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HOSPITAL ECOLOGY

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SUMMARY – A review of hospital ecology during the history of mankind is presented. It is noted that hospitals in ancient times and sanatoriums in subsequent historical periods were not accidentally located in natural ambient to take advantage of the most favorable factors of natural environment. Ancient medicine lacked the knowledge of the etiology of many diseases, thus tending to ensure optimal ambient and environmental conditions in the then hospitals. This tendency continued up to the discovery of infectious disease agents. Owing to the significant amount of knowledge and huge technological progress in current clinical medicine, modern hospitals are characterized by immense interpenetration and interaction of numerous factors, producing a major problem of preserving and maintaining the premises as free as possible from the potential adverse effects on both service users and providers. The use of novel materials and technologies entails new problems such as the sick building syndrome. The most important elements of hospital ecology are presented in detail, along with proposals for improvement of the condition in this segment of health care.

Key words: *Hospitals – environmental monitoring; Ecology; Occupational diseases – etiology; Risk factors*

Introduction

As early as the ancient times, Hippocrates of Cos, the Father of Medicine, a great Greek physician, also the father of medical and geographical ecology, in his landmark work on the water, soil, food, air and health, a primordial handbook for a young physician entering service in some unknown region, warns him what environmental factors and their health impact to consider, thus to be able to predict the expected specific morbidity in the respective population, and to identify the type and mode of preventive actions and activities to prevent the development of particular diseases. For example, Hippocrates draws young physician's attention to: macro- and microclimate factors and orography; whether drinking water is of mountain spring, underground, lowland marsh origin; what is the area wind-rose and what winds prevail; what are nutritional habits and rate of food intake; what are the population life habits, do they tend to move around, practicing physical activity, or they are lazy, avoiding work, tending to loafing, overfeeding, and excessive alcohol consumption.

It was not just by chance that hospitals in ancient times were located at ecologically most favorable sites, thus to protect the users from the potential avoidable risks while taking advantage of all environmental factors for health improvement. At those ancient times, many factors contributing to or even causing particular diseases were still obscure. Therefore, the medicine of the time tended to ensure optimal environmental conditions at the then hospitals and other health care institutions. This tendency continued with the discovery of agents causing infectious diseases.

The discovery of microorganisms and infectious disease agents, followed by the advent of antibiotics, chemotherapeutics and antiseptics, led to the euphoric utilization of chemicals. Among other consequences, this practice has exerted its unfavorable effects on both humans and ecosystems, which in turn has led to certain modifications in the design, structure and construction of hospitals. Nowadays, hospitals are generally located in urban centers due to population density and accessibility in case of emergency. In such conditions, both patients and medical staff are exposed to numerous

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stressors from the external, urban setting (aerial pollution, noise, vibrations, thermal pollution, excessive or inadequate insolation, energy and electromagnetic pollution). In addition, the use of modern synthetic materials and type of hospital construction elicit significant influence on the microclimate, air ionization, ionizing and nonionizing radiation, air conditioning, heating, etc.[1,2]. The patients and hospital personnel are exposed to dynamic processes interacting with both outdoor and indoor environmental factors. Since the first, second, third and up to the fourth technological revolution, besides for space and war technology (nuclear submarines), in terms of health ecology hospitals are the sites characterized by most intensive application and concentration of very complex devices, equipment and substances such as chemicals, diagnostic and therapeutic agents, radionuclides, ionizing radiation, electromagnetic and other forms of nonionizing radiation, lasers, cytostatics, etc., in the world[1,2]. Also, large amounts of various forms of energy should be added to all these, thus hospitals should be considered as being highly loaded with energy pollution. Besides, the great number of patients emitting various infective biological agents, radioactive patients submitted to therapeutic irradiation, and patients receiving chemotherapy should be taken in consideration. Accordingly, the hospital indoor ecosystem is very complex, reflecting on both patients and hospital personnel. The hospital immediate outdoor environment is frequently (especially in developing countries, including Croatia) ecologically loaded, mostly due to inappropriate local infrastructure, traffic, noise, aerial pollution and energy pollution, vicinity of manufacturing plants, etc.

There is scarcity of professionals dealing with hospital ecology in Croatia, while the related problems show a growing tendency becoming a reality (e.g., nosocomial infections, new emerging infectious and ecologic diseases, etc.). The objective of this presentation is to stimulate health authorities and medical schools to seriously consider target education of health professionals in this topic, and to urge research institutions to launch respective studies, thus to start systematic investigation of the topic in Croatia.

The Issues of Hospital Ecology

Only some substantial effects of construction materials and infrastructural plants, air, food, ionizing and nonionizing radiation, water, chemicals, drugs and therapeutic procedures, and nosocomial infections on the quality and ecologic characteristics and impacts of hospital indoor and outdoor environment are discussed.

The traditional hospital construction by use of classic construction materials, generally appropriate for the local climate and resources, has now been quite frequently and unreasonably abandoned, in part because of undue manipulation by designers, and construction companies and medical equipment manufacturers, being substituted by modern construction industry predominated by the use of concrete, iron, aluminum and large glass surfaces with forced ventilation and mostly artificial lighting. Excessive uncritical use of numerous artificial materials (plastics in particular) is frequently seen, although these have not yet been adequately tested at long term for potential unfavorable or even harmful effects. Such practice is present in all parts of the world irrespective of micro- and macroclimate, thus unnecessarily wasting enormous amounts of ever more expensive energy for heating, cooling and/or air conditioning. In addition to incurring unnecessary costs, air conditioners exert unfavorable effects on the users and personnel working in these premises.

Industrialized countries, Scandinavian countries, USA and European Union countries in particular, have responded to this trend by enacting by-laws regulating the use of building materials on constructing public institutions. So-called white, gray and black list of construction materials have been established; only white-list materials, generally well known and for centuries employed materials, can be used on public and individual building construction. The use of gray-list materials in public facilities (schools, kindergartens, hospitals, theaters, cinema, concert halls, etc.) requires special approval in writing, issued by health and ecology authorities, while such construction is submitted to regular control by inspection service. Also, it is nonecologic, uneconomical and nonfunctional to construct huge hospital buildings and complex facilities with large glass surfaces in the area with high insolation, thus implying additional costs for protection, cooling and maintenance of these glass surfaces[3-11].

Air

From the health ecology standpoint, air is not just a chemical mixture of gases at a well known ratio, its quality being ever more severely threatened by energy processes, but a significant electromagnetic medium relevant for human health. Owing to medical research into electromagnetic properties of air and its ionization in nuclear submarines after several-month stay under the sea and in space ships, modern health ecology perceives air as a mixture of positive and negative ions. According to the state-of-the-art, the air contains three types of negative ions: large, medium and small ones. The positive to negative ion ratio in the air is expressed by the coefficient of polarization. An indoor positive to negative ion ratio, i.e. polarization coefficient of 1:4 to 1:8, is optimal for human health and well-being. In nature, such a coefficient is found near waterfalls, rivers and in forests, i.e. in the areas of water to air interaction, where their motion produces optimal polarization coefficient for humans.

Although these data were unknown to ancient architects, they made successful use of these concepts. Let us just remind ourselves of the Hanging Gardens of Babylon, fountains and water basins in ancient apartments and public facilities as well as on squares. In the era before electric lighting, our grandmothers used to light candles to improve the air in the room when it felt stale and bad. Among others, candle flame produces air ionization, as demonstrated by respective measurements[1,2,11-20]. On the other hand, polarization coefficients of 1:30 through 1:50 to 1:200 are very unfavorable and uncomfortable for humans, and in nature they are found before storms and ligthning. However, such highly unfavorable coefficients of polarization were measured in large truck and trailer-truck cabs, mostly made of plastics; air flow through plastics and friction produce high amounts of positive ions as well as of large and medium negative ions, thus substantially modifying the coefficient of polarization, which has untoward effects on the central and peripheral nervous system, slowing down psychophysical reactions and leading to untimely tiredness. Therefore it is no wonder that in such conditions drivers just fall asleep and cause car accidents. These concepts have led to major corrections in the car construction[21-28]. Based on these data, air ionizers have been designed and constructed (such a device has to produce 50,000 small negative ions *per* second to be attested), with initial use in hospitals. In Israel, clinical trials including patients with bronchial asthma, where impaired ionization coefficients may, among others, trigger asthmatic attacks, were conducted in several hospitals. Individual ionizers were installed in some rooms accommodating asthmatic patients but not in others. During the study period, the patients accommodated in rooms without ionizers required medical intervention for asthmatic attacks at a higher rate than those accommodated in rooms provided with ionizers. Subsequently, favorable effects of ionizers were reported in patients with trigeminal neuralgia; intensive studies of the issue have been continued. The empirical knowledge about changes in human behavior depending on microclimate conditions characterized by untoward coefficients of polarization is perhaps best illustrated by a saying from Talmud, the old Jewish law collection, warning the judge: "… You are not to pass death sentence while the hot desert wind is blowing"[1]. A similar instruction was given by Hippocrates to a physician not to perform an operative procedure at such weather because the results were poorer and complications more common[1].

In Croatia, the measurement of these parameters has not yet been legally regulated as part of the microclimate factors assessment on official certification of public facilities.

Microclimate and sick building syndrome

The sick building syndrome is a term describing common symptoms reported by users of some premises (mostly offices and work areas supplied with air conditioners or ventilation systems), generally referring to the quality of air in the rooms. These symptoms are less pronounced than occupational diseases. The history of sick building syndrome dates as far back as 2500 BC, to the construction of the great Cheops' pyramid. The reasons for contaminated air removal were serious health problems and deaths among stone-masons carving the pyramid interior. Prolonged work indoors and stone carving caused the development of silicon disease. Channels were made from the large central hall and underground vault vertically to the pyramid sides as contaminated air outlet from Cheops' pyramid. The channels were open throughout the construction and used for efficient ventilation and contaminated air outlet from the pyramid interior. Upon completion of the construction, the channels were closed[18-20].

Nowadays, 4500 years later, we face the same problem of air contamination in closed areas, i.e. at work places, where the health problems in exposed individuals occur consequentially to this air contamination, referred to as the sick building syndrome[20].

Microclimate is a word of Greek origin, denoting the study and description of climate in a particular and small area. The quality of microclimate is substantial for all categories of dwelling premises because of the users' health conditions. As microclimate is regularly and closely related to the stay of humans, it is formed as an independent entity on planning, designing, managing and utilization of some facilities.

The sick building syndrome has primarily been associated with the known and unknown (uninvestigated and unexplained) effects on human body that occur due to the operation of a mounted technical (artificial) system or interaction of such a system with construction elements (emission, immittance, ionizing and nonionizing radiation). In the era of industrialized society, microclimate as ambient climate in urban setting and facilities has been socially determined in a dual fashion: through technics that is itself culturally and civilization determined, and through direct action of man as a constant or occasional user of multi-purpose buildings. The regulation is not only performed as technical assistance (opening the windows, setting the thermostat, etc.) but is an expression of emotional and intellectual power and abilities in a given situation.

Microclimate and pollution

Microclimate is the ground climate we live in. Microclimate can in part be perceived by our senses, e.g., heat, cold, humidity, staleness, noise, smell, dust seen in the beam of light, etc. The other part of microclimate cannot be readily perceived but its consequences are felt soon after a short stay in the area. These include dry throat, headache, fatigue, burning sensation in the eyes and mucosa, itching, etc., which are induced by odorless gases, low relative air humidity, air ionization and composition, and static electricity. The third part of microclimate is not perceived in a short period of time, however, chronic diseases develop at long term. These diseases are caused by bioenergy radiation, dust, odorless gases, radioactive radiation (especially radon), microorganisms, and a series of other processes in the materials[23,24].

Microclimate of a closed area is preloaded with classic urban air pollutants such as traffic and industry. Studies, observations and measurements indicate the microclimate of closed areas where urban dwellers spend up to 90% of life to be even more contaminated and harmful than the street atmosphere. This especially holds for the newly constructed facilities made of reinforced concrete and adapted premises with interiors made of modern materials (metal, synthetics), supplied with electronics and air conditioners. The air in these premises differs considerably from the outdoor atmosphere. Outdoors there is always some air movement, whereas in these closed indoor areas the air is still, being only set in motion by opening the door or window, or by some other artificial means. In closed areas, due to the small distance, the impact of various equipment radiation on the human body is quite different and stronger than it would be outdoors. In these premises of a relatively small area and volume, air pollution is by far higher than outdoors because of respiration, perspiration, heat emission by humans, coupled with emissions and radiation from the equipment, devices and materials.

Air pollution is especially high during winter heating season. The concentration of dust and aerosol increases during the heating season, when textile fibers from clothes and wall-to-wall carpeting, and various paper materials lose strength in dry air and turn fragile. As these fibers are mostly synthetic or have been chemically treated on manufacture, they are harmful for respiratory system as well as for the electronic equipment and devices. Of gaseous contaminants, formaldehyde found in furniture and carpet glues is very hazardous, as it remains volatile for years after installation[26].

Experts in the USA and Scandinavian countries were first to tackle the sick building syndrome. It was initially recognized from repeat complaints and occurrence of symptoms among employees from business buildings. It is a major health problem. According to studies conducted in these countries, some 30% of buildings can be classified as "sick buildings". The basic and major common symptoms of the sick building syndrome have been described by experts of the World Health Organization (WHO). The sick building syndrome has in part been explained by the basic physicochemical properties of the building with all technological processes, and psychosocial factors (age, sex, level of education, etc.), substantiated by microclimate measurements[21,22,24-37].

Food

In everyday life, and especially in hospital, food with its characteristics is not just the source of energy required for growth and maintenance of human body but also a medicine in many diseases. Therefore, hygienic and safe food is a *conditio sine qua non* at an inpatient institution[38-41].

With modern technology of almost industry based conditions of mass food preparation for a great number of users (e.g., tourism, restaurants, hospitals, military units, etc.), even minor errors may result in epidemics and involvement of a great number of people (salmonellosis, alimentary toxicosis, etc.). This has led to the development of a standardized system of control and survey of all risk points named Hazard Analysis Critical Control Points (HACCP) to prevent such events. The system is primarily directed to the microbiologic and chemical quality and safety of food. However, in a hospital setting, food as a medicine has some additional roles. For example, each diabetic has a strictly defined amount and caloric value of food allowed, whereas allergic patients, especially those with food allergy, require additional safety measures on food processing and preparation as well as in the choice of respective technologic procedures because errors in these processes may entail unwanted consequences and/or complications[38,39]. This applies to all steps from food preparation and user supply to the choice of cookware, washing and disinfection agents. Therefore, the HACCP system was developed in the 1960s at Pillsbury Co., by joint efforts of NASA and US Army Laboratories in Natick, to ensure production of safe food for astronauts in the Mercury program, and subsequently in Gemini program. The system was completed by the Apollo landing on the Moon. Two years later, the system was taken over by the Pillsbury Co. for commercial use and was first presented in public. Briefly, HACCP is a system of risk assessment and control critical points, an ingenious comprehensive and very demanding global inter- and multi-disciplinary concept of ensuring safety, quality and commercial acceptability of food[32,38,39]. It is a system of process surveillance that identifies and determines the possible hazards in food preparation, manufacture, packaging and transportation, which requires implementation of protective measures and food safety measures, along with the use of Good Manufacture Practice, Good Veterinary Practice and Good Hygiene Practice, and standard sanitary operative procedures[38,39,41]. The main principles of HACCP to follow on food manufacture are as follows:

1) identification and analysis of potential hazards (microbiologic, chemical or physical contamination);
2) identification of critical control points and respective intervention;
3) determination of critical limits of acceptability and unacceptability in the manufacturing process;
4) establishment of the system, monitoring of critical control points including frequency and mode of implementation, and possible corrections;
5) establishment of correct repair actions in case of critical limit violation;
6) verification;
7) establishment of good documentation system; HACCP is based on the Failure Mode and Effect Analysis (FMEA) engineering system, performed in six steps:
   (a) collection of basic data – unambiguous identification of the object of analysis (system, process, product) and clear defining of the products to be analyzed;
   (b) analysis of potential errors – detection of all theoretically possible causes of errors, deviation and failures, and of their consequences;
   (c) search for and assessment of risk priorities – based on the predefined scale, each error, action upon the object of analysis, its consequences for the user, probability of occurrence, probability of detection, and effects (process consequences, financial consequences, safety risks, etc.);
   (d) error grading – analysis of the potential risks to which the object may be exposed at any deviation (risk coefficient is calculated by multiplying the value of error probability by the value of error detection probability and error effect probability);
   (e) concept optimization – requiring some of the innovative methods (e.g., brainstorming) to find optimal solutions in the prevention and minimizing deviations, and to propose the improved form of the object analyzed; and
   (f) result evaluation – analysis of all actions, assessments, possible corrective activities, and generation of appropriate documentation.

HACCP is considered to be one of the most successful forms of FMEA. Since 1993, it has been published in Codex Alimentarius (by Food and Drug Administration, FAO and WHO) and has been proclaimed legal recommendation for all European Union countries[41-43]. It is expected that all elements of food quality and safety, HACCP and Good Laboratory Practice be implemented in hospitals worldwide.

Insolation

In hospitals, insolation is a significant element with favorable and desired as well as unwanted effects. Considering the highly variable climate characteristics in Croatia, this issue has to date been by far underestimated. Insolation, i.e. ultraviolet (UV) sunlight radiation, is a significant bactericidal, virucidal and germicidal agent of great value in the prevention of hospital infection. This especially applies to toilets, bathrooms, unclean storage areas, etc., where its action is very important and desirable. Unfortunately, in many hospitals, especially those of modern design, these areas are generally located in isolated, peripheral "dead ends", practically inaccessible to UV light.

On the other hand, too large glass surfaces enable excessive insolation of other areas, even with potential adverse effects, while being associated with expensive protective measures and unnecessary energy consumption, for cooling in summer and for additional heating in winter. Various technical solutions with artificial UV lighting are just another form of uneconomical wasting of resources and energy.

Water

While having some common characteristics, hospital wastewater also greatly vary among hospitals, depending on the type and size of hospital. Generally, the following types of hospital wastewater are differentiated:

a) hospital sewage,
b) infective and potentially infective wastewater,
c) pathologic wastewater,
d) chemical wastewater, and
e) radioactive wastewater.

Hospital sewage consists of wastewater from laboratories, toilets, bathrooms and laundries, and has all characteristics of general sewage. Infective and potentially infective hospital wastewater is generated at departments of infectious diseases, pathology and transfusion medicine, and contains pathogens (microbes, spores, viruses, parasite eggs, fungi and larvae) that may cause disease. This type of hospital wastewater contains cultures from microbiology laboratories, surgery, autopsy, excreta of isolation patients, hemodialysis, etc., and should undergo disinfection before release. Pathologic hospital wastewater, generated at departments of pathology and transfusion medicine, contains blood and other body fluids. Chemically contaminated wastewater is divided into hazardous and non-hazardous. Hazardous wastewater contains poisons and other substances that can cause acute and chronic effects, such as:

- corrosive liquids (acids and alkali),
- inflammable liquids,
- reactive substances (water-reactive or explosive),
- genotoxic liquids (mutagenic, carcinogenic, teratogenic) that can cause damage to genetic material, e.g., cytostatics,
- non-hazardous chemically contaminated hospital wastewater contains amino acids, organic and inorganic salts and sugars.

Radioactive wastewater is mostly generated in clinical hospitals, at nuclear medicine departments and laboratories.

Obviously, these facts should be taken in consideration on hospital designing, constructing, maintaining, functioning and decommission[11].

Since the occurrence of a new disease legionellosis in 1976 in the USA, the causative agent then discovered being named *Legionella pneumophila* because the disease was detected in American veterans, a number of bacteria of similar properties have been identified, the genus being named *Legionella.* The agent is found everywhere in surface waters and water supply systems. It is rather resistant and capable to survive in a broad range of 0 °C to 63 °C, pH 5.0 to 8.5, and oxygen concentration in water of 0.2 to 15. Temperature is the critical factor for legionella replication; it is rapidly replicated in warm water of up to 50 °C, accumulating with other microorganisms on the water surface to form a biofilm. Legionella adheres to various media, including plastics, rubber and wood, to form colonies. Organic sediment, lime scale and inorganic deposits provide favorable conditions for the formation of legionella colonies, while interaction with other environmental microorganisms may stimulate their growth. Reservoirs of heating and cooling systems and some water supply systems provide ideal sites for the development of legionella[14].

Legionella reaches lungs by inhalation of dispersed water droplets from showers, fountains in summer time, and in Jacuzzi baths. A water containing legionella may also enter gastrointestinal system. Rare cases of infection due to wound rinsing with contaminated water have also been reported. It is by no means infrequent that the infection occurs at a hospital, in patients hospitalized for quite different reasons, the risk being especially high in immunocompromised patients (e.g., organ transplantation, hemodialysis, diabetes mellitus, malignant neoplasms, AIDS). The disease is also present in Europe, where the number of patients has considerably increased over the last several years. Technological measures include occasional overheating of the heating systems and water chlorination. On the other hand, the use of ionization of water supply systems and heating/air conditioning systems in the control of legionella was introduced in 16 hospitals in the USA eleven years ago, since when no case of legionella has been recorded at these hospitals. Some European countries have passed regulations obliging the owners of public buildings such as hotels, health care institutions, etc. to take due measures for the control and prevention of legionella[11-15]. These regulations require regular bacteriologic analysis of water at high risk facilities and development of formal action plans for the control of infection. Croatian hotels and health care institutions will sooner or later face these obligations as well. In Europe, there are a number of companies primarily engaged in the manufacture of devices for purification of water supply and other systems for prevention of legionella infection[15].

Ionizing and non-ionizing radiation

The problems of ionizing radiation and its effects on human health and occupational exposure are well known and properly regulated at national and international levels. Every few years, the International Committee for Radiation Protection (ICRP) issues an updated BEIR Report, a report on the latest concepts on the monitoring and study of the effects of ionizing radiation in occupationally exposed individuals and in general population, with special reference to the experience acquired by the follow up of the exposed population after great disasters such as Hiroshima and Nagasaki nuclear bombs, Chernobyl accident, and other less known and recognized nuclear plant accidents[5,7-10].

Since 1980, non-ionizing radiation has become a subject of intensive research and studies of its effect on the human body and environment (flora and fauna). The use of electrical energy undergoes dynamic modifications not only relative to the environment but also according to the mode and intensity of utilization. Modern man is daily in close contact and interaction with numerous devices and electrical fittings, and thus with electromagnetic fields, in all aspects of living (local community, work and recreation setting, at home), literally from womb to tomb. At home and in local setting, these include various household appliances, from electric toothbrush to refrigerator, TV set, video devices, floor heating, electric sewing machine, digital clocks, hair drier, washing machine, vacuum cleaner, elevator, etc. At work place, there are computers and computer networks, laser printers, copy machines, telephones, microphones, lighting, TV network, fire alarms, technology and machines. In stores, there are computer cash desks, alarm systems, neon lighting, transistors, microphones, advertising displays, refrigerators, TV and video sets, etc. At leisure time (e.g., hobby) we are also surrounded by various machines; the more so, there are many toys for children powered by electric wiring *via* a transformer.

Some medical diagnostic and therapeutic instruments and devices may imply exposure of both patients and health personnel to rather high electric and magnetic fields. In addition, there are endogenous natural electric and magnetic fields that play a role in the complex physiology of all organisms, neuromuscular activity, glandular secretion and cell membrane function in particular.

Taking into account the extent of electromagnetic fields produced by modern man, the risk of exposure to these fields is by no means a surprising issue. Capacitance discharge and contact flow of electric current cause electric current flows known for long to pose a risk for the workers exposed to high electromagnetic fields. Man is constantly exposed to static magnetic field of the Earth, its intensity in our geographical region being about 50 mT. The static earth magnetic field is stronger at poles than at the equator[27-33]. The effect of electric and magnetic fields on humans was recorded as early as 1960 in the then USSR, in workers at high-voltage plants who frequently complained of headache, low mood, and impaired sexual potency. The report was only published in 1972 in Paris[26].

In Australia, several studies of the "epidemics" of upper extremity myalgia in civil servants upon office computerization were performed during the 1970-1976 period. Colligam and Murphy have published data on 16 patients suffering from a peculiar disease similar to mass psychosis, seven of them workers with the disease manifested at their work place, and nine students attending different schools (USA, 1975-1979). Their symptomatology was identical, i.e. fear from some infection and a feeling of some suffocating gas emerging. In 1979, Nancy Wertheimer published a study carried out in Denver in children with leukemia and their living conditions. The incidence of leukemia was 2- to 3-fold in children living in the vicinity of a power-transmission line. The study was focused on the effects of magnetic fields[16,17,34,35]. Since 1979, it has been repeatedly suggested in medical literature that exposure to electromagnetic fields can increase the risk of some malignant neoplasms, especially leukemia, malignant lymphoma and nervous system tumors. An increased risk has been associated with exposure to electromagnetic fields of extremely low frequencies (50-60 MHz), found in many apartments due to electrical fitting distribution[34,35]. Reports on an increased risk of malignant neoplasms based on epidemiologic studies of occupationally exposed workers and general population are rather inconclusive and inadequately substantiated.

Between 1980 and 1982, several studies on pregnancy disturbances and spontaneous abortions in female computer workers were published, describing the same neurasthenic disease picture as the 1960 report from the USSR[29-31]. Experiments in chicken, mice and rat failed to produce any valid result. Studies of the issue have been continued all over the world. In 1981, Samuel Milhom, an epidemiologist and dermatologist from the USA, published his study on occupational risks in electricians. Using mortality statistics of the State of Michigan, he singled out electricians, analyzed the causes of death in this group, and found that most of them had died from leukemia. However, the study was limited by the lack of information on the electric or magnetic field strength, length of exposure, and possible additional chemical or other contributing factors[35]. In 1983, David Savitz from Colorado, USA, published his study on the association between the effect of magnetic field and development of malignant neoplasms in children aged up to 14 years, according to their living conditions. The risk of malignant neoplasms in children was by 50% greater in houses with magnetic fields of 0.25 mT. The risk of leukemia was twofold in children living in houses with magnetic fields greater than 0.25 mT. The study aroused international interest and has been continued.

Results of studies of the potential effect of magnetic field on the occurrence of malignant neoplasms, performed in Canada and France, were published in 1990. During the project including workers in power plants in both countries, physical measurements of magnetic fields by use of dosimeters were performed during working hours. Results of the study indicated that an increased cumulative exposure yielded a twofold risk of acute myelocytic leukemia. A twofold risk of brain tumors was recorded in the individuals working at extremely high cumulative exposure to magnetic fields. No such association with magnetic field exposure was found for the remaining 29 types of malignant neoplasms under study[27-31].

A number of projects related to "electrical hypersensitivity", magnetic field and malignant neoplasms have been launched in Sweden since 1980. In this field of research, Swedish scientists take the leading position in the world. Results of these studies (epidemiologic; animal, cell and chromosome experiments) have best been summarized by Professor Anders Ahlbom, an epidemiologist from the Karolinska Institute in Solna (1990): "The hypothesis on the association between electromagnetic field and malignant neoplasm appears to be ever stronger from year to year. Yet, much remains to be done to confirm the relationship between the development of malignant neoplasms and low-frequency magnetic field (50 Hz). The results and facts obtained to date strongly support the hypothesis, justifying continuation of the studies"[34]. A study entitled Housing was carried out in Solna, Sweden, in 1993 and 1994. Principal investigators were Anders Ahlbom and Maria Feychting. The study included 440,000 adults and children (children suffering from leukemia and some types of carcinoma, and adults suffering from brain tumors). They all lived at 300-m distance from a 220 kV or 400 kV power-transmission line. Correlation of these data with data on patients with malignant neoplasms from Cancer Registry produced the following results: 142 children developed carcinomas of various seats and 325 developed leukemia. A magnetic field stronger than 0.2 mT was associated with a twofold risk, and a magnetic field of 0.3 mT with a threefold risk of disease in those living in the immediate vicinity of the power-transmission line. In this study, a twofold risk of disease was recorded at a distance of less than 50 m. There were 233 cases of brain tumor in adults; however, the effect of exposure on the development of malignant neoplasms at other seats could not be demonstrated. In Sweden, leukemia develops in 70 to 80 children *per* year. This study indicated that 0.5% of the Sweden population live at 50 m of 220 kV or 400 kV power-transmission lines, suggesting that less than one case of leukemia *per* year may be caused by the power-transmission line magnetic field[34]. Using Cancer Registry data, Brigitta Floderus investigated the prevalence of malignant neoplasms among motormen and conductors in Solna, Sweden, in 1993 and 1994. The group of study subjects were observed from 1960 till 1979, and then compared with the respective group of workers that had quit the job after ten years. The group of motormen, who are at highest exposure to electromagnetic fields, showed an increased rate of malignant brain tumors (astrocytomas were more common in younger subjects), pituitary tumors, and breast tumors in men (this tumor type is generally extremely rare in male patients)[34,35].

Newly emerging ecologic diseases

Nearly one hundred new "ecologic" diseases caused by micro- and macroclimate factors generated by man and man-invented technologies or technology emissions and effluents have been anecdotally described in the international literature. It is quite conceivable that the emergence of such diseases should also be expected in hospital setting, especially in health professionals with prolonged occupational exposure[29-31].

So, cataract has been recognized by the WHO as an occupational disease in sonographers performing full-time ultrasonographic (US) diagnosis for a prolonged period of time. Yet, it has until recently been claimed that US exerts no adverse effects on the human body, while ICRP recommends that a patient should not undergo US examination on the same day when submitted to x-ray examination[1,2]. Furthermore, idiopathic deep venous thrombosis was recorded in the personnel, nurses and physicians (predominantly younger), working at intensive care units. In this population (young, healthy people), the microclimate conditions (electromagnetic pollution, non-ionizing radiation, chemicals, and diagnostic and therapeutic procedures) were identified as the most likely morbigenous factors[1,2].

Upon the intensive introduction of computers in the 1980s, in industrialized countries in particular, the employees used to be exposed to PCs for up to 20 hours a day and started complaining of sandy feeling and burning in the eyes, burning face, mild nausea and vertigo. These discomforts usually disappeared over the weekend and resumed upon return to the work place; eventually they could not stay in these highly electrified premises anymore. Many of them could not stand daylight anymore, experiencing migraine attacks and lacrimal duct inflammation[1,2,27,29].

The phenomenon first occurred in Norway and has therefore been named *Norge sjuka,* i.e. Norwegian disease; subsequently it was reported in Sweden under the name *Bildskramsjuka*, i.e. screen disease. Swedish scientists are the leading in the world in this field of research, measurements, published studies and reports. A similar phenomenon was described in the USA, termed as total allergy, 20th century disease or multiple chemical sensitivity (MCS). It was the mass psychosis in America in 1979, the picture of the disease resembling that in Sweden[27,28]. In Australia, a "mystic" epidemics of upper extremity myalgia was recorded between 1970 and 1980, at the time of intensive civil service computerization. The phenomenon was thoroughly investigated and well documented by physicians; it was named repetition strain injury (RSI). Many "cases" were indemnified for occupational injury, while Australian physicians were criticized by the government for inadequate documentation of the phenemenon[1,2].

At first, neither medicine nor other sciences were ready to tackle the issue. Thousands of people were on long-term sick leave, while companies suffered great economic losses (expert staff, engineers and high-skilled personnel were involved). The patients showed identical picture of the disease (symptoms): they felt worse as soon as they approached electric devices, any time or any place. They were isolated from both their work and their families, while not receiving appropriate medical help either because physicians considered them just overworked and confused, thus recommending them sedatives and rest. Nothing could be verified by objective methods (examinations and testing); they suffered pains and discomforts that could only be described by the sufferer him/herself, as clearly stated by the old Finnish saying: "Only the one wearing the shoe knows where and how the shoe pinches". It was an entirely new problem in the working environment, and years of systematic investigation (detailed description by the sufferers, their own experience and observations, studies and description of work places and conditions, work structure and organization, etc.) have since elapsed to continue down to the present[27,28].

The exact cause and mechanism of onset still remain obscure, however, many interesting results and concepts have been obtained that are important for future studies, and some have already helped alleviate discomforts in those affected with the disease. Upon thorough and in-depth research, Scandinavian scientists have come to a conclusion that these individuals must be allergic to electric current. Yet, in classic clinical medicine the term and substrate of allergy is precisely defined. Allergy is the body's response to a substance that has already been in contact with the body and the presence of allergen and/or defense antibody (IgE antigen) can be demonstrated by laboratory blood testing. In the mentioned phenomenon of allergy to electricity no such antibodies are found. In this case, the response is similar to allergy yet without demonstrable specific blood reaction, thus it was termed hypersensitivity. That is why the Swedish Health Administration in its 1995 report proclaimed that the term electric hypersensitivity be used instead of electric allergy, and this new term and diagnosis have been included in the National Encyclopedia, along with description of the disease[34].

Upon long-term work on computer or sophisticated electronic devices, skin manifestations occur first, followed by the symptoms of facial pricking sensation, tiredness and fatigue, vertigo, fainting, headache, breathing difficulties, cardiac arrhythmias, hyperhidration, fever, listlessness (reduced responsiveness to stimuli), concentration impairments, and stress symptoms[1,2,27,28]. According to the current state-of-the-art on the issue, this electric hypersensitivity appears to be induced by a number of factors (individual, psychosocial, organizational, chemical and physical factors).

There are many books, studies, articles and reports on the phenomenon. Generally, it is concluded that electric hypersensitivity is a functional disease that is not cause by a single (physical) factor such as electromagnetic field but a number of factors (chemical) and their combinations are involved, inducing body response in certain circumstances. Which of the factors is potent enough to cause disability and other modes of social isolation, mental disturbances and economic problems? More than one hundred scientific projects and studies on the issue have currently been conducted all over the world trying to answer this question.

In addition to the indoor and outdoor hospital environment loading with ever growing technology and modern electronic devices, it is just occupational exposure of the health personnel that is expected to help elucidate this new disease entity.

Discussion

The presented account of the essential issues of health ecology clearly indicates that both interdisciplinary and multidisciplinary approach is required on hospital planning, designing, choice of location and structuring. A number of professions and professionals including ecologic issues should be included to make hospitals fully and properly functional with minimal adverse impacts from immediate and distant environment and *vice versa*. Due care should always be taken of the major specificities and variation among different hospitals, especially in terms of their function, role and capacity, waste material in particular.

Environmental aspect is predominated by the following elements:

a) emission from the use of energy source (fossil fuel for power plant),
b) electromagnetic pollution from power transformers,
c) heat pollution,
d) solid waste, general waste from patients, wards and kitchen, which should be sorted and collected in separate at the site of production,
e) toxic waste (laboratory chemicals, diagnostic agents, drugs – cytostatics, antibiotics),
f) infective waste (microbiologic waste, patient excreta, amputated body parts, organs, fetuses, hemodialysis, etc.),
g) radioactive waste (isotopes), generally in liquid form,
h) packaging material,
i) technologic waste (parts of instruments or equipment, or spare parts), and
j) liquid waste (sanitary and technologic water, precipitation, liquid chemicals, infective wastewater, human excreta, blood, microbiologic laboratory waste, etc.).

Conclusion

Hospital ecology is a significant field of high public health relevance also in Croatia, where there has been no systematic study of the issue but only some sporadic and uncoordinated attempts based on some personal interest. It is expected that a number of new hospitals will have to be constructed in the future, as most of the existing ones are located in old premises, constantly under reconstruction and restructuring, mounting new equipment and technology. These facts make the need of approaching the issue systematically, on inter- and multidisciplinary basis, even more actual.

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Sažetak

EKOLOGIJA BOLNIČKIH USTANOVA

J. Čiček

Razmatra se ekologija bolničkih ustanova tijekom povijesti ljudskog roda. Naglašava se činjenica kako nije slučajno da su u antičkim vremenima bolnice, a kasnije i sanatoriji bili smješteni u prirodnim ambijentima koji su trebali koristiti najpovoljnije činitelje prirodne okoline. Pramedicina je bila bez saznanja o etiologiji brojnih bolesti, stoga je u prabolnicama nastojala osigurati optimalne ambijentalne i okolišne uvjete. Taj se trend nastavio do otkrića uzročnika zaraznih bolesti. U modernim bolničkim ustanovama zahvaljujući značajnim saznanjima i velikom tehnološkom napretku u suvremenoj kliničkoj medicini postoji tijesna isprepletenost i interakcija brojnih činitelja, tako da se javlja značajan problem očuvanja i održavanja tih prostora sa što manje možebitnih štetnih učinaka za korisnike i pružatelje usluga. Uporabom pak novih materijala i tehnologija pojavljuju se novi problemi poput “sindroma bolesne zgrade”. U radu se podrobno razmatraju bitni elementi ekologije bolnica i daju prijedlozi za unaprjeđenje stanja u tom području.

Ključne riječi: *Bolnice – motrenje okoliša; Ekologija; Profesionalne bolesti – etiologija; Rizični čimbenici*