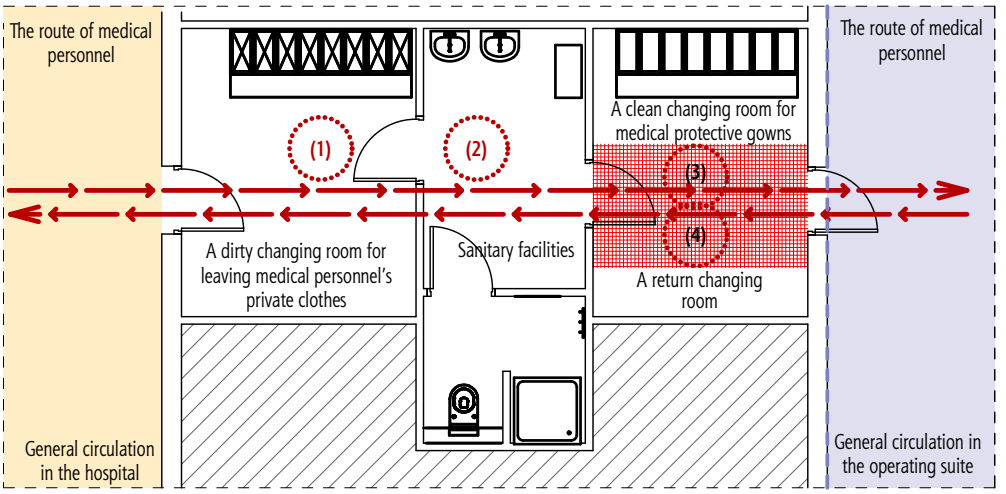
Within the basic understanding of the guidelines issued by the Minister of Labour and Social Policy, architectural solutions applied in the entrance zone of an operating theatre include a unit composed of three rooms: a dirty changing room, a bathroom unit and a clean changing room. The element that has not been defined in the legal regulations is the need for providing a return changing room, where medical personnel members who exit the operating theatre zone leave their potentially contaminated clothes. A clearly separated return changing room could allow for the reduction of the risk of contaminating clean clothes.

A return changing room is an element frequently observed in newly constructed hospital facilities. In the context of the currently applicable legal regulations, it is a non-standard architectural solution but its implementation results from the analysis of the process of entering and exiting the zone of an increased epidemiological hazard by medical personnel.

Defined in the current regulations, the general rules of designing changing room units do not refer to other problems typical of medical facilities. As a result, legal regulations have to be completed with more elements. For example, there are no recommendations on the procedures concerning footwear of medical personnel entering and leaving the operating suite zone. Considering the sanitary and hygienic regimes, footwear should be changed each time before staff members enter the operating suite zone and after they leave that area. Furthermore, footwear should be washed and disinfected each time before it is used again. Considering architectural design solutions, the implementation of a pass-through washing and disinfecting station between the dirty and the clean sections does not pose any functional problems at all (Figure 6.3.2.2). This solution allows medical personnel to perform hygienic procedures without affecting the efficiency of their work. It also considerably decreases the risk of transmitting microorganisms. However, the installation of such a device requires the implementation of an adequate layout. In the context of the standards applicable in Poland, this kind of a solution is non-standard in relation to the current requirements defined in the legal regulations. As a result, the discussed solution is applied to a limited extent.

The concepts alternative to the Polish regulations in the field of architectural solutions applied in medical facilities can be observed by a comparison of the solutions discussed previously to the design of the entrance zone of an operating suite in a German university hospital in Mittelbaden Baden-Baden (Figure 6.3.2.3). The solution is based on the progressive circulation with architectural and spatial tools that differ from the ones required in Poland. The procedure of entering the operating suite takes place in one changing room. It is contradictory to the regulations currently applicable in Poland, however,

it shows that epidemiological risk resulting from the contamination of clothes can be eliminated without the necessity of providing additional rooms. In the analysed example, the circulation of medical personnel is separated into dirty and clean circulation paths with the use of spatial solutions (e.g.: the doors can be opened from one side only) that reduce the possibility of misusing the separated space and acting against the procedures.




A plan of the changing room unit

Legend:

Activities carried out by the medical staff members under the procedure of entering the operating suite:

(1) Changing clothes - a changing room for leaving medical personnel's private clothes

(2) Sanitary activities - the sanitary facilities including a toilet, a shower, a hand washing and disinfection station

(3) Putting on protective medical gowns - a changing room for medical protective gowns

(4) Taking off protective medical gowns

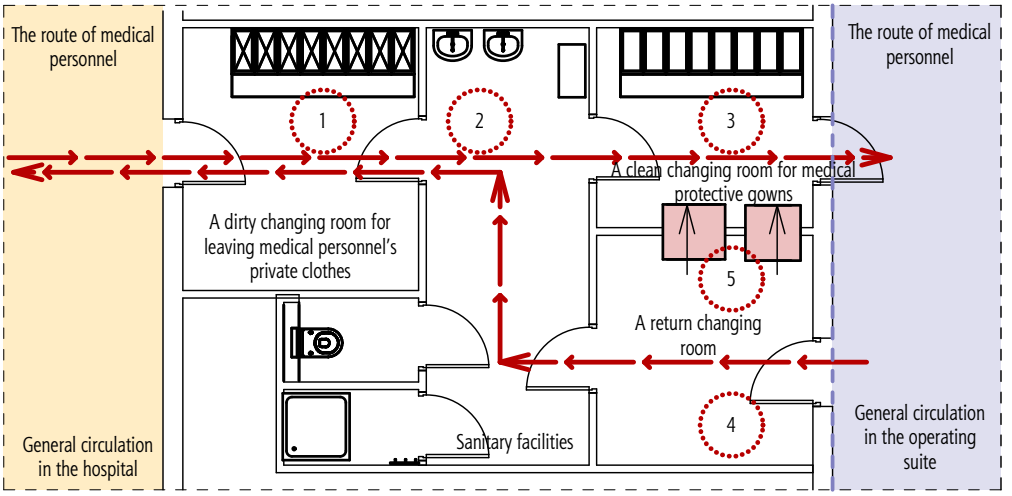
A place of potential contamination

A protected zone of the operating suite

A protected zone of the operating suite

The route of medical personnel

**Figure 6.3.2.1** The procedure of entering the operating suite through a changing room unit implemented in accordance with the minimal requirements stated in the ordinance of the Minister of Labour and Social Policy on the general regulations on occupational safety and hygiene; analysed and designed by the Author




A layout of the changing room unit extended by a return changing room

Legend:

Activities carried out by the medical staff members under the procedure of entering the operating suite:

1 Changing clothes - a changing room for leaving medical personnel's private clothes

2 Sanitary activities - the sanitary facilities including a toilet, a shower, a hand washing and disinfection station

3 Putting on protective medical gowns - a changing room for medical protective gowns

4 Taking off protective medical gowns

5 Washing and disinfection medical personnel's footwear (a disinfecting station)

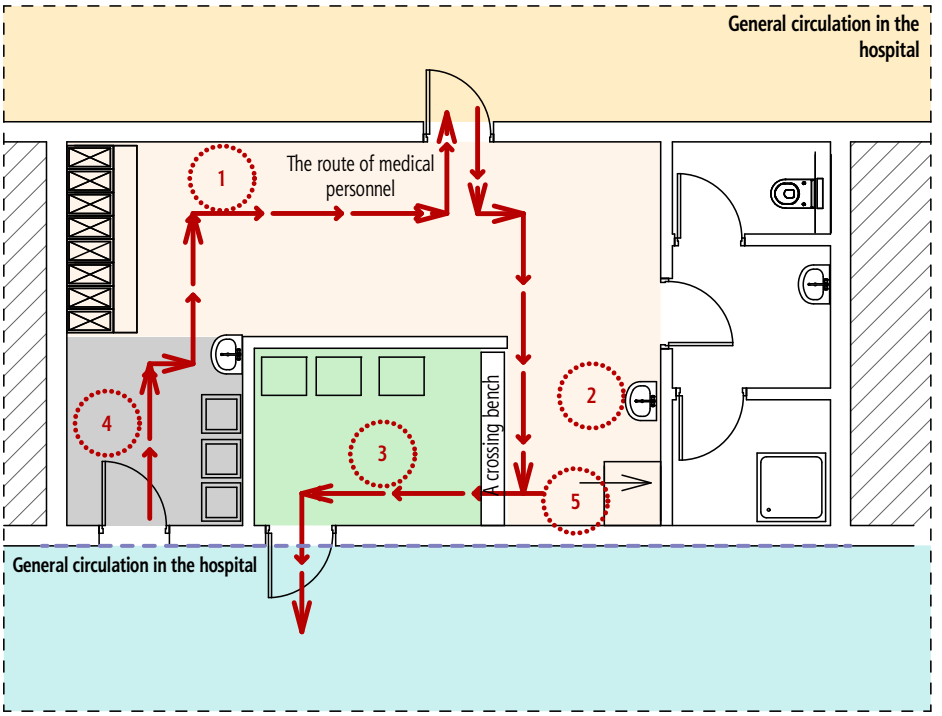
A protected zone of the operating suite

The route of medical personnel

A protected zone of the operating suite

A disinfecting station

**Figure 6.3.2.2** The procedure of entering the operating suite through a changing room unit implemented with additional elements resulting from good design practice and the analysis of the process. The implementation of solutions that reduce the possibility of clean clothes contamination and pass-through washing and disinfecting stations comes as a solution to the problems with the hygiene of the footwear worn in the zone of the operating suite; analysed and designed by the Author




A layout of a changing room designed in one room with a separated functional sequence line

Legend:

Activities carried out by the medical staff members under the procedure of entering the operating suite:

1 Changing clothes - a changing room for leaving medical personnel's private clothes

2 Sanitary activities - the sanitary facilities including a toilet, a shower, a hand washing and disinfection station

3 Putting on protective medical gowns - a changing room for medical protective gowns

4 Taking off protective medical gowns

5 Washing and disinfection medical personnel's footwear (a disinfecting station)

General circulation in the hospital

A clean zone in the changing room

A zone of medical personnel's private clothes and hygienic procedures

A dirty zone of the changing room

General circulation in the operating suite

The route of medical personnel

**Figure 6.3.2.3** The functional layout of a changing room unit of the operating suite; elaborated by the Author on the basis of a site visit in Germany

**Photograph 6.3.2.4** A display screen with a keyboard in the operating theatre (the elements of the equipment are made in a way that allows for systematic disinfection procedures); photographed by the Author

## 6.4 Medical equipment as a source of infections – the current architectural solutions based on the principle of progressive circulation

Architectural layouts of medical facilities are designed with the consideration of technological and ergonomic conditions and are strongly affected by process management. In the case of such close relations, design deficiencies do not mean that medical facility rooms do not comply with the current legal regulations. Architectural solutions can meet legally stated requirements and, at the same time, they may turn out to be impractical and can make proper implementation of medical procedures difficult, negatively affecting the level of safety (Janowicz 2018).

The process management performed with the use of architectural solutions is a tool permanently applied in medical facilities. It can be observed on the example of activities undertaken in the field of managing the flows of clean, sterile, dirty, used and contaminated materials (Figure 6.4.1). Both medical tools and medical equipment may come as serious threats in a medical facility. All invasive medical procedures are based on the contact of sterile materials and equipment (a medical apparatus or a surgical instrument) with patients' tissues or mucous membranes. The risk of transmitting infections during such procedures results from the possibility of introducing pathogenic microorganisms into the patient's body, causing hospital-acquired infections. An increase in this type of hazard can be caused by the lack of proper disinfection or sterilisation of reusable medical equipment.


**Photograph 6.4** A patient transfer station (in Poland it is assumed that a patient bed should not enter the area of an operating suite); photographed by the Author 2016

Therefore, it is important to achieve the assumed level of cleanliness during the procedures of disinfection and sterilisation. A vast set of medical equipment and instruments is divided into various categories in terms of the required level of cleanliness after their use in medical procedures. Among them, there are:

- items of high critical significance – items that have direct contact with the patient's sterile tissues, such as surgical instruments, laparoscopes, catheters, implants;
- items of low critical significance – items that have contact with the patient's undamaged skin, such as stethoscopes (Rutala and Weber 2004).

Based on the analysis of strengths and weaknesses and adequacy of the particular methods, persons who are responsible for the management of the processes involving the flows of medical equipment in a medical facility should select the best methods of disinfection and sterilisation. Following the recommendations should reduce or eliminate the possibility of transferring infections by medical equipment and instruments in healthcare facilities, decreasing the occurrence of nosocomial infections.

The ways of applying process management in architectural design of medical facilities can be observed, for example, while analysing the flow of surgical instruments. They undergo the process of sterilisation that involves technology contributing to the elimination of microorganisms from the processed material with the probability level of 1:1 000 000. The sterilisation procedure follows the principle of progressive circulation. According to the principle, the subsequent steps are followed: disinfection, washing, packaging, sterilisation. The process should be started with collecting contaminated instruments and ended with securing sterile instruments. The flow of the instruments should be started in the dirty zone, go through the clean zone and end in the sterile zone (Ponikło 2010: 23).

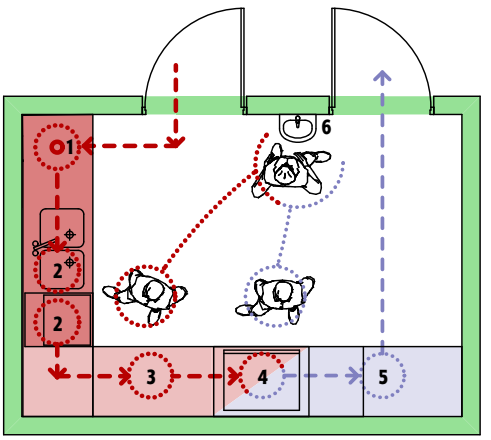
These problems are presented by comparing various standards applied during the selection of architectural solutions dedicated to sterilisation rooms, along with their influence on the quality and efficiency of the applied technologies.

According to the current legal regulations applicable in Poland, sterilisation processes can be carried out at outpatient departments in a unit of rooms defined as a sterilisation unit and in hospitals - in central sterilisation units (Journal of Laws 2012, item 739). Architectural solutions required in hospitals and outpatient departments differ in the attitude toward the acceptable level of risk involving undesirable events. The method to manage the process in both cases is based on the progressive flow of materials, from the dirty zone to the clean and sterile zones, however, with the implementation of some fundamentally different architectural solutions. In the case of a sterilisation procedure carried out in an outpatient department, only one room can be provided, where it is necessary to separate a technological line for medical personnel to perform all the required activities in accordance with the progressive circulation principle (Figure 6.4.1). This layout assumes the high awareness in medical staff members, because the incorrect use of the room, without following the defined principles, can easily end with undesirable events. The risk is typical of sterilisation procedures carried out on the same table, where – without the proper following of the progressive circulation and while failing to perform the right procedures – it is possible to mix the materials of different levels of contamination with microorganisms.

An organisational unit responsible for the sterilisation of medical equipment, surgical instruments and other materials used in a hospital is its central sterilisation unit (CSU). It should guarantee the adequate level of quality required for sterile items.

While designing a central sterilisation unit, a principle of the physical separation of dirty, clean and sterile zones must be followed. It is also necessary to design pass-through washing disinfecting and sterilising devices between these zones to reduce the risk of contaminating sterile instruments by their accidental contact with dirty items.

The comparison of the requirements set for the sterilisation processes carried out in an outpatient department and those carried out in a hospital indicate that there is a possibility to apply various levels of architectural security measures against the same hazards. In a hospital, they are implemented in a central sterilisation unit, where the possibility of making errors is significantly reduced by a physical




**A plan of a sterilisation unit located in a separate outpatient room**

**Legend:**

A technological line of a sterilisation unit:

1) A section (table) for contaminated materials for unloading and preparation to the washing and preliminary or main disinfection procedure;

2) A section for automatic or hand washing and disinfecting, including the washing and disinfecting equipment or a two-compartment sink;

3) A section (a table) for clean materials for checking and packaging before sterilisation;

4) A steam or low-temperature autoclave, excluding an ethylene oxide sterilizer;

5) A section (a table) for sterile materials;

6) A hand hygiene station outside the working table.

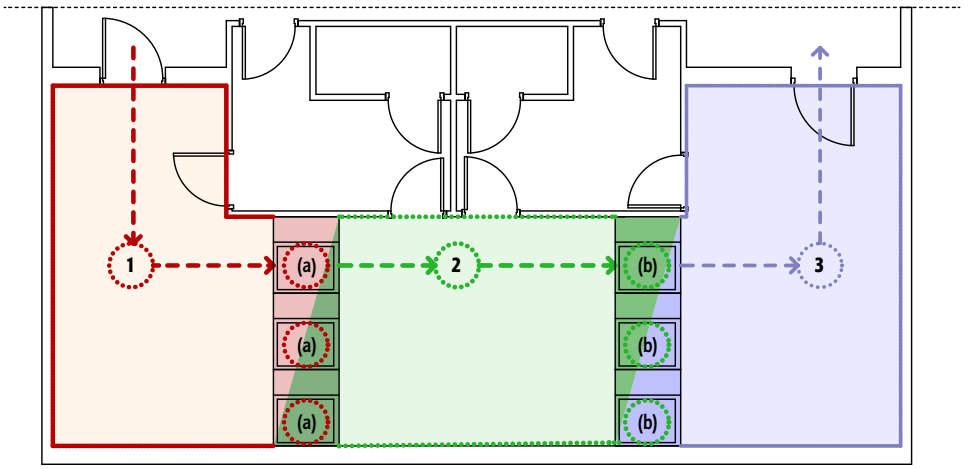
Architectural partitions

The flow of the materials

Note: in accordance with the Minister of Health on 26th June 2012 on the specific requirements for facilities and equipment used by entities providing healthcare services, spatial solutions for sterilisation units should provide a one-direction flow of materials at each stage of technological procedures, starting from the point of collecting contaminated materials to the point of distributing sterile materials for use.

**Figure 6.4.1** The progressive circulation on the example of the requirements defined for the sterilisation room in an outpatient department; analysed by the Author

separation of rooms, where dirty, clean and sterile items are processed. Technological solutions in the form of pass-through sterilisers and pass-through washing and disinfecting devices do not allow for the contact of clean and sterile instruments and reduce the possibilities of contamination by medical personnel's dirty hands. Medical staff members working in one room of the unit have contact only with instruments of the same cleanliness level.




A plan of a central sterilisation unit located in a hospital

**Legend:**
The zones of a central sterilisation unit:

1) A dirty zone for collecting, sorting, washing and preliminary and main disinfection procedures dedicated to surgical instruments and medical equipment, for washing and disinfecting transporting elements and trolleys, storing brand-new medical instruments and storing disinfectant supplies and for preparing disinfectant working solutions;

2) A clean zone for drying disinfected medical tools and equipment, checking and folding operating linen, packaging operating and surgical instrument sets, preparing input batches for autoclaves, storing brand-new medical instruments, providing and archiving documents referring to the sterilisation procedures;

3) A sterile zone for unloading sterile materials from autoclaves, storing sterile materials and distributing them to the particular hospital wards or to external recipients.

Devices:

a) Pass-through washing and disinfecting stations

b) Pass-through autoclaves

Architectural partitions as barriers between areas characterised by various sanitary and hygienic regimes

The flow of materials

Note: in accordance with the Minister of Health on 26th June 2012 on the specific requirements for facilities and equipment used by entities providing healthcare services (annex no. 1), spatial solutions for central sterilisation units should provide a progressive flow of materials, starting from their dirty zones to the sterile zones.

**Figure 6.4.2** The progressive circulation on the example of the requirements defined for the central sterilisation unit in a hospital; analysed by the Author

This situation indicates that the acceptable level of risk is not a uniform parameter and it changes, depending on the design context. Today, in Poland there is not any cohesive strategy pursued that could explain the reasons for the differences in the risk qualification criteria. The evaluation of adequacy and potential provided by architectural solutions should be carried out on the basis of a defined methodology and it should be confirmed by reliable scientific research. A broad scope of the discussed problem can indicate a need for the use of skills represented by interdisciplinary scientific research and implementation teams to provide a multi-aspect evaluation, considering the achievements in numerous fields of science.

A properly designed architectural layout of a discussed unit may facilitate proper behavioural routines in medical personnel, while following the assumed procedures of epidemiological risk management. Failing to comply with the procedures and making errors result from the low quality of personnel training provided under the programmes of preventing hospital-acquired infections and also from the fatigue of medical personnel members, who are often overburdened with their workload. Considering the aspect of epidemiological safety, the fatigue of medical staff members remains undetectable, because it is manifested with the same symptoms as errors made for other reasons. Despite the fact that the fatigue of staff members is relatively well described in specialist literature on occupational safety and hygiene, this problem has not been sufficiently analysed from the perspective of the architectural and ergonomic design of medical facilities. Considering medical personnel, fatigue can be related to

**Photograph 6.4.3** A central sterilisation unit (physical separation of the dirty, clean and sterile sections allows for reducing the possibilities of secondary contamination of medical instruments); photographed by the Author 2016

a number of negative phenomena, such as difficulty in focusing attention, limited abilities for planning and implementing some adaptation strategies, an increase in the number of errors and in the accident rates (Golonka et al. 2016). The need for in-depth scientific research in this field has been postulated by architects and ergonomists: *the level of reliability and safety in the field of medical procedures is lower by several levels of magnitude than it is in the fields of aviation and cosmic research (…). An improvement in this area requires an in-depth analysis of reasons for actual and potential undesirable events* (Pokorski and Pokorska 2017).

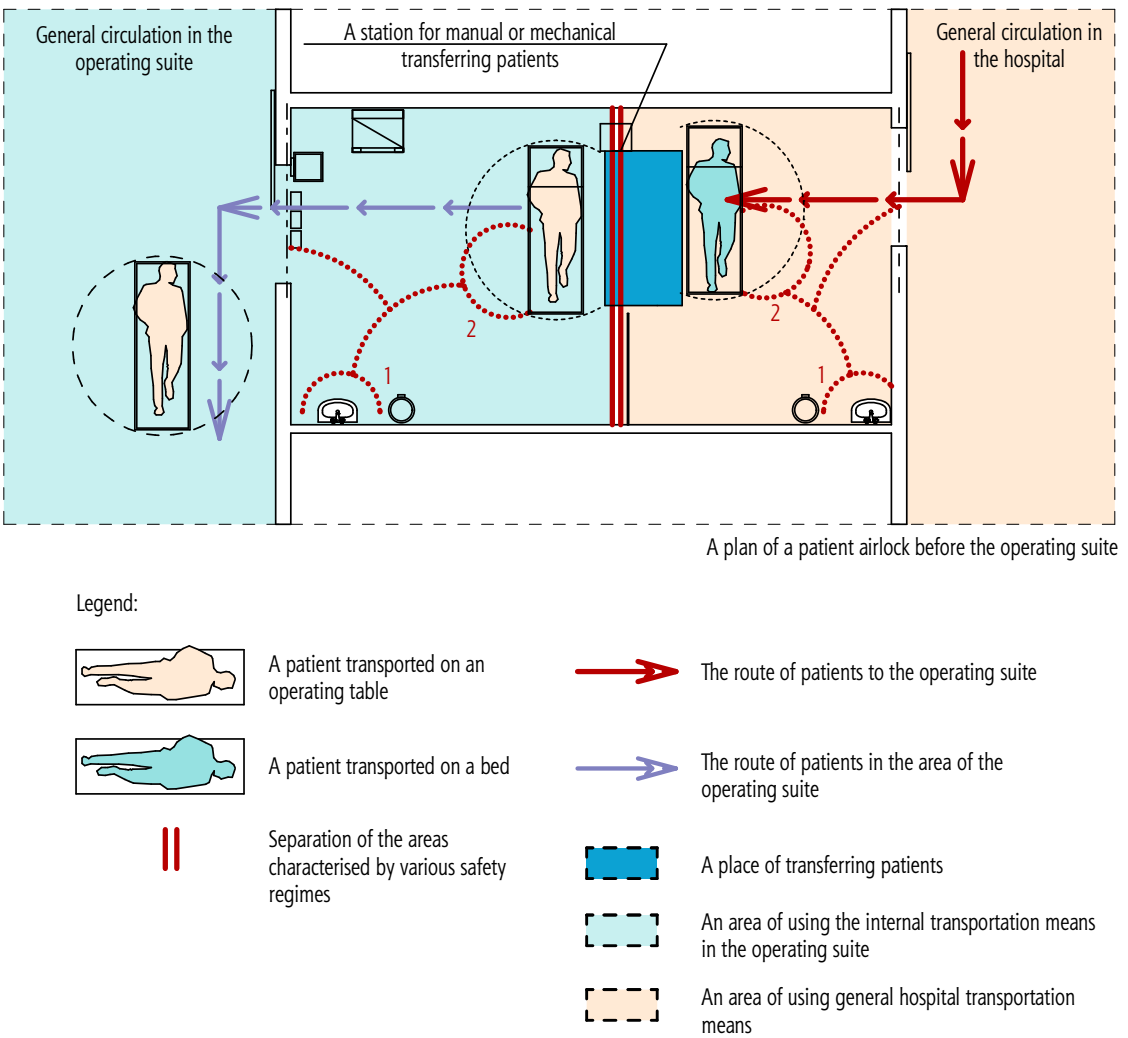



**Figure 6.4.4** A patient airlock. An example of reducing the migration of equipment elements between the areas characterised by various sanitary and hygienic regimes; analysed by the Author

## 6.5 Impact of hospital environment on infection transmission – the role of material solutions in disinfection processes

Hospital facilities are very complex constructional structures with their spatially designed environment. If a medical facility gets contaminated, its environment becomes a potential reservoir of nosocomial infections. Therefore, the quality of water and air, the procedures related to hospital linen and staff members' protective gowns, the flows of medical instruments and equipment, the processes related to sanitisation and disinfection undergo special supervision. The levels of the amounts of various microorganisms in a building can be affected through properly selected design solutions, including those pertaining to installation fixtures applied in the systems of mechanical ventilation, water supply and sewage, power supply and medical gases (Kaiser and Wolski 2007; 2011). Frequently, the limit parameters are assumed by some hospitals, for example for the air quality. They are applied not only to function as guidelines resulting from epidemiological reasons, but also to provide the comfortable use of the building (Ed. Pawińska 2011).


**Photograph 6.5** A sanitisation trolley (the sanitisation process involves moving sanitisation equipment into the rooms in order to provide efficient performance of the sanitisation procedures); photographed by the Author 2018

Providing the safe use of medical facilities is a complex, multi-layer process. Considering the vast scope of the discussed problem, the supervision over the proper functioning of a hospital requires the involvement of numerous specialists, including those working in the field of architecture. Architects are responsible not only for setting the parameters of a constructed environment, but also for the efficient integration of all the users and elements of the investment processes, including the choice of material solutions used for the interior design, the arrangement of medical equipment and the adjustment of the room layout to medical technologies.

Pollution and contamination of surfaces that cover constructional partitions, installations, sanitary devices, furniture and elements of mobile infrastructure are of the common occurrence in hospitals and they considerably contribute to the transmission of nosocomial infections. In medical facilities, these areas become reservoirs of numerous pathogens that are transmitted by patients and medical personnel (Boyce et al. 2002; Lankford et al. 2006; Caselli et al. 2018). Frequently touched by the users of healthcare facilities, material surfaces are contaminated with microorganisms that are harmful to human health, particularly to immunocompromised patients. A recent series of contemporary scientific research has proved that medical personnel can contaminate their hands and gloves through touching contaminated material surfaces and then transmitting infectious pathogens by those routes onto patients. Pathogens can be also acquired by patients through a direct contact with a contaminated surface. These relations are presented in a graphical model, in Figure 6.5.1.

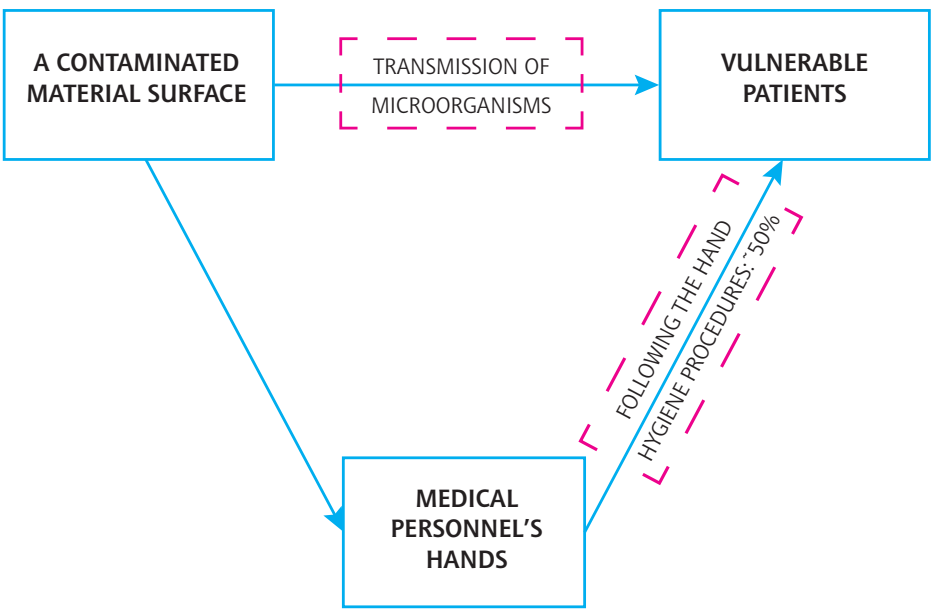



**Figure 6.5.1** A scheme of infection transmission from the contaminated environment (in: Kramer et al. 2006)

The contemporary research on the levels of contamination on various surfaces in rooms where patients have been hospitalised indicates that in the case of infections caused by *Staphylococcus aureus* strains the problem may refer even to 27% of the surfaces in a room and in some other cases (e.g.: departments treating patients with burns), contamination may refer even to 64% of material surfaces in a room (Boyce 2007 in: Tomanek 2015: 61). Furthermore, some pathogenic bacterial strains have the ability to survive on a dry surface for several days and even several months. Significant in clinical terms, the length of the existence of some bacterial strains on various material surfaces often used for covering main constructional partitions and furnishing of medical facilities is presented in a table below (Figure 6.5.2).

An element of epidemiological hazard identified in relations among patients, medical personnel and hospital environment is the occurrence of multidrug-resistant (MDR) bacterial strains. The contemporary scientific research studies indicate that despite the proper care provided to the cleaning of rooms and intensity of programmes dedicated to hand hygiene, these microorganisms are still present in the hospital environment. It results from, among other reasons, bacterial biofilms that protect microorganisms and are very difficult to remove, due to their increased resistance to detergents and disinfectant agents (Vickery 2012).

Considering the abilities for such a long survival period in microorganisms existing in the hospital environment, the current guidelines recommend the implementation of plans developed for cleaning and disinfection of surfaces in the areas where patient nursing is provided. The occurrence of infection sources in medical facilities leads to the contamination of various surfaces: walls, floors, ceilings, doors and windows. However, the areas indicated by some scientists as the places of a particularly increased risk of transmitting pathogens are the surfaces of furnishing in the immediate vicinity of hospitalised patients (Kramer et al. 2006).

More and more scientific evidence indicates that the rational cleaning or disinfection of the hospital environment may considerably reduce the transmission of healthcare-associated pathogens (Kramer et al. 2006; Boyce 2007; Vickery et al. 2012). This guideline should come as an important aspect included in the process of designing new and modernised hospital facilities.

The hospital environment is heterogeneous in terms of the epidemiological hazard levels. The functional and spatial layout of a building is divided into various areas, depending on the access provided to its users, medical services provided there or the organisation of the particular units. In specialist literature, there are four basic categories of the infection risk levels in the particular zones of a healthcare unit, namely:

1) low risk – e.g.: in administrative zones;
2) medium risk – e.g.: in waiting rooms and diagnostic rooms;
3) high risk – e.g.: in hospital wards and medical treatment rooms;
4) very high risk – e.g.: in the areas of operating suites, intensive care units (Hoban 2012).

Taking the above-listed classification into account during the design process leads to a gradation of design solutions and a combination of architectural achievements with hospital-acquired infection control in the hospital environment. As the routine cleaning of furnishing elements and other surfaces does not always remove pathogens, some improved methods of disinfecting the hospital environment are needed. However, more detailed guidelines for architectural design are provided with the information on the classification of functional and spatial layouts, depending on the programmes developed

| Bacteria strains | The time of surviving on the surface |
|---|---|
| *Acinetobacter spp.* | 3 days to 5 months |
| *Bordetella pertussis* | 3–5 days |
| *Campylobacter jejuni* | to 6 days |
| *Clostridium difficile* (spores) | 5 months |
| *Chlamydia pneumoniae, C. trachomatis* | ≤ 30 hours |
| *Chlamydia psittaci* | 15 days |
| *Corynebacterium diphtheriae* | 7 days – 6 months |
| *Corynebacterium pseudotuberculosis* | 1–8 days |
| *Escherichia coli* | 1.5 hours – 16 months |
| *Enterococcus spp.* including VRE and VSE | 5 days – 4 months |
| *Haemophilus influenzae* | 12 days |
| *Helicobacter pylori* | ≤ 90 minutes |
| *Klebsiella spp.* | 2 hours > 30 months |
| *Listeria spp.* | 1 day – months |
| *Mycobacterium bovis* | > 2 months |
| *Mycobacterium tuberculosis* | 1 day – 4 months |
| *Neisseria gonorrhoeae* | 1–3 days |
| *Proteus vulgaris* | 1–2 days |
| *Pseudomonas aeruginosa* | 6 hours – 16 months; on a dry floor: 5 weeks |
| *Salmonella typhi* | 6 hours – 4 weeks |
| *Salmonella typhimurium* | 10 days – 4.2 years |
| *Salmonella spp.* | 1 day |
| *Serratia marcescens* | 3 days – 2 months; on a dry floor: 5 weeks |
| *Shigella spp.* | 2 days – 5 months |
| *Staphylococcus aureus,* including MRSA | 7 days – 7 months |
| *Streptococcus pneumoniae* | 1–20 days |
| *Streptococcus pyogenes* | 3 days – 6.5 months |
| *Vibrio cholerae* | 1–7 days |

**Figure 6.5.2** The length of the survival of clinically significant bacterial strains on a dry surface (in: Kramer et al. 2006)

for cleaning and disinfection. In the theory of preventing nosocomial infections, another division of the hospital environment is also referred to, namely: a classification of its sanitary zones, where the relevant levels of the sanitisation plan are implemented in the particular rooms:

- zone 1 – permanent cleanliness – it includes sterile boxes, storage rooms for sterile materials, operating theatres and birthing suites;
- zone 2 – general cleanliness – it includes patient rooms, physician offices, internal circulation corridors, transport lifts and imaging diagnostics rooms;
- zone 3 – variable cleanliness – it includes medical treatment rooms, post-surgical treatment rooms, anaesthesiology and intensive care units, dialysis units, sterilisation units, infectious diseases departments and laboratories;
- zone 4 – permanent contamination – it includes toilets, dirty rooms and sluices, maintenance rooms (Ed. Dzierżanowska 2008 in: Grochowska 2011: 132)

Considering the vast scope of the problems discussed in the monograph, the questions pertaining to healthcare-associated infections related to the contamination of material surfaces is narrowed down to the management of the levels of pathogen contamination detected on partition surfaces with the cleaning and disinfection procedures performed in patient rooms. Due to a direct relation of architecture with material solutions, the impact of design concepts on the activities related to the achievement of the highest level of cleanliness in a hospital has been analysed.

The classification of the levels of material surface contamination is also provided for the particular types of rooms and their interior arrangement. Among others, a classification recommended by the Polish Association of Epidemiological Nurses is also implemented. It specifies material surfaces that can be contaminated by contact with patients' dirty hands (door handles, taps, soap dispensers, bed frames and items that have got contact with other parts of the patient's body (toilets, showers, floors) (Grochowska 2011).

Depending on the expected level of infection transmission risk, an adequate process of eliminating pathogens is selected for a designed room.

In hospital facilities, the selection of finishing materials should be related to the expected processes of sanitisation and disinfection, including their frequency and types of chemical agents applied in those processes. The characteristics of those processes can be presented through the activities performed at the three levels of efficiency, namely:

- sanitisation – the basic level involving cleaning, removing visible dirt and impurities by washing and dusting. When performed systematically, these activities reduce the amounts of microorganisms;
- disinfection – the second level of hygienic processes that involves elimination of pathogens with the use of chemical or physical agents. As a result, vegetative forms of microorganisms are destroyed. However, this method is not considered as efficient in the elimination of bacterial spores and lentiviruses;
- sterilisation – the highest level of hygienic processes; after sterilisation, all microorganisms are assumed to have been destroyed, with the survival probability lower than $10^{-6}$ (Fleischer 2009: 161).

Considering the guidelines that allow for the proper implementation of sanitisation and disinfection processes assumed in the hospital-acquired infection control, a fundamental challenge posed to

architecture is to provide layouts of rooms characterised by the proper design of architectural details that could limit the number of places that are difficult to clean and disinfect and to provide rational, economical and user-friendly material solutions.

Architectural solutions applied in medical areas should allow for multiple performance of disinfection procedures with the use of agents and tools typical of those areas. Microbiological contamination of the environment affects the level of nosocomial infections, therefore, efficient sanitisation, disinfection and sterilisation are factors that reduce hospital-acquired infections. As indicated in some scientific research studies, employing an additional staff member in a cleaning team working five days a week has resulted in a decrease in microbiological contamination by 32.5% in places that are commonly touched by patients and personnel. Also, a decrease in the rate of new infections with the methicillin-resistant Staphylococcus aureus (MRSA) by 26.6% (Vickery 2012: 53) has been reported. These results indicate the significance of efficient sanitisation to the reduction of the occurrence of nosocomial infections.

In Poland, the standards of cleanliness (sanitisation and disinfection) for surfaces in medical facilities are not specifically defined by legal regulations. The efficient maintenance of cleanliness usually involves reducing the amounts of microorganisms on the cleaned surfaces and adjusting work procedures to the requirements set for a particular medical facility, with the consideration of the cost optimisation parameter (Sergot-Kowalska 2016).

Considering some common problems with achieving high-quality results by cleaning teams, it is necessary to strive for the optimal design and arrangement of rooms where cleaning procedures take place. In patient rooms, it is possible to use mobile pieces of furniture, the arrangement of which allows cleaning procedures to be performed easily. In en-suite bathrooms, the efficiency of sanitisation processes can be improved by the implementation of wall-hung toilets, washbasins with hand contactless taps, floor-level recessed shower trays, reducing the number of places that are difficult to clean.

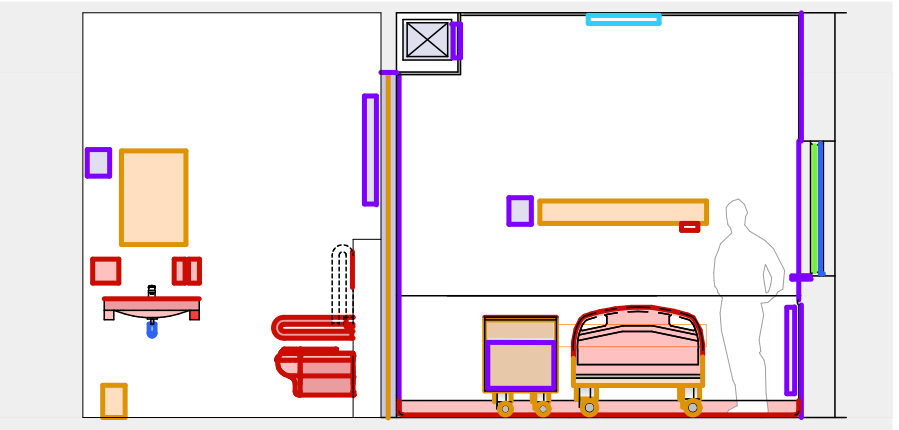
In specialist literature, there are various hygienic plans specified as the elements of hospital-acquired infection prevention (Pawińska 2011). They are based on various types of surface classification in terms of cleaning methods that are applied. Surfaces are divided with the consideration of the frequency of their disinfection into surfaces washed after interventions performed previously and surfaces washed regularly. Another division is based on the frequency of cleaning procedures performed in a room, according to a specified schedule: twice a day, once a day, once a week, once a month or once a quarter. Figure 6.5.3 presents a graphical visualisation of recommendations provided to patient rooms in a zone of general cleanliness that includes patient rooms, internal circulation corridors, physician offices, X-ray and ECG rooms and admission rooms – a low level of disinfection with the frequency excluding non-scheduled interventions (Grochowska 2011: 140-142).

Presented above, the graphical analysis makes it possible to observe that the plan in question does not consider any individual level of epidemiological risk, any additional hygienic procedures that result from the rotation of patients in the area of their hospitalisation and it also does not include any sanitisation or disinfection procedures for wall surfaces, which is particularly important in Polish medical facilities due to non-standardised distances between patient beds and walls.

The discussed scheme leads to the reduction of microorganisms on the surfaces of the furnishing and partitions within the room, however, it does not eliminate them completely. In the current situation, where multi-bed patient rooms prevail in the Polish healthcare system, this methodology of disinfecting rooms is burdened with a high risk of inefficiency. It is due to the fact that nursing rooms

are used for hospitalisation of many patients and hospitalisation schedules are not correlated with the procedures of full disinfection and sanitisation.

Required in various parts of the functional and spatial layout of a hospital, different levels of hygiene maintenance lead to a situation where in one medical unit various materials are applied to finish elements of constructional surfaces and there is a variety of design solutions applied. Architects face



A plan of a patient room with an en-suite bathroom

**Legend:**
The frequency of cleaning for the second zone of cleanliness - a patient room (the low level of disinfection)

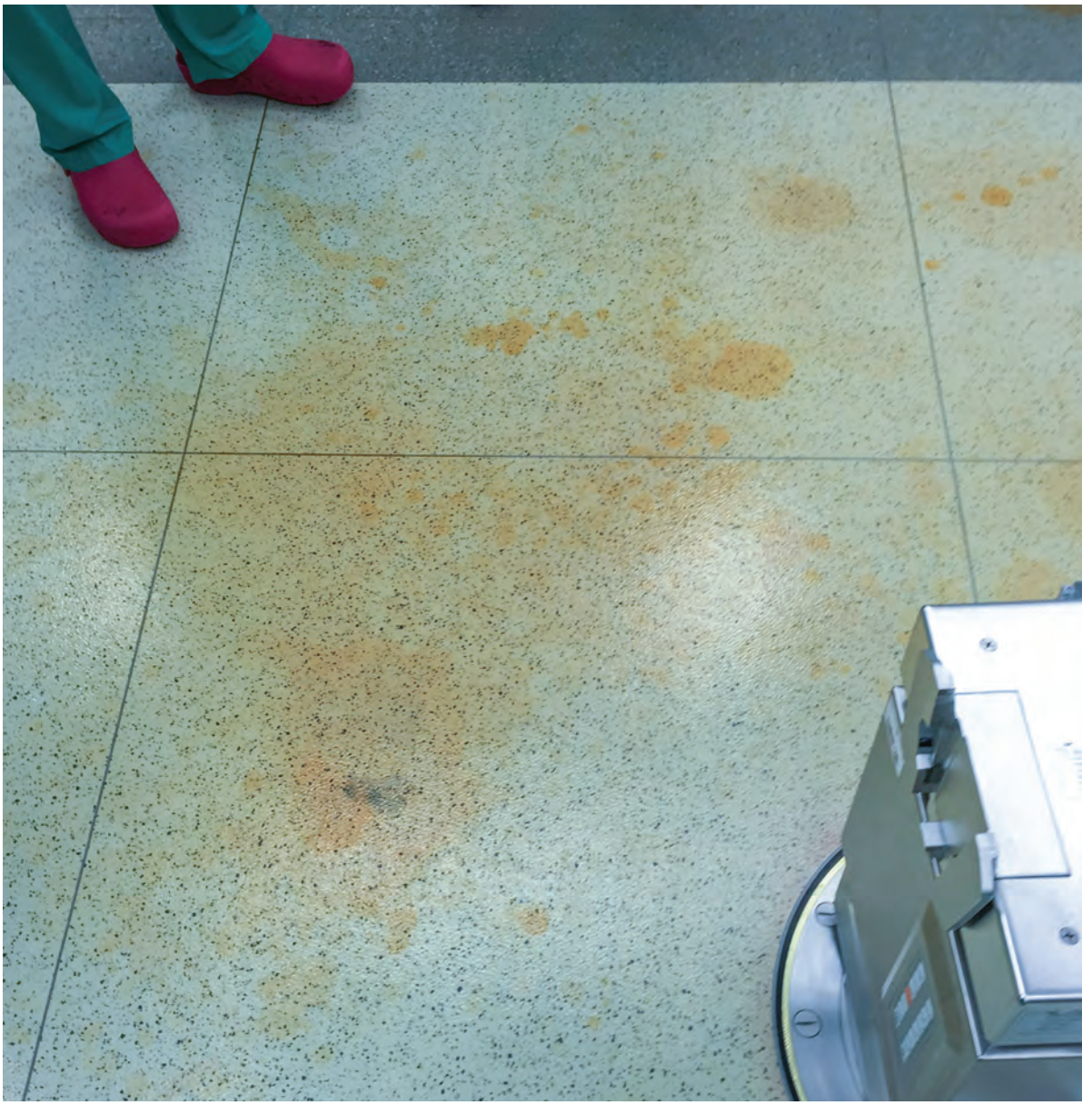
Sanitised and disinfected surface:

- Twice a day: contact areas, door handles, switches, bells, external casings of hand disinfectant dispensers, patient bed frames and chairs, washbasins, sanitary fixture elements, contactless areas, floors and skirting plinths
- Once a day: external surfaces of furniture and medical equipment, glass doors
- Once a week: internal surfaces of furniture, door frames, radiators, ventilation grates, lamps
- Once a month: internal surfaces of windows, window frames and panes
- Once a quarter: ceiling lamps
- Once a year or half a year: siphons, external windows

Note: the described procedure does not apply to some surfaces inside rooms, e.g.: walls

**Figure 6.5.3** A graphical visualisation of the recommendations provided to the cleaning procedures, according to the hygiene plan scheduled for patient rooms (general). Zone 2, general cleanliness – a low level disinfection, the frequency excluding non-scheduled interventions (Grochowska 2011:140-142); elaborated by the Author

a specific task of providing possibilities of everyday preventive sanitisation and disinfection of surfaces in an efficient and rational way. Cleaning procedures should apply to all the elements that have been potentially contaminated, including the furnishing and finishing elements, such as walls, floors, doors and windows.



**Photograph 6.5.4** A fragment of floor covering next to an operating table damaged by disinfectant agents (finishing materials should be adjusted to chemical agents applied during the procedures); photographed by the Author, 2016

The physical parameters of the finishing materials must allow for the elimination of microorganisms and their spores from all the surfaces.

Finishing materials that are to be applied in medical facilities should make it possible to perform sanitisation and disinfection procedures in an efficient way, without damaging the surfaces undergoing those procedures (Figure 6.5.4).

Commonly applied sanitisation and disinfection systems involve activities that affect the physical structure of material surfaces. Hence, architectural material solutions must prove their high resistance to:

- mechanical action: caused by friction caused by the operation of machines, high pressure or muscle power;
- chemical action: caused by chemical agents applied in the process of cleaning;
- temperature of cleaning solution: when cleaning agents of high temperature are applied (Sergot-Kowalska 2016).

Physical parameters of constructional materials used for interior design must allow for the elimination of bacteria and viruses from their surfaces. For finishing materials, the requirements set for the selection specification indicated in the current regulations applicable in Poland are of very general nature. In the ordinance issued by the Minister of Health on 26th June 2012 on the specific requirements for facilities and equipment used by entities providing healthcare services, there are some paragraphs setting requirements for finishing materials (used for covering floors, walls, ceilings and equipment), their resistance to washing and disinfection. However, the discussed Polish regulations do not indicate any parameters specifying such resistance. For example, they do not solve the problem related to the classes of resistance to chemical agents and abrasion. Such criteria must be particularly respected in rooms of higher hygienic regimes, where safety depends on proper disinfection processes, especially: in operating theatres, birthing suites, birthing-adjusted patient rooms, patient rooms in anaesthesiology and intensive care units, post-surgical treatment rooms, burns treatment rooms and rooms dedicated to blood collecting and processing.

This situation provides a lot of space for interpretation. Apparently, the discussed provisions allow for the implementation of uniform, identical solutions to all medical facilities, however, the variety of methods and agents applied in the process of disinfecting surfaces in medical units results in the fact that not all the washable and disinfectable materials are suitable for the particular medical areas. Furthermore, apart from their approval for the use in medical facilities, not all the hygiene certificates issued for finishing materials provide the information on their level of resistance to disinfectants. Not all hygienically sealed ceilings are resistant to scrubbing, namely: to mechanical action. This fact results in some further complications, because despite the indication of the need for disinfection, the assumptions referring to disinfection of the particular areas of a medical facility are not discussed. Moreover, the requirements set for the cleanout openings in the partitions are also not indicated. In the architectural context, the problems of disinfection are related to the necessity of implementing material solutions adjusted to the expected procedures.

Bacterial adhesion and subsequent development of biofilms on material surfaces come as serious challenges in the selection of such surfaces for medical facilities. Preventing those phenomena is of high significance, due to the fact that antibiotics-resistant bacterial strains appear more and more frequently. Efficient antibacterial surface layers may be based on the anti-adhesion principle that prevents

adhesion of bacteria or on bactericidal strategies, when microorganisms are destroyed before or after they contact the surface (Caselli et al. 2018). The contemporary technology of materials engineering provides solutions in which the characteristics of some paint coats prove to be efficient in reducing the spread of nosocomial infections. Apart from mechanical resistance to abrasion and chemical agents, these materials have also bactericidal and fungicidal qualities.

A very important parameter that should be considered in the selection of constructional materials for the interior design of hospital rooms is their resistance to mechanical damage caused by hitting with beds during patient transportation, with instrument trolleys or by intensive circulation of users. Any cracking and scratching in constructional materials considerably lower sanitary and hygienic standards. Hence, surfaces that are particularly exposed to mechanical damage, such as wall corners, doors and door frames, cladding protecting walls at the height of handrails of transport beds should be strengthened. A popular solution involves installation of wall cladding and handrails, covering walls with materials resistant to hitting, damaging and disinfection procedures.

The most popular material for manufacturing medical furniture that must meet the requirements of high epidemiological regime is stainless steel. It is resistant to corrosion, mechanical damage and,

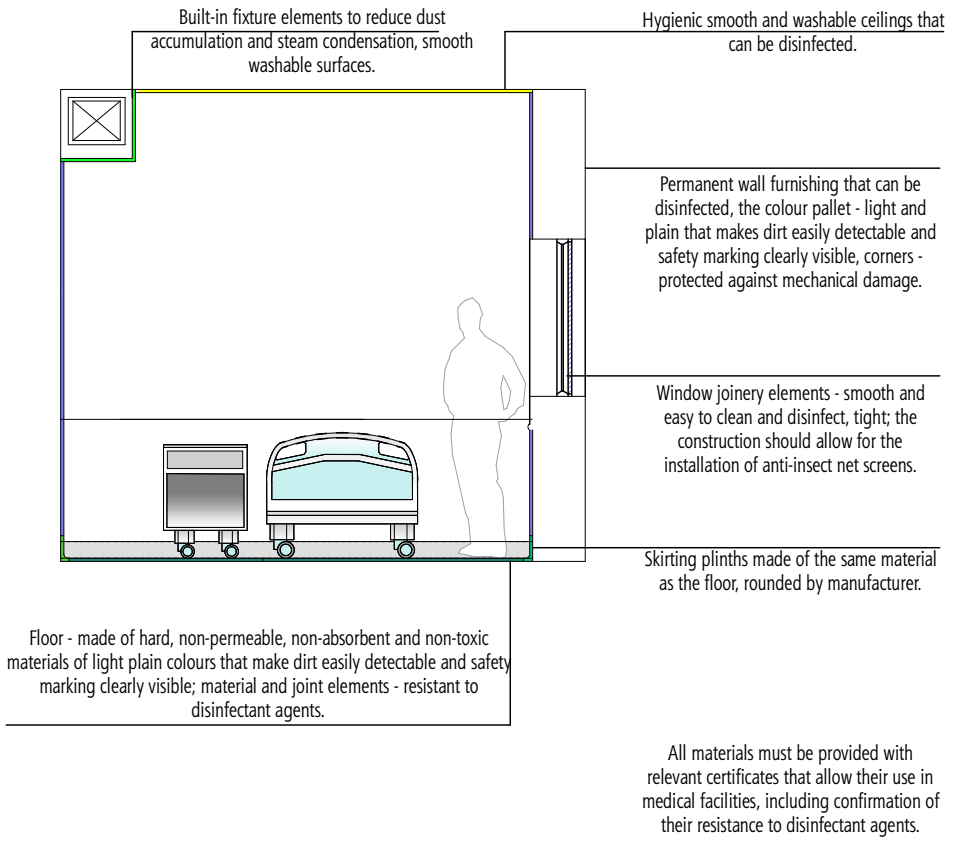
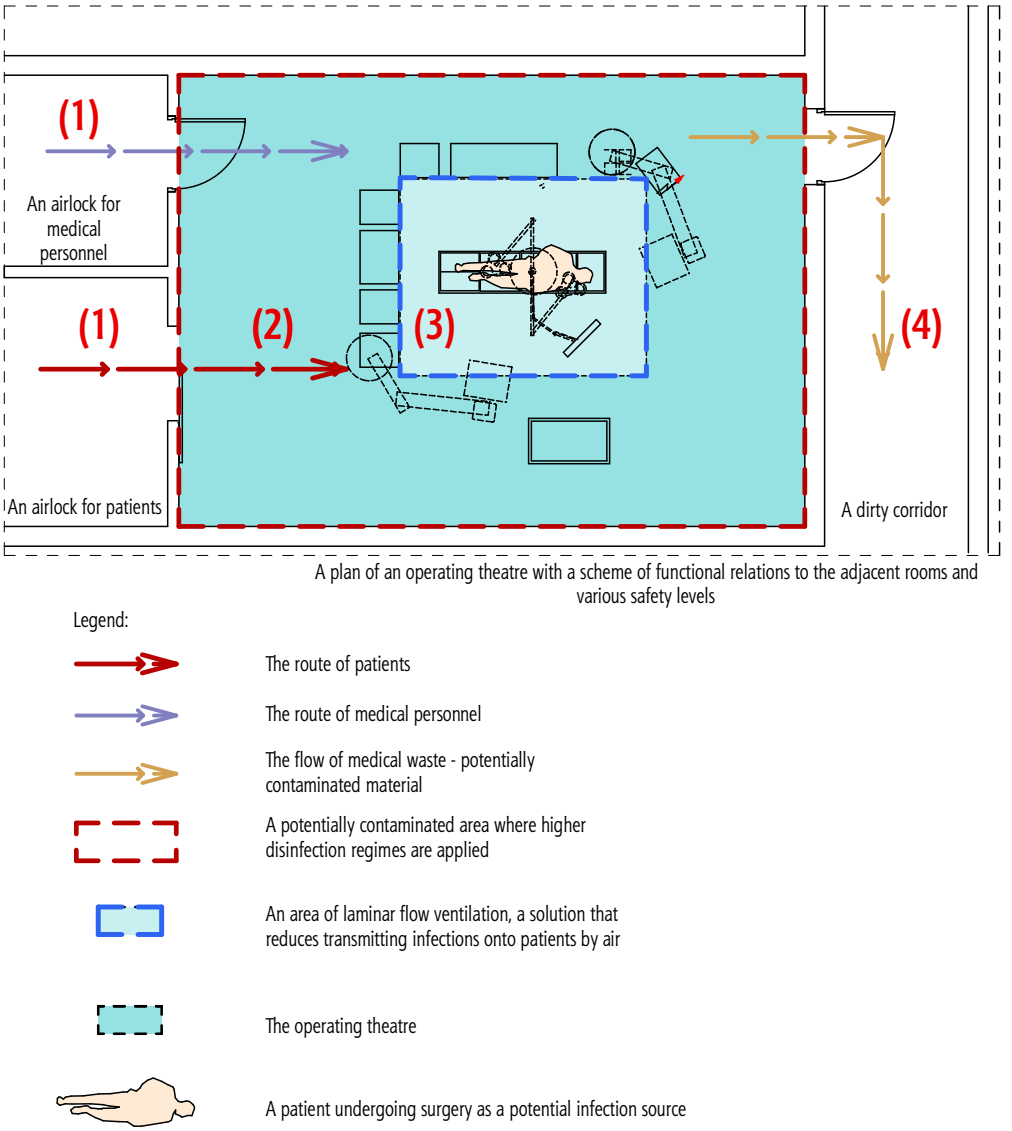



**Figure 6.5.5** A scheme of materials requirements set for the rooms of higher regimes; analysed by the Author

additionally, it is easy to clean, being particularly resistant to disinfectant agents (Gębczyńska-Janowicz and Konarzewska 2018).

A little less common material applied to cover surfaces frequently touched in medical facilities is antimicrobial copper. Its bacteriostatic and bactericidal qualities have been already documented in numerous clinical research studies. Surfaces made of copper alloy not only reduce reproduction of microorganisms but also eliminate them efficiently (the elimination of bacteria can reach the level of 90% within several hours) (Casey et al. 2010; Złotkowska 2016).




A plan of an operating theatre with a scheme of functional relations to the adjacent rooms and various safety levels

**Figure 6.5.6** A scheme of the gradation of materials requirements set for the rooms of higher sanitary and hygienic regimes; analysed by the Author

The impact of the requirements related to sanitisation and disinfection on design solutions can be observed on the example of the requirements set for the particular surfaces in a medical facility (Figure 6.5.5).

Material solutions are also related to some additional aspects, such as colour palettes. Architecture is to bring aesthetic values into the space of medical facilities that are of significant functional and psychological importance to patients and medical personnel (Gębczyńska-Janowicz and Konarzewska 2018). Colour palettes gain on significance in healthcare facilities due to sanitisation processes carried out there, because they improve possibilities of quick optical assessment of cleanliness in a medical unit. Solutions applied in interior design offer the possibility of the visual separation of various areas, where the particular sanitary and hygienic standards are going to be implemented, along with relevant procedures of sanitisation and disinfection. Mapping a hospital in such a way requires a clear definition of the roles performed by the particular areas and principles that must be followed there. It is also relatively easy for graphical presentation. Considering epidemiological reasons, good design practice encourages the use of materials in light, uniform colour palettes.

The rational design of architectural material solutions dedicated to medical facilities is a difficult task. The space must be designed in a cohesive and multi-aspect way. The assumed solutions should facilitate epidemiological prevention by the proper and safe use of the building.

In this context, it is important to develop standards including the specification of materials and solutions that should be applied in medical facilities and in various areas in hospital units, with the consideration of disinfectant agents used there, the frequency and principles of disinfection. Considering the universal character of such a document and after the analysis of its efficiency, it could become a nationwide recommendation.

## 6.6 The informative function of architecture in the prevention of hospital-acquired infections

The risk of nosocomial infections refers to a vast part of the human population. It includes people who come to hospital facilities to seek for medical assistance, medical personnel and people who are not directly related to medical procedures, families and friends who visit hospitalised patients and non-medical staff members. Architectural solutions must facilitate organisational activities undertaken to provide epidemiological safety to all the users of medical facilities. One of such elements incorporated into the discussed solutions is the optimal design of internal circulation, including information policy pursued within the space of a medical facility. The correct routines can be promoted among medical personnel members through relevant training and through the implementation of relevant procedures; however, these tools are difficult to implement for patients and visitors. Hence, it is necessary to use visual information signs to elicit the right and desirable behaviour expected from the users of a medical facility.

In specialist literature, there have been numerous attempts made at providing a definition of relations among architecture, its users and the role of communication in the space. In the *Dictionary of Architecture Psychology this question is described in the following way: the work of an architect always re-*

*quires making conscious or unconscious decisions of psychological nature on designing behaviour through the impact exerted by the space on people* (Lenartowicz 2005: 85). Making architectural decisions affects the behaviour of people who are going to use the designed space. It can induce users' desirable behaviour and, in this way, affect epidemiological safety in the analysed space.

In the context of applying architectural achievements to prevent hospital-acquired infections, design solutions implemented in a medical space should become *encouraging and undoubtedly confirming messages* (Eco 1972: 321) themselves. Their aim is to provide conditions for the use of space that will force, induce or encourage users to follow safety principles resulting from the properly implemented medical procedures and, consequently, affecting the epidemiological safety of medical facilities providing healthcare services.

Architecture can be a carrier of communication and information about solutions pertaining to the field of epidemiological safety. One of the objectives of such a message is to affect users' behaviour. The techniques applied to achieve that aim in medical facilities are typical of marketing communication (Janowicz 2015). In the process of communication, the architecturally designed space becomes one of its channels, also shaping the conditions in which the information is conveyed. This function of architecture is particularly important in the context of the permanent nature characterising the promotion of proper behaviour in the field of preventing infections in medical facilities. *Communication with other people is a basic means of conveying collective experience (…). Both neurophysiology and psychology confirm the thesis referring to the decisive role of communication in developing human awareness (…), it*

**Photograph 6.6** A template of a biological hazard warning sign (efficient communication is fundamental for the development of the safety system in a medical facility) (template based on the Journal of Laws 2005, no. 81, item 716, annex no. 3)

*is a dynamic process, in which a human being affects other people's perception in a conscious or unconscious way, influencing their behaviour* (Goban-Klas 1999: 39).

Properly conducted communication affects safety. The ergonomic, intuitive and correct use of a particular space is not an obvious element. As indicated by a scientific research survey on epidemiological problems resulting from the use of operating theatres, systematically run training turns out to be insufficient. Further analysis carried out among operating suite staff members on the level of their knowledge about epidemiological control programmes and the extent of being familiar with the instructions issued in that field indicates that only a small group of employees have got sufficient information. As indicated in the discussed research study, only 6.7% of the surveyed physicians and 23.4% of the surveyed nurses have been familiarised with all the instructions on the use of the operating theatre, pertaining to the prevention of hospital infections (Matern-Buchel 2011 in: Pokorski and Pokorska 2017: 14.)

Proper communication allows for the implementation of solutions informing users about the character of the particular space they are in and about their expected behaviour. Marketing activities, including those of informative nature, are applied in architectural design (Janowicz 2012). They are also carried out in healthcare facilities and they affect, among others, the relations between medical units and patients, medical personnel and patients, medical units and medical personnel (Bukowska – Piestrzyńska 2012).

In the field of safety management, it is possible to indicate a broad field of activities involving merchandising techniques developed in the context of commercial architecture. In the contemporary cultural context, patients are more and more often perceived as customers. Therefore, the techniques applied to design commercial facilities are transferred into the field of designing healthcare facilities. Activities related to architectural persuasive communication are aimed at forcing or facilitating specific consumers' behaviour (Janowicz 2012). Users who undergo such activities are not always aware of these processes, due to the fact that people code information on the conscious and subconscious levels (Malim et al. 1997; Heath 2006). In the context of techniques applied to affect users and to achieve the expected changes in their behaviour in commercial space, the methodology of designing commercial space has been relatively well discussed (Kreft 2002). The problems of affecting human behaviour with the use of architecture can be also observed in medical facilities (Janowicz 2015). According to Maslow's hierarchy of needs, architecture may meet safety requirements through the quality of solutions and their context. It may also inspire higher needs, including purpose and aesthetics (Janowicz 2012).

The examples of communicating through architecture include the use of proper lighting, management of the flows of users, the use of colour palettes to indicate boundaries of the particular areas of limited access. Other architectural activities related to communication are oriented toward positive or negative motivation. They can involve, among others, ergonomic solutions that can induce desirable behaviour and safe use of constructional objects. The use of knowledge on ergonomic and architectural solutions based on the defined infection transmission routes allows for the reduction of the possibilities to transmit infections and to limit the spread of infectious pathogens.

**A model of an impact exerted on epidemiological safety in a medical facility can be presented in the following way:**

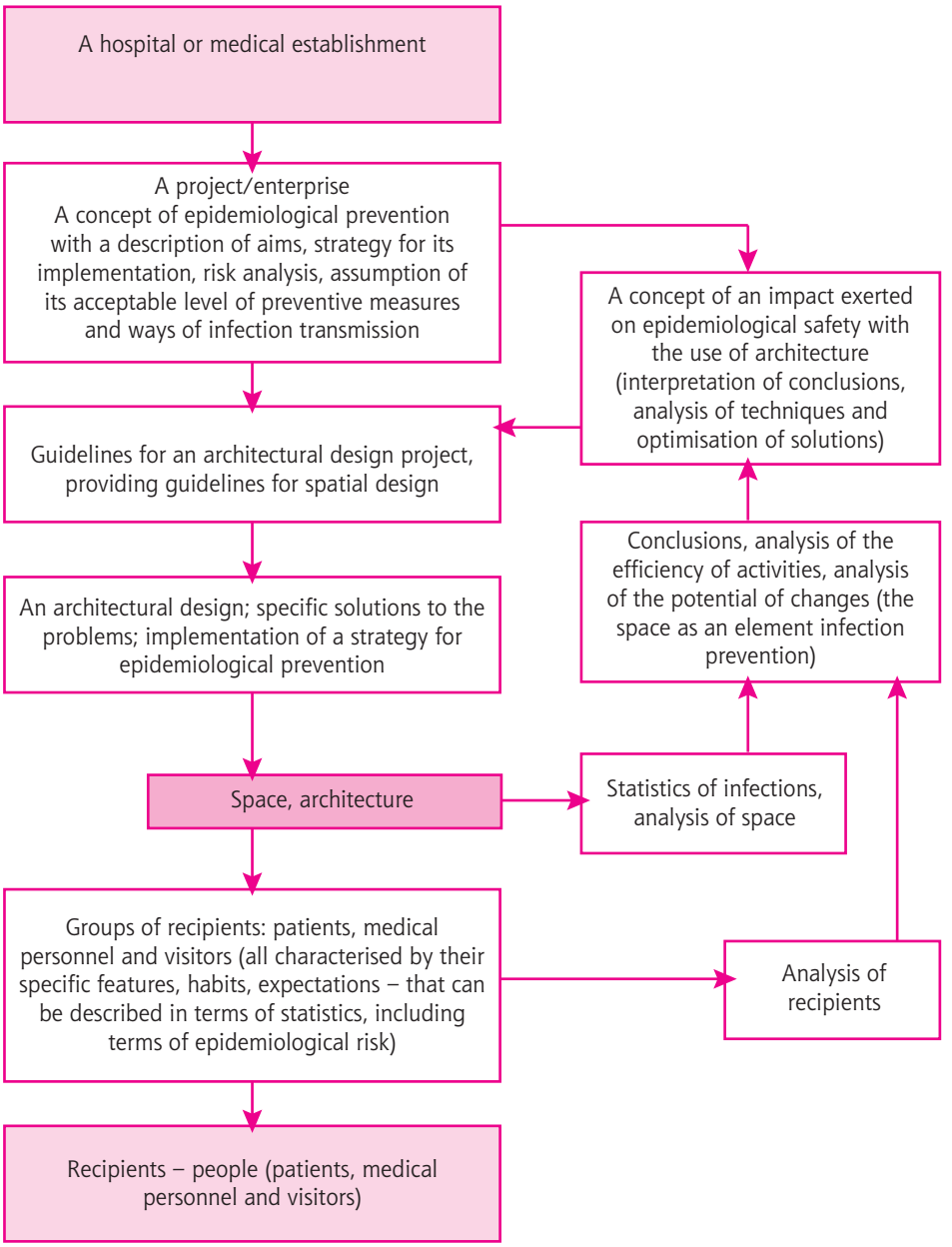



**Figure 6.6.1** A model of affecting epidemiological safety; elaborated by the Author

Skillfully and properly implemented, the strategies of affecting users' behaviour through architectural and ergonomic solutions contribute to the improvement of safety and comfort of the space usage. Erroneous solutions may result in a number of damages that can be divided into three basic groups:

- economic loss that can be estimated, e.g.: low productivity;
- economic loss that cannot be directly estimated, e.g.: loss of health;
- moral loss that cannot be estimated in terms of economy, e.g.: suffering (Górska 2007: 29).

In the hierarchy of motivation, safety (including epidemiological safety) comes as the second most important human need (Maslow 1943). Hence, users of medical facilities usually voluntarily follow the procedures required there. It is important, however, to inform them about situations requiring their special attention or about the required changes in their behaviour at the right moment. In the interior design of medical facilities, it is achieved by the use of various elements, such as banners, information signs and boards and neon signs. They are applied not only to create the image of a medical facility and relations of its users with the organisation but they are also intended to support the safe use of the space.

In scientific research on the process of implementing information and signalling elements, they are described as:

- selection of information carriers;
- selection of signalling and information devices;
- location of signalling and information devices (Górska 2015: 95).

The current regulations applicable in Poland impose an obligation of informing about biological hazards, however they do not specify numerous aspects of its implementation in architectural objects. Today, the freedom in shaping communication about desirable behaviour in medical facilities comes as a serious deficiency of the current system. The potential of informative activities can be observed on the example referring to the analysis of the role of communication in the principles of proper hand hygiene promoted by the World Health Organization. Assuming that medical personnel members have already been trained and learnt about following the rule of five moments for hand washing, the graphical materials providing information about this rule come as reminders. However, for people who accompany patients, they perform a more important role. They provide basic information on the hygienic rules that are mandatory in medical facility. Visitors and family members often cooperate with medical personnel, participating in nursing procedures, but they do not usually receive equally extensive training in the field of hospital-acquired infection control. Informing users of medical facility space about the proper ways of following the procedures and about current hazards contributes to the improvement in the general level of safety. Moreover, all the users become parts of the control system in relation to the proper behaviour expected from other people, including medical personnel, in the field of hand hygiene procedures.

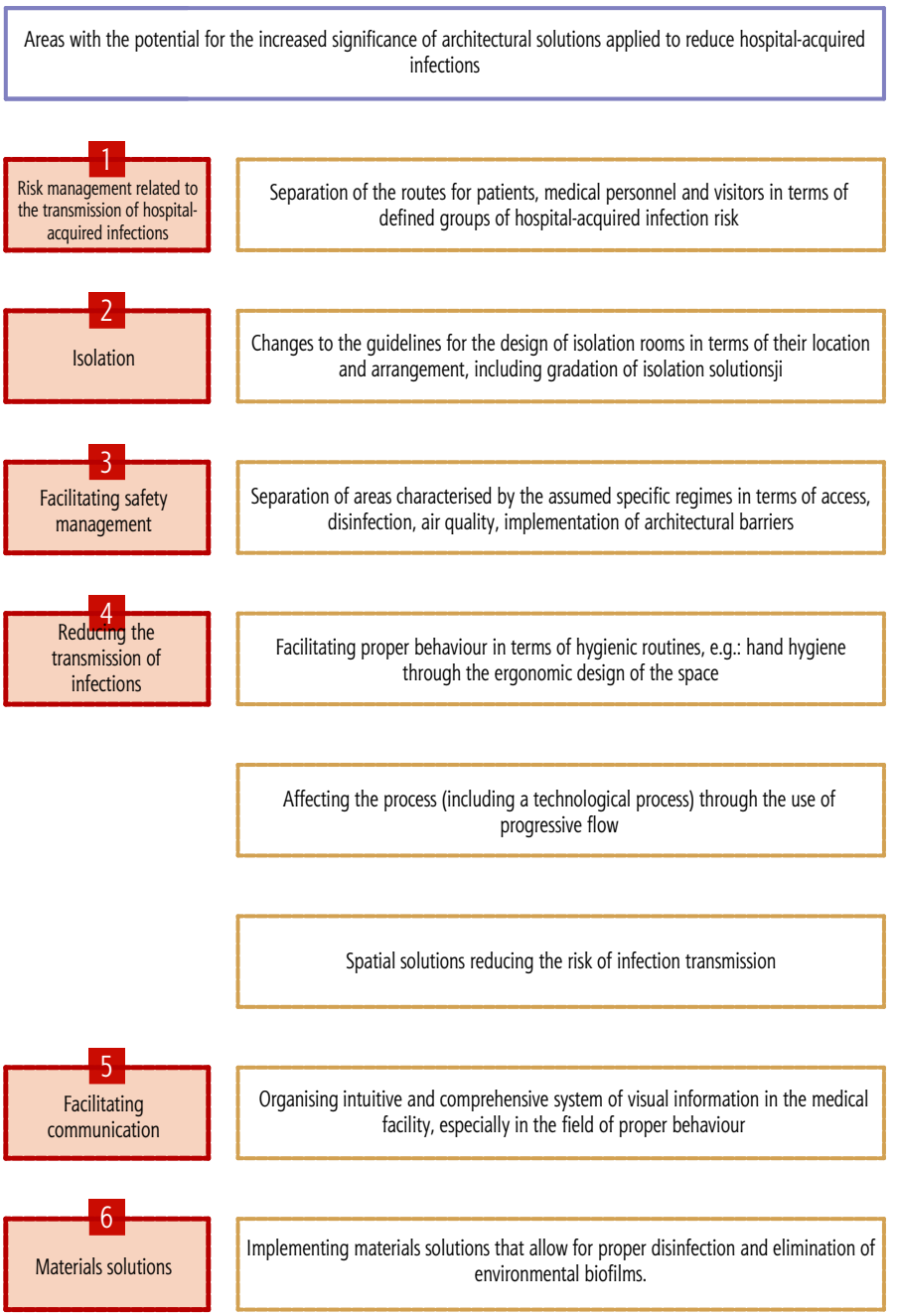



**Figure 6.6.2** The areas with the potential to increase the significance of architectural solutions in reducing hospital-acquired infections; elaborated by the Author

# 7. Conclusions

## 7.1 Deficiencies in the current legal system supporting epidemiological surveillance

Today, a principle according to which the state shares the responsibility for the health of its citizens is commonly recognised in the world. The principle also states that everyone has the right to protect their health. In Poland, this principle is guaranteed by the Constitution of the Republic of Poland, as one of the fundamental rights (Journal of Laws 1997, no. 78, item 483). The same legal act imposes an obligation on the public authorities to combat epidemic diseases (art. 68, section 4).

The current system of epidemiological safety applicable in Poland refers to the problems of architectural spatial design of medical facilities, indicating minimal requirements that must met in that respect. In the light of the analysis carried out with the consideration of the current international scientific research, it turns out that they are highly insufficient. The Polish regulations do not provide a complete description of the standards developed for the spatial design of medical facilities. They only indicate the selected obligatory architectural elements, such as the necessity of providing some particular rooms. Supervised by the State Sanitary Inspectorate, healthcare entities are obligated to indicate the compliance of medical facilities, where they provide healthcare services, with the current legal regulations in terms of their spatial organisation. Resulting partially from the succinct provisions of the legal regulations, a dangerous aspect of this situation consists in the possibility of obtaining a positive opinion on the compliance with the requirements pertaining to the architecture and technology of a particular medical facility stated by the Minister of Health, despite the fact that the level of nosocomial infections in that medical facility is increased and a change to the architectural solutions applied there could contribute to its decrease.

Managers of healthcare entities have a possibility to implement additional solutions in the field of safety. They are obligated to evaluate risk, to monitor the occurrence of hospital-acquired infections and alert factors and to prevent undesirable events. A reliable analysis of epidemiological risk should lead to the implementation of spatial solutions that are more specific and go beyond the current legal regulations. However, such an undertaking can be carried out only after the involvement of a larger group of experts. At the stage of its implementation, it will also generate additional costs. Therefore, it is important that hospital infection control teams should be able to rationally increase the requirements stated by the current legal regulations pertaining to architecture.

Considering hazards resulting from hospital-acquired infections, more scientific research on the optimisation of architectural solutions in medical facilities is necessary. Due to the insufficient number of specialists in the fields of medical microbiology and epidemiology in Poland, a small number of microbiological tests and very general guidelines in the field of the spatial design of medical facilities, managers of healthcare units must make decisions without any reliable data that could allow them to properly evaluate the current risk. While analysing costs and advantages resulting from the optimisation of architectural solutions, they should consider the knowledge based on contemporary scientific research studies and limit the role of intuition.

Most components of the epidemiological process and the factors that affect the level of nosocomial infections are of universal nature and have been analysed relatively well in numerous scientific

research studies. However, there is still necessary to search for optimal architectural solutions in the field of designing medical facilities, in the context of the proper epidemiological control. The need for continuous updating the guidelines stated for designing buildings where healthcare services are going to be provided results, first of all, from the following factors:

- the dynamic development of medical technologies;
- the increase in epidemiological hazards related to the common occurrence of multidrug-resistant bacterial strains in hospitals;
- more frequent hospitalisation of immunocompromised patients, including hospitalisation related to the aging of the society;
- the global trend of people moving among the continents;
- changes to the requirements that must be met by hospitals;
- the advancement of knowledge, including scientific research in the field of microbiology.

In numerous cases, medical units in Poland are not able to cope with the necessity of an independent search for optimal spatial solutions. Alternative architectural solutions should undergo a multi-aspect analysis, based on a large set of data obtained from scientific research studies, because as indicated

**Photograph 7.0** Operating tables waiting for patients in the circulation pathways within an operating suite (an example of the elements that should be included in an architectural design, with the consideration of problems related to hospital-acquired infections); photographed by the Author, 2016

by the contemporary analysis: *the choice of competing programmes to obtain the largest health advantages from the limited resources requires the measurement of some key economic results* (Graves 2018). In this context, the development of nationwide guidelines for designing hospital facilities that are updated on an on-going basis becomes an urgent need.

Frequent changes to the legislation, the lack of specific guidelines in numerous fields of epidemiological safety and the advancement in the discussed field result in the fact that the current legal regulations turn out to be insufficient. As a result, newly constructed and modernised medical facilities may pose an increased risk of hospital-acquired infection outbreaks, despite the fact that they comply with the current legal regulations. Moreover, without using the potential of architecture, their possibilities to pursue an efficient policy in the field of infection prevention are reduced.

## 7.2 The unused potential of architectural solutions in the prevention of hospital-acquired infections

Currently observed in Poland, a deficiency of specific guidelines in the processes of programming and designing architectural objects intended to perform medical functions results in a decreased level of safety. The problems have been discussed, based on the analysis of various sources of infections and infection transmission routes with the participation of medical personnel, patients, medical instruments and equipment. The analysis has proved that architectural solutions have got the potential to reduce nosocomial infections and the spread of alert pathogens. It has also indicated that at present this potential has not been fully used. The necessity of the modification of the epidemiological protection system has been already noticed by medical circles. A report developed jointly by the Association of Hospital Epidemiology, the Polish Society of Hospital Infections, the Polish Association of Epidemiological Nurses indicates the necessity of reaching a consensus in the field of changes to be made in the hospital-acquired infection control system in Poland and modifying the current system of hospital accreditation, which should be the foundation of the hospital-acquired infection control. The accreditation standards should stem from evidence-based medical knowledge and they should be developed in cooperation with experts and associations involved in hospital-acquired infection control (Bulanda et al. 2016: 13). As indicated in the description of organisational and spatial hospital structures, there are numerous functional areas where it is possible to reduce transmission of infections with the use of architectural solutions. In Poland, considering the scarce number of relevant guidelines, the improvement is possible even with the use of relatively simple spatial solutions. It confirms the need for providing more scientific research in the field of architectural design of medical facilities, with the consideration of the present knowledge and the conditions of the Polish healthcare system.

Considering epidemiological hazards transmitted to medical units by patients, the analysis has confirmed the ability of architectural solutions to provide efficient patient flow management and to decrease contaminated areas and numbers of people exposed to infections. Considering nursing areas, this can be achieved, among other factors, through the following:

- designing the space in a way that decreases the need for patient circulation around a medical unit;

- reducing unnecessary contact between patients, between patients and visitors who come to see other patients;
- reducing the number of rooms that are shared by patients – e.g.: shared sanitary facilities accessible from the general circulation pathways;
- providing the prevailing number of single-bed rooms within the spatial structures of medical departments, where medical treatment and observation of immunocompromised patients take place;
- applying materials and spatial solutions that allow for efficient disinfection of rooms, patient beds and other elements of medical equipment.

As it has been proved in the monograph, considering medical personnel as a potential source of infection requires the implementation of additional design solutions. Through ergonomic layouts of rooms and an optimal selection of medical technologies, architectural solutions may contribute to a decrease in the levels of fatigue in medical staff. Hence, they may considerable reduce the possibilities of errors that may lead to the occurrence of hospital-acquired infections. Furthermore, proper spatial solutions facilitate and – in some extreme cases – allow for the adequate performance of medical

**Photograph 7.2** A storage room in an operating suite (the architecture of a medical facility should include a number of auxiliary rooms, such as storage rooms for sterile medical instruments); photographed by the Author 2016

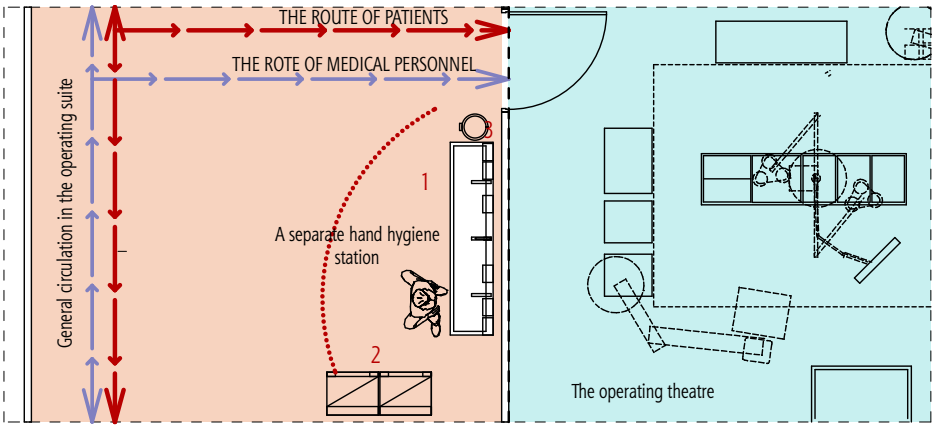
procedures in terms of the requirements in the field of preventing hospital-acquired infections. This aspect has been analysed on the example of hand hygiene problems, methods related to the application of individual protection and relevant spatial solutions that contribute to a decrease in the contamination of medical personnel's clothes and efficient management in the field of separating clean and soiled hospital linen.

As it has been analysed on the example of a design of a functional and spatial layout of a central sterilisation unit, architectural solutions also affect the risk of errors occurring in technological processes. Due to the adequate spatial design based on the principle of progressive circulation within that particular organisational unit, the zones of dirty, contaminated, clean and sterile materials have been separated and the principles for the material flows and for the circulation of medical personnel between those zones have been implemented. The management of the flows of contaminated materials is also applied within the area of an operating suite, where the circulation pathways used by medical personnel, patients and materials should be separated.

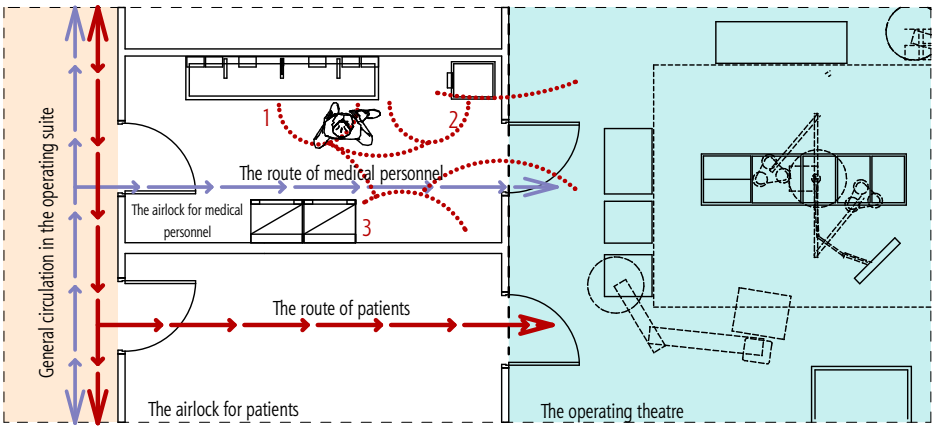
The analysis presented in the monograph allows for indicating the possibilities of the implementation of additional spatial solutions that are not required by legal regulations, however, they have got the potential to reduce infections and the spread of infectious pathogens, especially in the fields of:

- managing the circulation of patients in a medical facility, including the risk of admitting infectious patients;
- reducing infection transmission among patients and among patients and other users of medical facilities;
- reducing the potentially contaminated areas;
- facilitating the processes of sanitisation and disinfection;
- supporting medical personnel in performing medical procedures through the ergonomic spatial layout of medical facilities;
- defining the space of various levels of epidemiological risk and sanitary and hygienic regimes in order to assign them with adequate organisational activities;
- facilitating proper behaviour in terms of hygiene;
- supporting the information system, including the assumed safety system, its elements and proper behaviour within the area of a medical unit;
- designing the areas where safe organisational activities can be implemented during emergency situations, such as for example, an epidemic of A/5N1 influenza.

Today in Poland, the question of the optimal design of the physical environment of medical facilities is rarely approached as an element of the legal system, which would encourage the development of a consistent system and procedures of infection control. Adapting cohesive standards in architectural solutions dedicated to medical facilities in Poland should become one of the tools leading to a decrease in the level of nosocomial infection occurrence and to a decrease in costs incurred as a result of treating infections in hospitalised patients and current prevention in the field of sanitation and disinfection. The systematic scientific research on the impact exerted by architectural solutions applied in the hospital space on epidemiological problems is highly important, because the relations between hospital architecture and nosocomial infection rates are not always obvious, considering their multi-aspect characteristics (Dettenkofer et al. 2004).




A plan with a marked hand hygiene station in front of the operating theatre; version A




A plan with a marked hand hygiene station in front of the operating theatre; version B

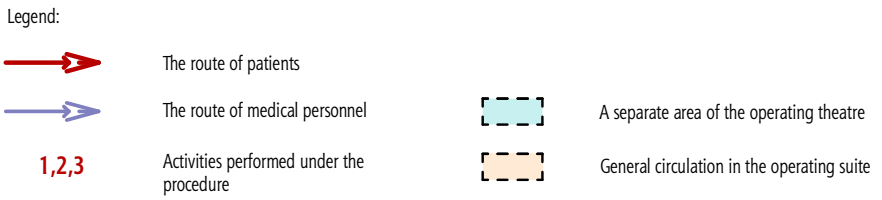



**Figure 7.1.2** A difference in the standards followed by various European countries; version A: a hand hygiene station designed in the circulation paths in front of an operating theatre in the University hospital in Mittelbaden, Baden Baden, Germany 2015; version B: requirements set by the Polish regulations – providing a separate preparation room for medical personnel, in accordance with the ordinance of the Minister of Health of 26th June 2012 on the specific requirements for the facilities and equipment of entities providing healthcare services

The necessity of preparing medical facilities to the occurrence of some unexpected epidemiological hazards on a large scale should be also emphasized. The experts of the World Health Organization recommend undertaking activities that should prepare hospital facilities to a possibility of unexpected pandemics and treating those activities as priority tasks (Zingg et al. 2015 in: Bulanda et al. 2016). Carried out in that field, the analysis proves the necessity of making changes to the healthcare system, also in terms of architectural solutions. The access to modern medical facilities that function properly in technical and epidemiological terms is an important element of safety.

The shortage of scientific research studies and the lack of clear, broad standards stated for the design of medical facilities confirms the need for the systematic development of architectural solutions related to the problem of infection transmission. The reasons to start such activities can be technological changes, the advancement of knowledge and threats posed by the fact that microorganisms keep developing their drug-resistance. In Poland, considering the economic conditions oriented toward reduction of costs related to the implementation and exploitation of investments and the insufficient level of scientific research carried out in the discussed field, theoretical studies pertaining to the questions related to the use of architectural tools to improve epidemiological safety become more and more significant. The analysis discussed in the monograph presents the potential of architectural solutions to increase the level of epidemiological safety in medical facilities.

## 7.3 The need for active participation of architects in interdisciplinary hospital infection control teams

Architectural design is inevitably related to a particular type of responsibility assumed by architects. It results from the necessity of preparing a particular area in the way that reduces the possibility of various threats posed to its future users. Hence, the properly performed processes of architectural design and implementation of constructional facilities are obviously related with reflections on the possible occurrence of various hazards. In the context of epidemiological prevention, the role of architecture is particularly significant. It involves the synthesis of various requirements, reasons and conditions. *In the investment process pertaining to medical facilities, architects must bear the responsibility for coordinating labour and knowledge of people working on the particular project and for creating of a modern and safe medical unit (*Grzymała-Kazłowski 2014). In some countries, it is possible to observe striving for the acknowledgement of architects' knowledge and skills in the field of designing medical facilities. In the United States of America, the American College of Healthcare Architects provides a certification system to architects to confirm their preparation to work in this particular field of architecture (ACHA 2018). In Poland, there are no such requirements stated and architects taking their professional examinations acquire the right to design all types of buildings. While taking the examinations to obtain the professional right for architectural design, architects do not have to demonstrate their knowledge in the field of legal conditions required in the design of healthcare facilities. The list of legal acts that candidates must be familiar with for the examination to acquire building qualifications in the specialty in architecture with a license to practice, provided by the National Chamber of Polish Architects, does not include regulations on the principles stated for the design of medical facilities (IARP 2019). Still,

the proper design of medical facilities requires architects to have additional knowledge in this field. This dependency was described as early as in the 1970s: *Designing healthcare facilities differs considerably from other fields of design. It is affected by a vast variety of problems, the scale of those objects and the complex specificity of various medical treatment technologies, depending on the types of diseases, patients' age, climate, etc. Furthermore, the continuous advancement of medical and technical knowledge causes changes in opinions in the fields of medical treatment methods and principles of organisation and management* (Juraszyński et al. 1973: 7). Such an approach toward the discussed problems proves that there is a need for cooperation between architects and a wide range of experts to implement objects that will come as a synthesis of needs and corresponding relevant guidelines covering numerous fields of knowledge. It indicates that the National Chamber of Polish Architects assumes the use of investors' resources, including specialist physicians, as a kind of complementation of the process in which the functional and utilitarian programmes and architectural concepts are developed with the consideration of knowledge in the field of epidemiology. However, the data provided in the report issued by the Supreme Audit Office (2018) indicates the shortage of specialists in that area. Hence, in numerous cases, architects deprived of any sources of specialist knowledge, are not able to adjust architectural solutions in an optimal way to the current requirements in the field of hospital-acquired infection control. In hospital buildings, epidemiological problems are intertwined with technical requirements, psychological reasons, recommendations of occupational health and safety, aesthetic and social ques-

**Photograph 7.3** Storage racks for clean linen (prevention of hospital-acquired infections requires the implementation of the rules for clean and soiled linen management); photographed by the Author 2014

tions and, unavoidably, with economic assumptions. While developing architectural design projects, architects are forced to provide a synthesis of knowledge from all those areas and they are not always provided with sufficient support from administrative departments of medical units.

A design project of a modern hospital building should come as a result of an interdisciplinary study of the problem. *The effort aimed at improving patients' safety must be based on theory, rooted in evidence and assessed in a reliable way. While undertaking design activities, it is necessary to refer to various disciplines combining the knowledge of clinical specialists, administrators, system engineers, psychologists and sociologists. Such interdisciplinary scientific research teams are still scarce but they keep growing slowly* (Carayon 2017: 15). However, in the Polish system, there has not been any methodology formulated so far for the development and scope of such projects.

Today, in Poland, interdisciplinary teams responsible for epidemiological safety in medical facilities have been limited. It can be observed at the level of medical units, where the hospital infection control teams do not have to include any representatives of technical services, and also in the activities undertaken at the national level as well (NPOA 2018).

Carried out by a team of experts at the International Federation of Infection Control, an analysis of the justification of including the principles applied in the design of the medical environment (architecture and technical infrastructure) into control and prevention programmes, has led to a conclusion that counselling in the field of design, construction and renovation of buildings is the key task for hospital infection control teams (Lytsy et al. 2016). The deficiencies of this approach can be observed in the recommendations provided under the national programme of antibiotics protection, referring to patients suspected with serious infections acquired during their hospitalisation in intensive care units. They are mainly of medical nature, including organisational and diagnostic activities and selection of the types of medical therapy (Hrynkiewicz 2014). Meanwhile, numerous guidelines provided by the international programmes of hospital-acquired infection prevention refer not only to medical and organisational solutions but also to solutions directly related to architectural design of hospital environment. Excluding some specialists from the process of developing optimal standards negatively affects prevention of nosocomial infections. *The knowledge of medical professionals on undesirable events in the healthcare system is practically limited to medical reasons, such as undesirable effects of medicines and procedures that are applied. Usually, nosocomial infections are referred to on such occasions (…). The reasons for undesirable medical events that come from the outside of the healthcare system, its ergonomic deficiency and its sub-systems are not mentioned at all* (Pokorska et al. 2015: 545). Such an approach reduces the chances for the optimal architectural design of medical facilities. Hence, it increases the risk of hospital-acquired infections.

The need for a holistic approach toward the problems of designing the work environment in medical units has been also indicated by the World Health Organisation by indicating that in order to identify hazards and factors contributing to undesirable events, it is necessary to provide an expert analysis allowing for the translation of knowledge based on epidemiological data into activities aimed at improving the healthcare system. In this way a system is developed, *the efficiency of which is measured by the improvement in clinical outcomes and its indirect measure is the number of recommendations* (WHO 2005: 56). Observed in Poland, the shortage of interdisciplinary expert teams providing continuous analysis of the correlation of epidemiological data and relevant architectural solutions may lead to inefficient methods applied in the field of reducing nosocomial infections and the spread of alert agents,

resulting from an erroneous or incomplete identification of the reasons for undesirable events. If there is a necessity of identifying the cause of an undesirable event, people who have followed the procedures in the wrong way are usually pointed out. In such cases, the multi-aspect background of the problem is rarely analysed, *whereas the actual initial reasons for undesirable medical events are most often latent errors in the system and they are frequently to be found outside the system. Usually, nobody can find the fault (the primary reason for an undesirable event), including healthcare professionals* (Pokorska et al. 2015: 546). Apart from the participation of physicians, microbiologists, epidemiologists and nurses, the efforts aimed at the improvement in epidemiological safety additionally require cooperation with specialists working in the fields of architecture, ergonomics, psychology, management (including risk, quality, human resources and process management) and materials engineering. The efficient implementation of optimal solutions requires integration of knowledge and conclusions drawn from theoretical analysis in various fields of science and scientific research studies. The optimisation in healthcare is possible, however it requires the use or development of an adequate methodology. Considering the level of complexity and the possibility of error in the evaluation of various conditions, the implementation of the outcomes of theoretical scientific studies in the form of design solutions should be validated and should undergo a reliable verification of the results. Hence, the process of epidemiological protection with the use of architectural solutions should not constitute a one-off set of guidelines, but it should provide a set of standards that undergo continuous assessment and evaluation.

**Photograph 7.3.1** Time passing and technological advancement bring changes to sanitary and hygienic standards (the photo presents a surgery lamp produced around 1980); photographed by the Author, 2022

**Photograph 7.3.2** A hybrid operating theatre (an example of an operating table integrated with an advanced diagnostic equipment); photographed by the Author, 2016

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3. Act of 26th June 1974 on the Labour Code, with later amendments (Journal of Laws 1974, no. 24, item 141).
4. Act of 6th September 2001 on infectious diseases and infections (Journal of Laws 2001, no. 126, item 1384) – repealed.
5. Act of 5th December 2008 on preventing and combating infections and infectious diseases in humans, with later amendments (Journal of Laws 2008, no. 234, item 1570).
6. Act of 15th April 2011 on medical activities, with later amendments (Journal of Laws 2011, no. 112, item 654).
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8. Ordinance of 12th April 2002 of the Minister of Infrastructure on technical conditions specified for buildings and their location, with later amendments (Journal of Laws 2002, no. 75, item 690).
9. Act of 7th July 1994 on the Construction Law, with later amendments (Journal of Laws 1994, no. 89, item 414).
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12. Ordinance of 10th November 2006 of the Minister of Health on the requirements to be met by healthcare facilities and equipment in professional and sanitary terms (Journal of Laws 2006, no. 213, item 1568) - repealed.

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