

Puchkova Oxana

Indoor climate in hospitals. What are the risk factors for patients?

Bachelor's Thesis
Building Services Engineering


December 2012



MIKKELIN AMMATTIKORKEAKOULU

Mikkeli University of Applied Sciences

DESCRIPTION

 <p>MIKKELIN AMMATTIKORKEAKOULU Mikkeli University of Applied Sciences</p>	Date of the bachelor's thesis 29.01.2013	
Author(s) Oxana Puchkova	Degree programme and option Building Services Engineering	
Name of the bachelor's thesis Indoor climate in hospitals. What are the risks factors for patient?		
Abstract <p>Creating and maintaining a good microclimate conditions in hospitals very important and significant task. Bad microclimate can be the reason of the deterioration of the patient health. This work consider large amount of different health hazards such as airborne infectious agents (legionella, fungi, tuberculosis, bacteria and viruses),viruses, irritants and toxic agents (formaldehyde), radiation, anesthetic gases contains in the hospital. All this hazards affects on the patient health condition and becomes so called “risks” factors.</p> <p>The main idea of this work to find out the most important risk factors for patients in hospitals, what diseases they can cause and what are the main sources of bacterias and viruses transfers. Also this Bachelor Thesis presents European and Russian standards and requirements to Indoor Air Quality and ventilation systems in hospitals.</p> <p>The theoretical part contains the methods of monitoring and preventing risk factors by adequate works of ventilation system, different types of disinfection and by controlling of the pressure difference in the hospital’s rooms.</p>		
Subject headings, (keywords) Indor climate, hospital, risk factors, air pollutants, infections, ventilation system, temperature and relative humidity values, pressure control, filtration, disinfection.		
Pages 29	Language English	URN
Remarks, notes on appendices		
Tutor Marianna Luoma	Employer of the bachelor's thesis	

CONTENTS

LIST OF TERMS.....	2
1 INTRODUCTION.....	4
2 AIMS.....	5
3 METHODS.....	6
2 INDOOR AIR POLLUTANTS.....	6
2.1 Who are at greater risk?	6
2.2 Factors related to patient risk.....	8
2.3 Hospital indoor air pollutants and infections	8
2.4 Transfer factors	10
3 STANDARDS AND REQUIREMENTS	11
3.1 Comparison of the foreign standards	12
3.2 Russian standards.....	14
4 VENTILATION SYSTEMS.....	15
4.1 Ventilation features	15
4.1.1. Ventilation of operating rooms	17
5 PRESSURE CONTROL	18
5.1 The difference between the positive and negative pressure.....	19
5.2 Differential pressure control	20
6 FILTRATION	21
7 DESINFECTION	23
7.1 Gassing disinfection.....	23
7.2 Wet disinfection	23
7.3 Disinfection with ultraviolet rays.....	23
8 MEASUREMENTS	25
9 DISCUSSION AND CONCLUSION	29
BIBLIOGRAPHY	31

LIST OF TERMS

Alimentary system- the series of structures by which sounds are received from the environment and conveyed as signals to the central nervous system; it consists of the outer, middle, and inner ear and the tracts in the auditory pathways.

Aspergillus spores- higher genus of fungi that can cause human's diseases.

Benzene- a liquid hydrocarbon, C₆H₆. It is toxic by transdermal absorption, ingestion, or inhalation; chronic exposure may cause bone marrow depression and aplasia and leukemia.

Bronchitis- is a lungs disease. Bronchitis is an inflammation of the air passages between the nose and the lungs. It is usually caused by a viral infection, but can also be caused by a bacterial infection.

Emphysema- is a chronic respiratory disease where there is over-inflation of the air sacs (alveoli) in the lungs, causing a decrease in lung function, and often, breathlessness.

Glutaraldehyde- disinfectant used in aqueous solution for sterilization of non-heat-resistant equipment.

Halothane gas- high toxicity gas which can affect to the central nervous system.

Legionella bacteria- a genus of aerobic, rod-shaped bacteria. That includes the species that causes Legionnaires' disease.

Mycobacterium tuberculosis- aerobic bacterium that causes tuberculosis.

Nitrous oxide- (N₂O) A colourless gas with a slightly sweet odour (also called "laughing gas"). One of the six major greenhouse gases, nitrous oxide is emitted by chemical fertilizers and burning fossil fuels.

Nosocomial- pertaining to or originating in a hospital. Nosocomial infection an infection acquired during hospitalization.

Pathogenic- Having the capability to cause disease. Producing disease. Relating to pathogenesis.

Pneumonitis- inflammation of the lung. Pneumonitis may be caused by a virus or may be a hypersensitivity reaction to chemicals or organic dusts, such as bacteria, or molds. Dry cough is a common symptom. Compare pneumonia.

Pneumonia- is an infection of the lung that can be caused by nearly any class of organism known to cause human infections. These include bacteria, amoebae, viruses, fungi, and parasites.

Prophylaxis- is a measure taken to maintain health and prevent the spread of disease.

Reanimation room- room for emergency medical care, resuscitation and intensive care patients.

RSP-respirable suspended particulates. RSP are the proportion of suspended particulates with a nominal aerodynamic diameter of 10 micrometres or smaller and they have the ability to penetrate deeply into the lungs. Depending on their sources and the existing meteorological conditions, RSP can be made up of a number of different constituents.

Staphylococcus aureus- a bacterium that causes furunculosis, pyemia, osteomyelitis, suppuration of wounds, and food poisoning.

TVOC-total volatile organic compounds. Are organic chemicals that have a high vapor pressure at ordinary, room-temperature conditions. They include both human-made and naturally occurring chemical compounds.

1 INTRODUCTION

The hospital is the basic sanitary institute of health services. The main purpose of this institute is the function of prophylaxis, diagnosis, treatment, rehabilitation, health education, medical training. In-patient treatment success depends on the hospital environment. This includes a lot of parameters including optimal room hygiene, contributing to the rapid recovery of patients. Hygienic conditions prevent the emergence and spread of nosocomial infections, which are the most formidable factor affecting the hygienic comfort of the hospital. Microclimate of the hospital premises is determined by the thermal state of the environment, depends on the temperature, humidity and air velocity. Comfortable microclimate conditions are provided with heating and ventilation, air conditioning units in separate rooms or central air conditioning. Indoor climate in hospitals is determined by a combination of temperature, humidity, air mobility, the temperature of the surrounding surfaces and thermal radiation. Microclimate parameters determine heat of the human body and have a significant effect on the functional status of the various systems of the body, health and performance.

Hospital's hygienic is providing an optimal condition for patients and medical staff; protect the medical staff from the effects of occupational maleficence (such as chemical and physical agents, hospital infection, etc.). The introduction of new technologies in medicine is linked to the achievement of hygiene science, rules and regulations which can provide the level of technology and security in complex procedures (work with radionuclide, lasers, organ transplantation). This optimal conditions can be achieved only with an integrated approach to the design, construction and operation of the hospital buildings, which takes into account recent scientific. Climate parameters depend on the thermo physical characteristics of processes, climate, seasons and quality of the heating and ventilation systems in hospitals./1./

The fight with unpleasant effect for the working environment is realized by using technology, sanitation. There a lot of technological measures including replacement of old technologies and equipment, automation and mechanization, remote control.

2 AIMS

The main aim of this Bachelor thesis is the researching of the most important risk factors for patients in hospitals. This work also contains a few researching questions. First of all, what are the most harmful bacteria and viruses and the influence of these types of bacteria on the human health. What diseases they can cause and what are their main sources or transfer factors of bacteria and viruses.

In this Bachelor thesis there is also studying of the main European standards for hospital rooms and premises. It is very important point due to hospital is very non-ordinary places for researching and investigations. Then the next aim is comparison of the measured temperature and relative humidity values in a Russian hospital and the comparison of the results with the normative values according to Russian and European standards.

3 METHODS

In this thesis the main method is the studying the literature sources and standards, which are required for hospital premises. At the beginning of this Bachelor thesis there is consideration of the different types of indoor air pollutants and contaminants in the hospitals.

Ventilation system has a direct impact on the indoor air quality, so it is important to study the design features and standards requirements. This Bachelor thesis considers different kinds of filters of the ventilation system and what is the main purpose of the ventilation filter. Then there is the information about the other ways of the cleaning air in the hospital including disinfection, using of UV lamps.

The second method is the studying the Russian standards, such as: GOST R 52539-2006/12/, SNIP 41-01-2003/13/, GOST R ISO 14644-1-2002/14/.

The third method is the measurements of the thermal conditions in a hospital in Russia. Air humidity and air temperature are monitored by data logger in the autumn and summer period. After that, there is comparison of the results with the standards values.

The measurements were made in the hospital which is located in the Saint-Petersburg city. The height of the studied reanimation room is 5 meter. The floor area of the premise is 45 m³. The premise is counting on the 5 patients. So, this premise is really difficult place to create the good indoor climate due to the sizes parameter.

2 INDOOR AIR POLLUTANTS

2.1 Who are at greater risk?

Some people are more sensitive to indoor air pollution than others. For some, the polluted air in the room is a significant risk factor for serious illness and sometimes life-threatening health effects. These groups include children, old-aged persons, people with chronic illnesses and also people who are exposed to constant stress and a weak immune system. Indoor air is the medium that contains the set of visible and

invisible contaminants. These contaminants generally fall into one of two categories: particles and gases, vapors and odors.

“Inhaling particulates can cause eye, nose and throat irritation and increase the risk for the respiratory infections. Healthcare professionals are especially concerned about the long-term effects of inhaling fine particles (less than $2.5\ \mu\text{m}$ – also referred to as PM_{2.5} or fine PM), because they can be passed very deeply into the lungs where they can remain during the years or be absorbed into the bloodstream. Inhalation of fine PM have been linked with the increasing of the respiratory health problems such as asthma, bronchitis, pneumonia and emphysema; hospitalization for heart or lung disease; and even premature death” /2/.

Children are more susceptible to ill effects of air pollution than adults. Due to the low weight, the air they breathe has a greater affect more than for adults. This leads to an increase of pollutants in the body. Children exposed to high levels of VOCs were four times more likely to develop asthma than adults. Therefore it is extremely important to control the quality of air in hospitals, where people are at great risk to health.

In the spread of the hospital infection through the airborne route is the most important and therefore the constant attention should be paid for the maintenance of the cleanliness in the patient rooms and in the reanimation or in the surgeon room.

The main component of the air pollutants in the hospitals are the smallest contaminants of the particle size, which are sorbed by the microorganisms. Sources of different contaminants are mostly ordinary and special clothing of the patients and staff, soil dust from the air flows and so on.

So the methods which have the purpose to reduce the contaminants of air pollution primarily have the aim to reduce the influence of the sources of contamination. Sometimes the patients can also be a potential source of the pollution. Constant and proper air change rate of the premises in the hospital is the main point to except the opportunity of the development of the infections inside the hospital.

2.2 Factors related to patient risk

Healthcare facilities have to pay particular care and attention to indoor air. People with pre-existing health problems who are going through treatment and those who may have depressed immune systems are very susceptible to indoor air exposures. There are some key factors that make indoor air quality particularly important in health care settings.

1. Patients at risk: healthcare facilities house many persons with heightened susceptibility to infections, respiratory distress, and other problems associated with air contaminants
2. Occupant density: Because the density of people in health care settings is relatively high, at risk patients are likely to be in close proximity to infectious individuals.
3. Aging systems: Many hospitals are aging and their ventilation systems are outdated and are in serious need of maintenance and repair./3/.

Hospitals are divided into different classified areas, according to the level of risk that patients present in each case; as higher the probability of air pollution, the higher the control that should be implemented. Special control should be applied for immuno-depressed patients and surgical areas.

2.3 Hospital indoor air pollutants and infections

Nosocomial infections (hospital infections) are one of the biggest challenges of health. Hospitalized patients has a risk of catching hospital bacteria with increased resistance to drugs. Nosocomial infection is clinical disease of microbial origin that affects the patient as a result of hospitalization. Infection's symptoms, which can occurred regardless of the location of persons in hospital./4./

Every year in Russia registered from 30 to 50 thousand case of nosocomial infections. The infection is considered nosocomial if it first appears after 48 hours or more after being in the hospital.

Depending on the extent of the spread of infections are : /4./

- Infections of the cardiovascular system
- Localized infections
- Infections of the skin and subcutaneous tissue (burn, operational, etc.)
- Respiratory infections (bronchitis, pneumonia, etc.)
- Infections of the eye
- Infections of the alimentary system
- Infections of the central nervous system of types of different chemical bacterias

Also a lot of types of different chemical bacterias exist in different public places. The paragraph below present this information.

”In commercial buildings and public places, the important indoor air parameters have been identified and are well understood. They include carbon dioxide (CO), carbon monoxide (CO₂), nitrogen dioxide (NO₂), ozone (O₃), formaldehyde (CH₂O), total volatile organic compounds (TVOC), respirable suspended particulates (RSP), radon, and total bacterial count. These can adversely affect our health with various degrees of severity, ranging from sick building syndrome (SBS) to building-related illnesses (BRI), such as cancers. Besides the above-mentioned airborne pollutants, there are other serious chemical contaminants of considerable concern for hospitals, including glutaraldehyde (C₅H₈O₂), nitrous oxide (N₂O), and latex allergens. Recommended exposure limits of C₅H₈O₂ and N₂O are shown in Table 1” /5/.

Table 1. Exposure limits of chemical pollutants /5, p.2/

Reference	Glutaraldehyde (C ₅ H ₈ O ₂) ppm	Nitrous Oxide (N ₂ O) ppm
UK HSE (1998)	0.05 (8 hr)	-
OSHA (1992)	0.2 (15 min)	-
NIOSH REL (1999)	0.2 (ceiling)	25 (8 hr)
ACGIH (1994)	0.05 (ceiling)	50 (8 hr)
NOHSC (1995)	0.1 (8 hr)	25 (8 hr)
OSH (2002)	0.2 (15 min)	25 (8 hr)

“ Airborne microbial contamination are also serious factors in hospital IAQ (Indoor Air Quality). Pathogenic microbes with diameters of 1 to 5 μm can be suspended in the air, enabling disease to be transmitted easily. Table 2 presents the sources of harmful microbes, including multidrug-resistant Mycobacterium tuberculosis (TB) bacteria, Legionella bacteria, methicillin-resistant Staphylococcus aureus and Aspergillus spores” /5/.

The Table 2 shows and explains for the reader the sources of airborne microbial pollutants.

Table 2. Sources of airborne microbial pollutants /5, p.3/

Pollutants	Sources
<i>TB bacteria</i>	<ul style="list-style-type: none"> • When an active TB patient coughs, sneezes, or speaks, airborne TB droplets will be generated.
<i>Legionella bacteria</i>	<ul style="list-style-type: none"> • A common source of this bacterium in hospitals is the water mist discharged from the cooling towers and then drawn into the indoor environment through the outdoor air intake. • Other probable sources include evaporative condensers, potable water systems, and hot water systems.
<i>Staphylococcus aureus</i>	<ul style="list-style-type: none"> • The bacteria are present on the skin and in the nose, blood, and urine of an infected patient. During some surgical procedures that require the use of power tools, such as oscillating bone saws and bone drills, microbial aerosols will be generated.
<i>Aspergillus spores</i>	<ul style="list-style-type: none"> • Hospital renovation or nearby construction work are major sources of aerosolized <i>Aspergillus spores</i>. • The fungal spores from soil, plants, animals, and dust particles can attach themselves to the clothing of healthcare workers or visitors.

2.4 Transfer factors

One of the main distribution channels of bacteria's and infections is the airborne route. For example, microscopic pieces of skin desquamation can carry *Staphylococcus aureus*, a common cause of postoperative suppuration. Bacteria, viruses, fungi and spores are in the air on their own. As a rule, they "sit" on aerosol particles small enough to be in the air for a long time. Other sources of pollutants can be respiratory and other medical equipment, linens, bedding, beds, health products, dressings and sutures, implants and sutures, transplants, clothing, shoes, hair and etc. The bacteria can persist for a long time on the linen if special treatment, as well as on the hands due to lack of proper hygiene.

It has been proved , that even with strict care and supervision of all medicines after 6 days become infected. Besides, bacteria never leave the hospital premises and every doctor, every visitor, food is a carrier of microorganisms, bacteria and viruses. Next figure illustrates potential sources.

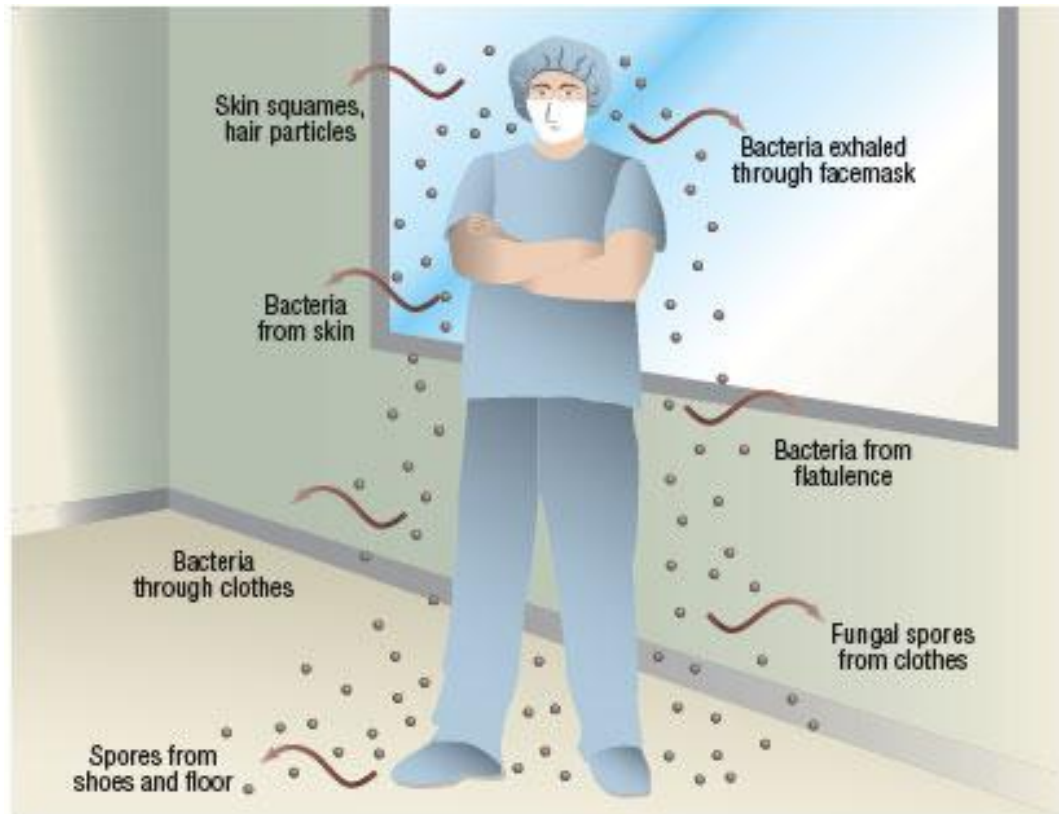


Figure 1. Various bioaerosols created by hospital workers can escape clothes and facemasks and form a virtual cloud. /6, p.3/

3 STANDARDS AND REQUIREMENTS

Ventilation requirements are on the basis of the standards of air quality for hospitals. The standards gives the values for the temperature, the relative humidity, the air change rate, the types of filters, the pressure relationship to adjacent areas, and the cases when the air may be repeatedly used. Also, some of the standards are used for thermal comfort. All these requirements are classified according to the purpose of the premises to meet the requirements of patients, staff and to resist the infection.

Standards present different patients requirements and different temperature limits and relative humidity for example, so the evaluation of this parameters is very important. It is also important to consider the type of disease. Some categories of patients such as AIDS patients should be particularly taken into account. For these patients, the temperature must be low enough to reduce the growth of microorganisms and reduce the risk of infection. The type and complexity of the operation is defined by the standards. In this case, beside to the basic parameters (temperature, humidity, air velocity), also the following parameters should be taken into account: the number and type of equipment, light, time operation, clothing of the medical team.

Requirements for thermal comfort medical team and the patient should avoid the possibility of hypothermia./7./

There is the presentation of the least of the few European standards to ventilation and air conditioning system for thorough researching:

- Europe (DGKH et al, 2002; CBZ, 2004; VDI, 2004; NFS90: 351:2003) /8./
- Brazil (7256 NBR, 1982 and MS, 2002) /9./
- the U.S.A. (ANSI/ASHRAE 62.1-2010; ASHRAE, 2005; ASHRAE, 2003; ASHRAE, 1999, and AIA, 2001; CDC and HICPAC). ISO 14698, Clean rooms and associate controlled environments./10./

3.1 Comparison of the foreign standards

It is very important to maintain good indoor air quality for patient safety and surgical team, particularly in operating rooms. The ventilation system influence on the functionality and efficiency of operating rooms. It controls the level of comfort and the level of airborne contaminant, which often presents post-operative wound infection risks to the patients./5./

Close attention should be paid to control of aerosols, anesthesia gases and smoke. All these substances are considered in operating rooms as pollutants. Some gases used in the surgery, for example, Halothane gas, has a high toxicity and can affect the central

nervous system. The smoke can be generated by laser or electrosurgery unit. Smoke contain toxic gases and vapours such as benzene, formaldehyde, dead and live cellular material (including blood fragments), and viruses. So, concentration of gases and aerosols in the operating is critical and needs to be controlled./7./

The ventilation requirements are determined by standards for the IAQ in hospitals and the type of surgery. These requirements are presented bellow.

DGKH 2002, German standard, which contains a lot of requirements for drafting technical guidelines for HVAC in hospitals. There are a lot of important recommendations about the different types of the contaminants in the surrounding area of the operating table and instrument table, which can directly or indirectly contamination the surgical site. One of the important part of this standard is the description of protection level needed for the instrument table and operating table. These factors are very significant when we talk about the surgeries or neurosurgery./7./

The British Medical Council recommends common requirements for the ventilation system. The ventilation system according to this standard, have to dilute a lot of types of bacteria. Also, the ventilation system has to create a perfect microclimate for the operating team and patients. Related requirements are: temperature ($23^{\circ}\text{C} \pm 3^{\circ}\text{C}$); relative humidity (40-60%); fresh air allowance 10 h^{-1} with total air changes 25 h^{-1} ; air filter using HEPA ($E=99.97\%$); and positive pressure./7./

Spanish standard UNE100713 is recommended three-stages of the filtration to ensure a better and easier maintenance of the indoor climate conditions in the hospital.

The U.S.A Federal Standard 209B recommends three types of surgery premises. The first level is a quite low level of the germs (septic an aseptic surgery) and the last one is considered only caesarean surgery. The requirements recommended for the first type of surgery are: temperature of $19\text{-}24^{\circ}\text{C}$; relative humidity of 45-60%; minimum airflow rate of outdoor air ($15 \text{ m}^3/(\text{m}^2/\text{h})$); minimum air change rate (25 h^{-1}); minimum filter requirements (G2/F2/A3 – E-75-84%, 70-89%, 99.97%), recommended (G2/F2/A3); and positive pressure. For the second type of surgery is recommended temperature of $19\text{-}24^{\circ}\text{C}$; relative humidity of 45-60%; minimum airflow rate of outdoor air ($15 \text{ m}^3/(\text{m}^2/\text{h})$). Swiss standards have been used as a reference or as a addition-

al standard in some countries in Europe, for example, in The Netherlands, France and The Czech Republic./7./

So there are a lot of the different standards and requirements nearly in each European country. Some counties use the standards from the other countries, Swiss for example. So the values of the main microclimate components are various for the different countries. The minimum temperature is from 15°C and 17°C, when the maximum is 27 °C. The value of the relative humidity is ranged from 30% to 60%. The air change rate minimum is 10 h⁻¹. The maximum reported rate is 25 h⁻¹ ./7./

3.2 Russian standards

Russian requirements for heating, ventilation, microclimate are established in SanPiN 2.1.3.1375-03 "Hygienic requirements for accommodation, facilities, equipment and operation of hospitals, nursing homes and other health centers" /11/.

Heating, ventilation and air conditioning systems should provide optimal conditions of the microclimate and indoor air treatment facilities. Parameters, such as design temperature, ventilation rate, the purity of the room category of hospitals, including in day care are given in Appendix № 5 to SanPiN 2.1.3.1375-03. GOST R 52539-2006 "Air cleanliness in hospitals. General requirements"/12/ This standard establishes requirements for cleanliness of indoor air treatment facilities and methods of ensuring means of ventilation and air conditioning. The standard deals with air pollution particles and microorganisms. The standard requirements are the normative basis for the design and certification of new and reconstruction of existing hospitals, and can also be used to increase the level of cleanliness in the existing premises./12./

Nowadays, in Russia the following standards are applied:

1. SNIP 41-01-2003 " Heating, ventilation and conditioning ".
Implementation date: 2004-01-01 /13/.
2. GOST R 52539-2006 "Air cleanliness in hospitals. General requirements".
Implementation date: 2007-01-01 /12/.
3. GOST R ISO 14644-1-2002 "Clean rooms and associated controlled environments"/14/.

4 VENTILATION SYSTEMS

4.1 Ventilation features

The main objective of ventilation is to provide the lowest levels of bacterial, chemical pollution and dust in the air of hospital facilities. Hospitals should have supply-exhaust ventilation or mixed ventilation, which provides air-thermal balance of premises. The organization of ventilation shouldn't allow the flowing of air mass from the "dirty areas" (space) to "clean." Ducts can be installed with vertical collectors in areas with the same sanitary requirements.

In the patient's rooms with mechanical ventilation air must be submitted to the corridors, gateways that separate ward section and separation from the elevator lobbies. The temperature of the air in the corridors should be like in the clean room (to prevent air flowing from the difference of gravitational forces).

“Mechanical ventilation is essential for diluting indoor air pollutants by exhausting the contaminated indoor air and introducing clean outdoor air into an air-conditioned building. ASHRAE, AIA, and CDC have recommended air change rates for outdoor air and total air for major healthcare facilities in terms of air changes per hour (ACH), as summarized in Table 3” /5, p.3/.

For areas in which the value of pollutant concentrations is related to the number of occupants, the outdoor air requirements are given as the value of the volume of outdoor air which is taken per occupant. Such requirements are determined and the determinations of these requirements are based on considerations, professional judgment, and subjective evaluation. The values of requirements are also summarized in Table 3. /5, p.3/

Table 3. Ventilation requirements /5, p.3/

Area	Outdoor air change rate ACH*	Total air change rate ACH	Outdoor air requirement L/s/Person
Patient room	2	4	13
Operating theatre	15	15	15
Intensive care unit	2	6	8
Infectious isolation room	2	6**	-
Protective isolation room	2	15	-
Protective isolation room	2	6	-

* ACH refers to the number of air changes per hour for an enclosed Environment

** For newly constructed and renovated infectious isolation rooms, a higher level of protection by means of 12-ACH total air change rate should be provided.

In all areas of hospitals, except of operating rooms, along with a forced mechanical ventilation system natural ventilation may be used. It is carried out through small windows, folding transom and other devices that can be opened. The volume of fresh air in the rooms must be at least $80 \text{ m}^3 / \text{h}$ for 1 adult and 1 child. Aeration chamber at least 4 times per day.

Ventilation in patient's rooms should be done so as to limit the flows of air between the patient's rooms department and adjacent floor. Therefore, the corridors of the patient's rooms department should be equipped with forced ventilation with a multiplicity of 0,5 corridor flow. The entrance of the gateway should be equipped with exhaust ventilation. Exhaust ventilation of the patient's rooms is through individual channels (ducts), because of air of vertical direction doesn't pass to other premises.

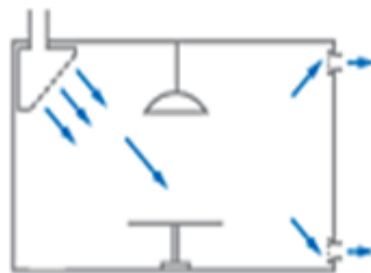
In the Infectious Diseases Hospital for each floor, the patient's rooms department and other surrounding areas should be equipped with independent mechanical ventilation systems./15./

4.1.1. Ventilation of operating rooms

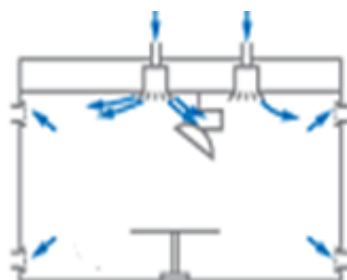
Prevention of postoperative complications is of great importance to the effective ventilation functioning. To prevent the transfer from patient's room in the operating unit and other facilities that require special clean air, should be provided to them a gateway to air overpressure. Air flow must be directed from operating in adjacent rooms (pre-operative, anesthetic, etc.), and from them - to the corridor, and an inflow has no less than 20% get over the hood. The air from the air conditioning system is fed into the upper zone area (not less than 2,5 m from the floor), and the extract - from two zones: the upper (40%) and lower (0,4 m from the floor - 60%). The air that is fed to the operating room should be cleaned on a two-stage system (coarse and fine cleaning). Filters should be inspected monthly, cleaned and replaced./15./

By examining of common requirements for ventilation and air conditioning, it can be concluded that the proper organization of air currents (directional, in directional) is one of the most important conditions for the required air quality and patient safety. Flow must take out a clean area, all the particles given off by people, equipment and materials. Figure 2 shows the most common schemes of the air supply to the operation room.

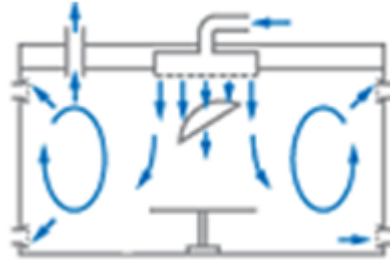
a) the flow of air through the slanted grille;



b) the flow of air through the radial ceiling diffusers;



c) perforated sheet ceiling panel with vertical air flow;



d) unidirectional vertical air flow through the mesh ceiling diffuser;



e) the air supply hose from the circular flow diagram.

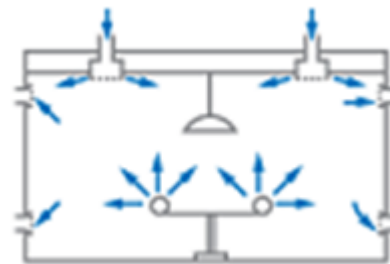


Figure 2. Schemes clean air in the operating area /16/.

5 PRESSURE CONTROL

One of the main parameters of the ventilation system is pressure. The fan sucks outdoor air and forcing it into the room creates a pressure difference between the atmosphere and this room. Because the difference can be positive or negative, distinguish positive and negative pressure. Both are measured in relation to standard air pressure. In ventilation systems are used over or under pressure. It depends on different cases when the air is removed from the room or when the air is blown into the room. Fan, taking away the outside fresh air create a negative pressure in the duct between the intakes air and the fan. This negative pressure causes a flow of air from outside (where the pressure is higher) in the air intake.

“Negative room pressure to prevent cross-contamination from room to room. A negative pressure room includes a ventilation system designed so that air flows from the corridors, or any adjacent area, into the negative pressure room, ensuring that contaminated air cannot escape from the negative pressure room to other parts of the facility” /17/.

5.1 The difference between the positive and negative pressure

It is important to keep in mind that positive and negative pressure have different effects on ducts. Positive pressure in the volume creates a force outward. Requirements of the ventilation system for the room, where the infectious patients locates are quite different. Supply ventilation system is installed. This supply ventilation system creates air pressure to prevent the spread of infection in the corridors. Individual exhaust ducts are installed to remove air from the chambers and to avoid air infiltration to other areas of medical institutions.

Corridor ventilation of the hospitals should create a small overpressure, and the removal of air from the chamber implements through individual exhaust channels. So, designing and installation of the ventilation in the hospital is quite complex task. It must be remembered that making a mistake can be harmful to health, and in some cases, can cause death of the patient. Table 4. presents the appropriate differential pressures for typical hospital facilities

Table 4. Differential pressure control /5, p.4/

Area	Differential pressure
Infectious isolation room	Negative
Equipment sterilization room	Negative
Laboratory	Negative
Intensive care (reanimation)	Positive
Protective isolation room	Positive
Operating/surgical room	Positive
Pharmacy	Positive
Patient room	Equal

5.2 Differential pressure control

Operating a differential pressure between two hospital areas, such as reanimation room and corridor as illustrated in Figure 3, can limit the air leakage in a single direction through the door.

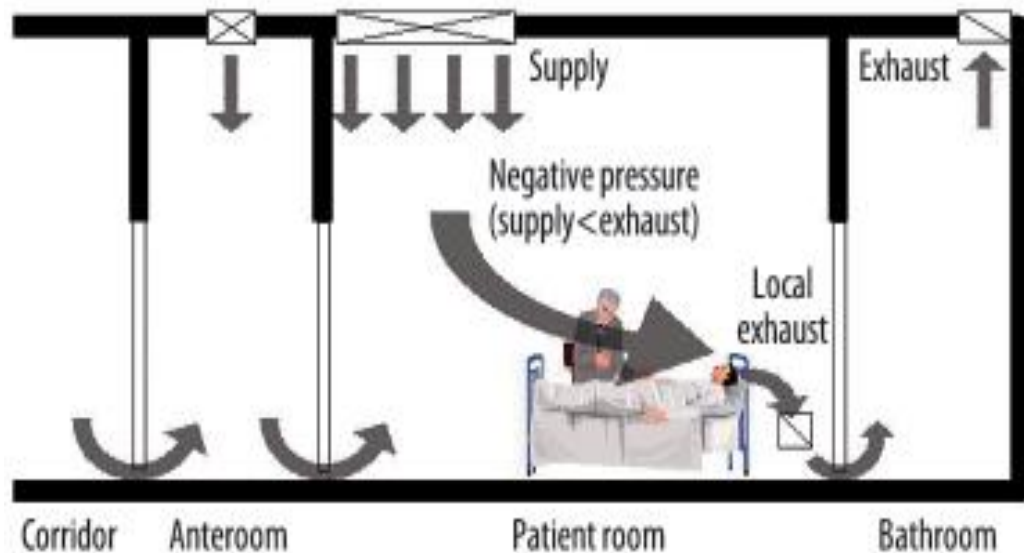


Figure 3. Differential pressure control in infectious isolation room /5, p.4/

So, for prevent nosocomial infection, the air pressure distribution among various facilities of a hospital should be controlled. Table 4 presents the differential pressures for typical hospital facilities. The differential pressure should be at least 2.5 Pa so that any intrusions due to door opening, elevator movement, and other normal activities will not change the positive or negative pressure or the airflow direction. The Department of Human Services in Melbourne, Australia, recommends a different isolation room design. A special door with a door grille is used to facilitate the differential pressure control. Maintaining a differential pressure demands constant attention to air balancing. The loading of an HEPA filter will increase the pressure drop, reduce the supply air, and thus may cause a positively pressurized room to become negatively pressurized. So, for that reason regular maintenance of the filtration system should be enforced. For a critical area, a differential pressure monitoring system is recommended for continuous checking of the operating condition. More relevant details can be found in references for isolation room designs and ventilation control for the prevention of nosocomial transmission of tuberculosis./5./

6 FILTRATION

Air filters are designed to clean the supply or exhaust air. Since the degree of contamination in the environment may be different, the filters are divided into several types. There are three main classes: pre-filters (coarse), fine filters and complete cleaning (Hepa filters). All three classes of filters can detect particles of different sizes. Within each class there is also a certain gradation filter is efficient cleaning.

For a healthcare facility filtration system usually consists of a pre-filter and a final filter as shown in Figure 4. A pre-filter removes large particles for a clean heat transfer medium and should be located ahead of the cooling/heating coil. The dust spot efficiency of those filters is 25–30%. The efficiency of the final filter should have at least 90% to collect nearly all fungal spores of 2–5 μm diameter and bacteria in colony-forming units of 1 μm diameter or larger¹⁵.

A pre-filter with 25–30% dust spot efficiency should be located ahead of the cooling/heating coil, to remove large particles for a clean heat transfer medium.

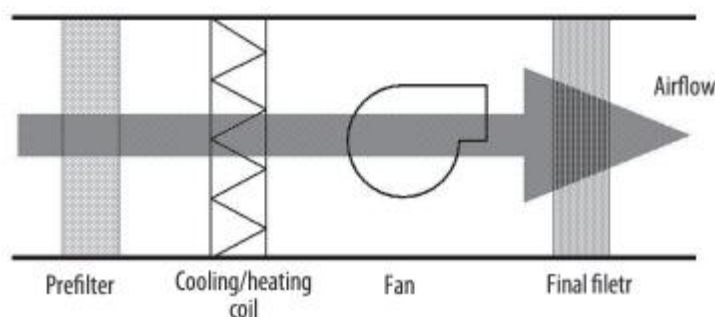


Figure 4. Configuration of filtration system /5, p.4/

For crippling care rooms, such as operation theaters and intensive care units (reanimations) normally used three-stage filtration.

Pre-Filters (BS-6540) : Primary purification filters are used for the first phase of a multi-stage air purification systems. This filters can also be used as primary in a single-stage ventilation systems. Efficiency is 70% down to 10 Microns. Filters can be washed and cleaned and usually installed at inlet of airstream./18./

Fine filters (BS-6540-part-I) : Air fine filters used in multi-stage ventilation systems after the passage of air through the primary purification filters. These filters clean the air from the dust, that is why they are widely used in rooms with high hygienic requirements, such as hospitals, clinics, laboratories , pharmaceuticals and others. Filters having efficiency 99% down to 5 Microns. These filters are washable./18./

Hepa filters: Complete cleaning filters can detect very fine dust, detain microorganisms, aerosol particles, so they are used in rooms with ultra-high standards of the air condition quality. With efficiency 99.97% down to 0.3 Microns used for operating rooms and intensive care units. These are special high flow types with more media to handle higher./18./

On the Figure 5 presented aerial view of fine filters, which are often used in hospitals. The filter is made of a long sheet of fibrous material (fiber diameter 0,65-6,5 micron spacing of 10-40 microns), folded like an accordion, as well as the body with the elements, retaining sheet when folded.

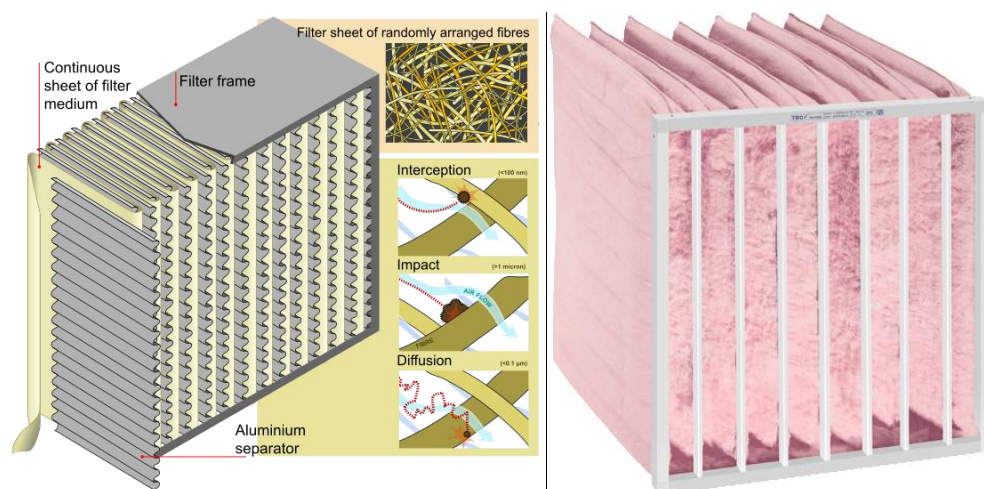


Figure 5. Fine filters /19./

Also for fine air in ventilation systems are used ULPA-filters. This ultra highly (ULPA) filters with the ability to hold very small particles and efficiency up to 99.975%. They are used for final clean air is just before feeding air into the room. Built in ceiling devices, ULPA-class filters U15 and U16 delay of particles larger than 0.12 microns./18./

Every type of filter has certain filter material. Pre-filters contain synthetic fabric or metal mesh. The fine filters are used fiberglass with impregnated or without it, also used activated carbon. For delicate cleaning as filter material acts glued fiberglass or paper with a hydrophobic coating./18./

7 DISINFECTION

Disinfection is the set of different substances that are applied to non-living objects to destroy that are living on the objects.

7.1 Gassing disinfection

Gassing disinfection has a lot of differences according to comparison with other methods of microbial treatment. This type of disinfection is carried out under normal or slightly elevated temperatures and used in the presence equipment and devices in the premise. Gassing disinfection provides reliable processing due to effective gas penetration in the material.

In the case when the relative humidity value in the room is sufficient, gassing disinfection effectively neutralizes microorganisms and their aggregates in the dry condition. The main disadvantage of this method is the relatively high cost, high level of toxic and also the possibility of explosion.

7.2 Wet disinfection

Wet disinfection also has a wide range of different combinations with acceptable value of bactericidal activity and low level of corrosive action. For example, mixture of phenol derivatives with a detergent, which is produced on the commercial basis and widely used in hospitals, particularly in the United States of America.

7.3 Disinfection with ultraviolet rays

The sources of the short wave length ultraviolet rays with a wave length from $2,537 \cdot 10^{-7}$ to $2,1 \cdot 10^{-7}$ m are used for disinfection. Maximum bactericidal effect of UV rays have a wavelength of $2,4 \times 10^{-7}$ to $2,8 \times 10^{-7}$ m. Modern mercury vacuum lamps more than 90 % of their energy emit with the wave length $2,537 \cdot 10^{-7}$. In this case the quantity of the emitted energy is quite small, so the penetrating power of the ultraviolet rays in this case is also quite small./20./

The effect of destruction of microorganisms with UV rays in the air and on surfaces depends on the intensity and duration of exposure, relative humidity value, types of the suspended microorganisms in the air and so on. Ultraviolet rays provide their best antimicrobes properties at a relative humidity below 60 %. Viruses are also inactivated by UV rays.

Maximum results in the processing of the ultraviolet rays can be achieved by combining the direct radiation and radiation with shielding devices. Direct radiation is recommended in the absence of people, or if they have protective glasses and masks. In the presence of human radiation level must not exceeded $0,001 \text{ W/m}^2$. In this case the decontamination of air is achieved by convections flows, which is carrying out the microorganisms in the zone of radiation.

In the Figure 6 there is UV-device in the reanimation room of the hospital in Saint-Petersburg, Russia.



Figure 6. Ultraviolet rays device

8 MEASUREMENTS

Temperature and relative humidity values are one of the main factors in the assessment of the microclimate conditions. These values affect on the thermal comfort of the patient in the hospital rooms. For that reasons the level of temperature and relative humidity have to be in the normative level according to requirements. Temperature and relative humidity values in the hospital also influence on the infection control and doctor comfort.

Reanimation room is the place of the highest risks in the part of the patient infection due to non-execution of the requirements which is accepted to the hospital premises. There are quite difficult conditions to provide the cleaning of the reanimation premises. So for that reason there is a constant danger of the patient infection in the after operation period. For avoiding this situation it is necessary to calculate the operate activity in the case when there is 80 per cent loading of the reanimation premise. So creation of the good microclimate conditions in the reanimation premise is very difficult, but significant task.

Location is a hospital in Saint-Petersburg, Russia. Floor air of the reanimation room is 45 m². Height of the room is 5 meter. There are 5 beds for 5 patients in the reanimation room. During the measurements 5 patients were in the reanimation room, doors were opened even at night and also all windows were closed. The data logger location is on 1,6 meter height, under the supply air devices.

Microclimate parameters

Air temperature

In the areas with one direction air flow for providing comfort of the medical personal and patient there should be the opportunity of the air flow temperature regulation. According to the Russian Gost R 52539-2006 the range of the temperature regulating is set up from 18 to 24 °C. Specific values of the air flow temperature can be chosen by the project organization. Also the distance control should be considered for regulating the temperature of air flow in the reanimation premise./12./

Air humidity

In the premises in which air humidification should be provided according to the medical requirements, minimum acceptable air humidity have to be 30 per cent when the temperature is 22 °C.

In the separate cases in dependence of the patient condition there also can be applied air humidification. For the fulfillment this hygiene requirements period disinfection and controlling of the air humidification system should be provided. Cooling of the outdoor air should be provided in the recirculation system. This outdoor air has to dried in the range, which is prevented the moisture condensation on the coolers of the recalculation air.

Summer time

The relative humidity and air temperature were measured in the reanimation room in summer time.

The weather outside was:

Air temperature is +18 °C, rainy and foggy, air humidity 98%.

Data logger was located on height of 1,6 meter under the supply air device.

According to Russian requirement (GOST R52539-2006) the value of the temperature in reanimation room have to be in the range from 18° - 24°C. According to measurements (shown on the figures 7,8) the minimum value of the temperature is 23,5°C and the maximum value of the air temperature is 25,7 °C. Minimum value of the relative humidity is 45% and maximum is 64%. The average value of the relative humidity is 55 % and the average value of air temperature is 24,6 degree Celsius. As we can see from the figure the maximum value of temperature is rather high than it must be (25,7°C instead of 24°C). As the temperature of the outside air is not so high (+18°C), the reason of the high temperature level can be inadequate work of the air supply equipment. Taking into account the fact that people after operation is very weak and sensitive. Minimum changing of the air temperature can affect on the patient condition. So for this reason there is impossible to permit the increasing of air temperature inside the room and for this situation is very important to apply the cooling system

especially in summer. So, the schedule of the aeration has to be maintained very strictly, if the using of the cooling system is impossible for any reasons.

Despite the outdoor rainy temperature the value of the relative humidity is acceptable so there is no necessity to use a humidifier.

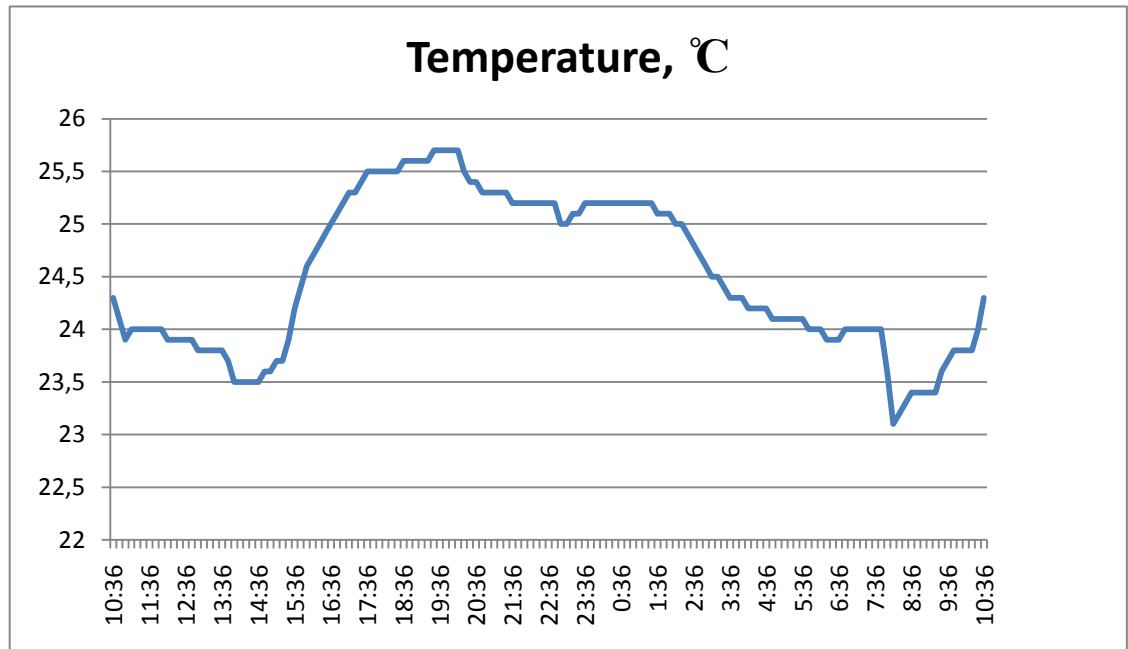


Figure 7. Air temperature in the certain summer time

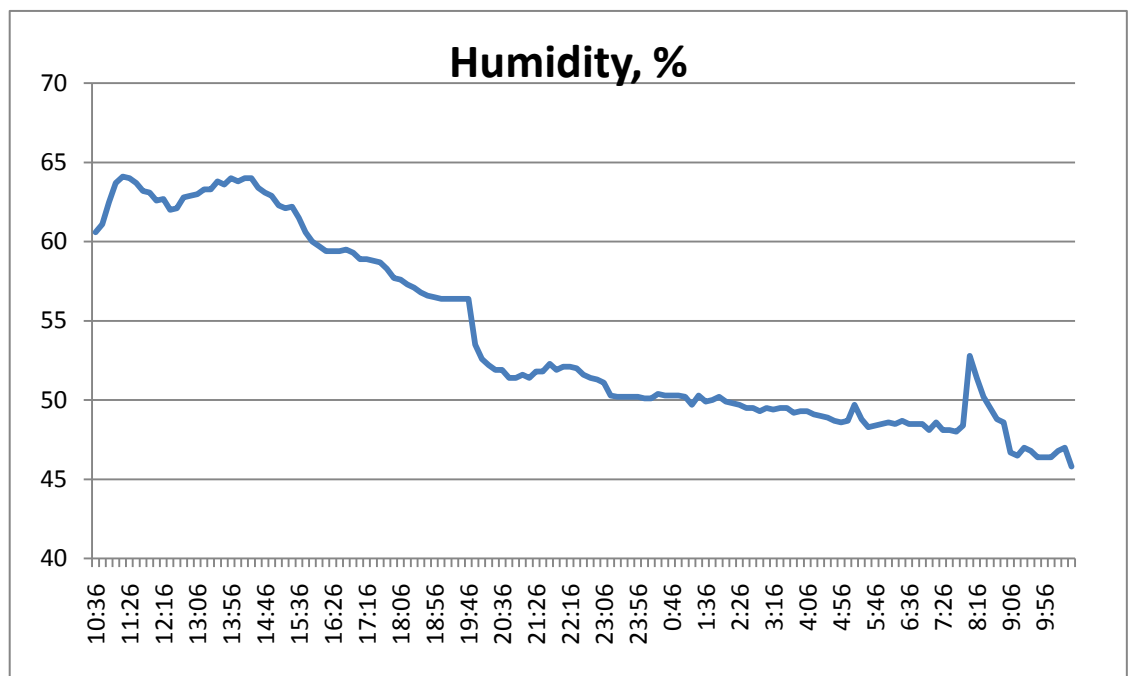


Figure 8. Air humidity in the certain summer time

Autumn time

Measuring of the relative humidity and air temperature in autumn.

Weather outside:

Air temperature is +10 °C, sunny, air humidity 92%.

Data logger was located on height of 1,6 meter under the supply air device.

From the figure 3 and 4 we can see that temperature and humidity were changing during the day, but not excided the standard's values.

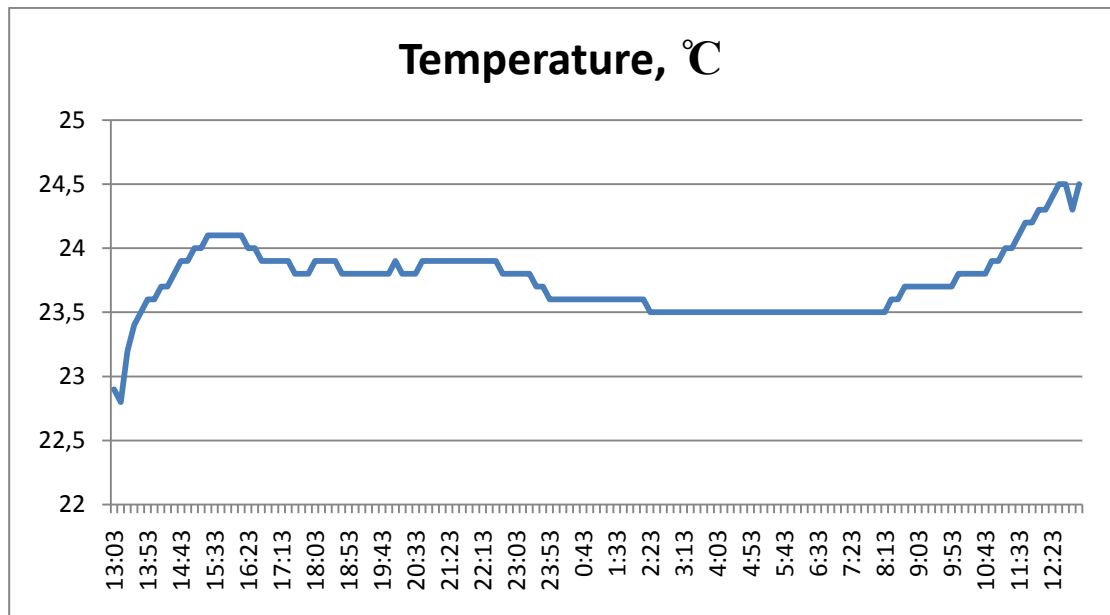


Figure 9. Air temperature in the certain autumn time

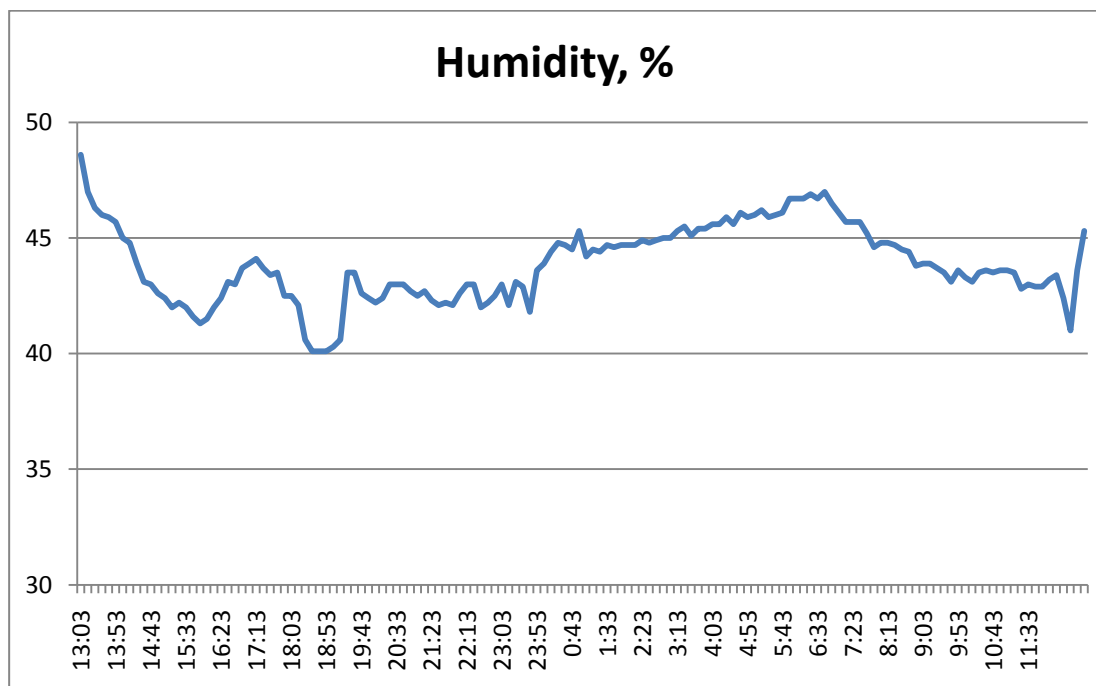


Figure 10. Air humidity in the certain autumn time

9 DISCUSSION AND CONCLUSION

Creating and maintaining a good microclimate conditions in hospitals very important and significant task. Bad microclimate can be the reason of the deterioration of the patient health. Also microclimate in the hospital is quite important point for the doctors and other personnel who work in the hospital every day. Large amount of different health hazards such as airborne infectious agents (legionella, fungi, tuberculosis, bacteria and viruses), irritants and toxic agents (formaldehyde), radiation, anesthetic gases contains in the hospital. All this hazards affects on the patient health condition and becomes so called “risks” factors. For that reason it is very significant to fulfill the monitoring and control of these parameters by adequate works of ventilation system, different types of disinfection and by controlling of the pressure difference in the hospital’s rooms. All these definitions were described during the theoretical part of this Bachelor thesis.

The main question of this Bachelor thesis was researching of those risk factors for patients in hospitals. This work also contains a few research questions. What are the most harmful bacteria and viruses that exist and the influence of these types of bacteria on the human health and what are the reason of appearance of these viruses. What diseases they can cause and what are their main sources or transfer factors of bacteria and viruses. These questions were considered through different searching instruments.

First of all it was the searching of the different sources of literature and studying the European and Russian standards and requirements for hospitals. It was very important point due to hospital is very non-ordinary places for researching and investigations.

Also theoretical background part of this Bachelor thesis considers the main risk factors for patient in the hospital and presented a lot of requirements for the different types of rooms and premises of the hospitals. Then this Bachelor thesis contains measurements of the temperature and relative humidity values during the summer and autumn period in the real reanimation room of the hospital which is located in the Saint-Petersburg. The result of these measurements allowed making an assessment of the quality of the microclimate conditions in the reanimation room. Then there were getting values of temperature and relative humidity were comparing with the Russian requirements. All in all the values of the temperature and relative humidity was in the

normative range. So, the comparison of these values presented that there was adequate microclimate condition in the reanimation room.

The assessment of the microclimate in hospitals should also contain the measurements of CO₂ level, quantity of different air contaminants and level of the air velocity from the supply devices. Unfortunately, there was no opportunity to make these types of measurements due to the location of the searching reanimation room and for this reason absence of the quite sophisticated equipment.

Also this Bachelor thesis considers different ways which prevents the forming of different types of bacteria and viruses. The main role of the prevention of these contaminants plays disinfection. The most common and widest method of disinfection in Russia was considered also in this Bachelor thesis.

BIBLIOGRAPHY

1. Е.И.Гончарук. Санитарно-гигиенический и противоэпидемический режим хирургических отделений больниц. Киев 1999
2. Indoor Air Quality & Sensitive Population Groups. PDF document.
<http://www.proudgreenhome.com/whitepapers/3284/Indoor-Air-Quality-Sensitive-Population-Groups> No update information available. Referred: 29.10.12
3. D. Riley, J. Freihaut,, W. P. Bahnfleth, Z. Karapatyan4, IAQ T3S1 Innovative techniques in IAQ. Indoor Air Quality Management and Infection Control in Health Care Facility Construction. PDF document.
http://www.engr.psu.edu/iec/publications/papers/indoor_air_quality.pdf (p.2)
 No update information available. Referred: 29.10.12
4. Внутрибольничная инфекция, понятие и природа совместной ВБИ.
 WWW document
http://www.medicinform.net/immun/immun_spec11.htm No update information available. Referred: 29.10.12
5. Michael Leung, Alan H.S. Chan. Control and management of hospital indoor air quality. PDF document
<http://www.johnsonmedical.com/2011/article/pdf/Healthcare%20IAQ.pdf> (p.2-3)
 Last update 01.03.2006. Referred: 2.09.12
6. Air-treatment system for controlling hospital-acquired infections. WWW document.
http://hpac.com/ventilation-iaq/air-treatment_controlling_hopital/index3.html (p.2-3)
 Last update 02.04.2008. Referred: 28.10.12
7. M. A. Melhado, J. L. M. Hensen, M. Loomans and L. Forejt. Review of operating room ventilation standards. PDF document
http://www.bwk.tue.nl/bps/hensen/publications/06_acv_melhado.pdf
 No update information available. Referred: 1.09.12
8. The Association of German Engineers
<http://www.dgkh.de/informationen/fachinformationen/leitlinien/> Last update 01.02.2012 Referred: 29.10.12
<http://infostore.saiglobal.com/store/details.aspx?ProductID=549445> Last update 2003 Referred: 4.11.12
<http://www.vdi.eu/engineering/vdi-guidelines/vdi-guidelines-details/>
 No update information available. Referred: 7.09.12

9. Salim Lamha Neto. Instalações Prediais Ordinárias E Especiais. Brasília,1995.
<http://www.anvisa.gov.br/servicosaude/manuais/prediais.pdf> Last update 1995.
Referred: 9.11.12
10. ASHRAE 62–1989. Ventilation for Acceptable Indoor Air Quality.
<http://www.ashrae.org/>
http://www.bwk.tue.nl/bps/hensen/publications/06_acv_melhado.pdf
Last update 2006. Referred: 3.10.12
11. SanPiN 2.1.3.1375-03 Hygienic requirements for accommodation, facilities, equipment and operation of hospitals, nursing homes and other health centers.
http://www.tehbez.ru/Docum/DocumShow_DocumID_538.html
Last update 18.06.2003. Referred: 9.10.12
12. GOST R 52539-2006 Air cleanliness in hospitals. General requirements
<http://gost.ruscable.ru/cgi-bin/catalog/catalog.cgi?i=3488&l=>
Last update 12.09.2008. Referred: 9.10.12
13. SNiP 41-01-2003 Heating, ventilation, air conditioning
<http://docs.cntd.ru/document/1200035579> Last update 2009. Referred: 16.10.12
14. GOST R ISO 14644-1-2002. Cleanrooms and associated controlled environments
http://www.yondi.ru/inner_c_article_id_367.phtm Last update 1.04.2004
Referred: 05.10.12
15. Микроклимат помещений лечебных учреждений. WWW document.
<http://cap2.ucoz.ru/publ/27-1-0-352> No update information available. Referred:
5.11.12
16. А.П. Иньков. Особенности проектирования систем вентиляции и кондиционирования воздуха для объектов здравоохранения.2002
http://www.abok.ru/for_spec/articles.php?nid=1599 No update information available.
Referred: 28.10.12
17. Indoor Air Quality. WWW document.
<http://www.filterair.info/articles/article.cfm/ArticleID/> No update information available. Referred: 10.11.12
18. Vipin Kaushal, P.S. Saini, A.K. Gupta. Environmental control including ventilation in hospital. WWW document.
<http://jkscience.org/archive/volume64/environ.pdf> (p. 1-3) Last updated: 30.11.2004
Referred: 7.11.12

19. Фильтры тонкой очистки <http://www.folter.ru/index.php?id=27>

No update information available. Reffered: 25.11.12

20. О.В.Мироненко. Общие требования к обеспечению качества больничной
средс. WWW document <http://www.maps.spb.ru/ordinator/element2.2.3.htm>

Last update 2003. Reffered: 28.11.12

