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Ergonomic Criteria for Bathroom and Toilet Design with Consideration to Potential Health and Hygiene Hazards for Users

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Abstract

The threat to health and social life resulting from the spread of the Sars-CoV-2 coronavirus causing the COVID-19 disease has influenced people's awareness of the need to maintain appropriate hygiene conditions in every area of life. The use of public bathrooms and toilets has also become a controversial topic. The aim of the study was to investigate the risks associated with the use of bathrooms, taking into account the potential risk of coronavirus infection. Another goal was to analyse and indicate the possibilities of protection as well as the application of design solutions in order to maintain appropriate hygienic and healthy conditions in these spaces. As a result of the research, factors and precautions that should be taken into account in the process of designing and implementing these facilities were identified. Design possibilities were examined in the field of the functional and spatial arrangement of bathrooms, and the selection of material solutions, elements of equipment, fittings and technical installations with a particular emphasis on potential threats related to bacteria and viruses, including coronavirus in public bathrooms. Design criteria for bathrooms have been defined, taking into account potential health and social life hazards and the possibility of their elimination thanks to the use of available knowledge, modern technology and innovation.

Keywords: bathroom and toilet design, innovation, hygiene, health, Sars-CoV-2 coronavirus (COVID-19)

1. Introduction

Public bathrooms and toilets evoke negative feelings among most users virtually all over the world. Usually, their dubious sanitary and aesthetic conditions, public nature and the necessity to share them with other people, as well as psychological and cultural conditions make using them unpleasant. These facilities usually leave much to be desired and would benefit from upgrades not only in relation to the appropriate level of cleanliness, aesthetics, technical condition, functional and spatial organisation, and types of equipment but also in terms of ensuring a sense of privacy. As the world dynamically changes, and with it the lifestyle of societies and the social attitude towards freedom, privacy, convenience and social principles and norms, personal issues such as the use of the bathroom and toilet are also subject to change.

At present, difficulties for societies around the world caused by the threat to public health resulting from the spread of the SARS-CoV-2 coronavirus (Covid-19) strongly influences people's awareness of the need to maintain appropriate hygiene conditions in every area of life. The use of public bathrooms and toilets has also become a controversial topic – there are questions raised ass to whether their use is safe, what factors may pose a risk to health and what precautions should be taken in order to guarantee an adequate level of hygiene and comfort of use and minimise the risk of infection whilst at the same time eliminating users' feelings of fear and insecurity. The threat to health and life also affects home hygiene habits, including the requirements for maintaining cleanliness in residential bathrooms.

According to experts, we become infected with the coronavirus by contact with other people. Experts also say that we will have to permanently change our current habits and learn new behaviours, especially in public spaces (Wojnarowski, 2020). Maintaining social distance, hand hygiene and respiratory protection are the basic strategies. Public bathrooms and toilets are places where new habits and behaviours can prove particularly useful, given their functions and usage. Small bathrooms, the need for several people to stay in a small space at the same time, and the multiple use of sanitary facilities in short intervals of time is the reason for close contact between individual users.

Certain cultural changes can be predicted, especially those related to keeping distance in direct social contacts. Some are willing to accept it, even claiming that the new model of living and working remotely can bring many benefits. It turns out that the new work system can be much more effective, it can increase the productivity of employees, and at the same time allow for savings in transport, communication, fuel, business trip costs, renting office space, etc. (Wojnarowski, 2020). Of course, such changes may only be appropriate for certain professions and for particular types of work; therefore, introducing any restrictions relating to the use of public places, including, for example, reducing the availability of shared toilets as a consequence of the development of remote work, would be taking the easy way out and evading the issue. In addition, it should be taken into account that not everyone is able to come to terms with the prospect of limiting direct interpersonal contact and not everyone is positive about such drastic changes in lifestyle. Not everyone has such opportunities. Not always and not everywhere does such a possibility exist. As architects, we should respect these facts and, to the best of our ability, try to provide favourable conditions to those who need and expect them. Using knowledge, ingenuity, previous experience, as well as available technological achievements, we can ensure that the current situation, which causes significant fear and concern for health and life, is not so severe, especially taking into account the need to use places that may be a source of particular risk.

The need to maintain appropriate hygiene conditions is crucial; its importance is undeniable, not only in the face of the current pandemic but also taking into account other diseases. It is also extremely important to be aware that sources of infection and disease include both public toilets and home bathrooms, the users of which can also infect each other.

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2. Methods and content of research

Social awareness of the need to maintain appropriate hygiene and healthcare conditions is the main problem in the ergonomic design of modern public hygiene and sanitation facilities. This study aims to investigate the factors responsible for hygiene and health in bathroom spaces, based upon studies of literature, Internet web searches, previous studies, and study materials of foreign related research institutes. It is important to examine the risks associated with the use of bathrooms and toilets, taking into account the potential risk of coronavirus infection and maintaining appropriate hygienic and health conditions in these spaces.

This research includes factors and precautions to be considered in the design and construction process of these facilities. The research also concerns design possibilities in the field of the functional and spatial arrangement of bathrooms, and the selection of material solutions, elements of equipment, appliances, sanitary devices, fittings and technical installations, taking into account the risks associated with coronavirus in public bathrooms.

Research has become the basis for determining ergonomic design criteria relating to the maintaining of hygienic and health conditions in bathrooms and toilets.

3. Hygiene problems in bathrooms and toilets

Maintaining cleanliness in bathrooms and toilets is the basis of leading a hygienic lifestyle and avoiding the risk of contamination from bacteria and viruses. Many infectious diseases caused by salmonella, E.-coli, and staphylococcus bacteria originate in the hygiene and sanitation environment. This has a lot to do with hygiene habits and mistakes in bathrooms and toilets. In order to prevent infections, it is important to recognise both the individual habits associated with the risk of disease transmission and understand the causes of these customs. A better understanding of this issue should involve the multidisciplinary methods necessary for the effective promotion and design of hygiene practices. Dust, germs, mites, microscopic water droplets from the toilet, which float in the air when flushing and settle on paper towels, toilet paper and on all fittings, handles, buttons, flush plates and doors. Another source of bacteria and viruses is the floor, which is exposed to external pollution and splashes of water from the toilet (*Higieniczne ciekawostki*, 2004; *Niewidzialni w domu*, 2004).

The use of toilet bowls and toilet seats turns out to be a serious problem. The washbasin area is a space that also requires protection, taking the risk of infection into account. Another place that may pose a risk of contamination is the waste disposal area.

It is important to not only thoroughly clean the entire bathroom and disinfect individual elements of the equipment but also to shape the habits and behaviours of users that may influence the effectiveness of protection against infection.

Design activities of architects should focus on the correct functional and spatial arrangement and the implementation of solutions that can guarantee the safe use of bathrooms and toilets.

It is also worth considering the applicable regulations regarding the design of hygiene and sanitation rooms and buildings. Some of these should be subject to certain modifications in order to improve the conditions related to the hygienic use of bathrooms and toilets.

4. Bathrooms and toilets as a source of health hazards

When discussing the criteria related to hygiene in the bathrooms, the risk of infection from bacteria and viruses (including coronavirus) should be taken into account.

Potential sources of coronavirus infection in bathrooms and toilets include:

1. Close respiratory contact.
   Small and cramped bathrooms, the need for several people to stay in a small space at the same time, and their use of sanitary facilities within short time intervals are the reasons for close contact between individual users.
2. Using the toilet bowl and toilet seat.
   Research shows that the virus can be transmitted through faeces and urine, so the toilet can be a source of potential danger. Virus particles may be sprayed during toilet flushing.
3. Direct contact with all surfaces and elements of bathroom equipment.
   Microscopic water droplets from the toilet, which float in the air during flushing, settle on paper towels, toilet paper and also on all fittings, handles, buttons, flush plates and doors. Another source of the virus is the floor, which is exposed to external pollution and splashing water from the toilet.
4. Waste zone and improper waste disposal.
   Used paper towels, hygienic tissue and other items of waste contribute to the transmission of the virus.
5. Use of hot air dryers.
6. Inadequate hygiene in bathrooms and cleanliness control, lack of proper disinfection. Due to the characteristic microclimate in bathrooms with increased temperature and air humidity, any negligence regarding cleanliness and hygiene may favour the growth and transmission of viruses and bacteria.
7. Lack of appropriate hygiene and cleaning products and their inappropriate location in the bathroom.
8. Lack of adequate ventilation.
9. No markings or information regarding the safe use of bathrooms.
10. Inadequately trained, equipped and protected cleaning staff.
11. Improper arrangement of bathrooms, for example too small and cramped vestibules with washbasins; usable spaces that are too small preventing the free use of devices and the simultaneous movement of other people without close contact; too small distances between washbasins and urinals and/or no separation between them; no entire and solid separations of toilet stalls.
12. Incorrectly selected and applied finishing materials and elements of equipment that could ensure easy maintenance of hygiene in the bathrooms and their convenient use and cleaning.
13. Lack of solutions, amenities and security measures that could facilitate the use and cleaning of bathrooms and thus increase protection against the risk of infection.

5. Maintaining cleanliness and hygiene in bathrooms and toilets - cleaning, disinfection, protection

Due to the microclimate of high temperature and air humidity in bathrooms and toilets, any neglect of cleanliness and hygiene may be troublesome with consequences that are often invisible to the naked eye. On contaminated bathroom surfaces, bacterial flora and microorganisms, such as fungi, develop very quickly under the influence of heat and moisture. Their action may be harmful both for the surfaces they live on but, more importantly, they may endanger the health of users. Therefore, great care for order and hygiene in the bathroom is important not only for aesthetic reasons (Werpachowska, 2002).

The basic activity related to maintaining proper hygiene is the constant control of the level of cleanliness of the bathroom and the use of agents that are effective in fighting the threat. Research is currently being performed to identify which agents can actually help maintain sufficiently hygienic conditions for us to feel safe, especially in the face of the coronavirus risk. In the statement of the Chief Sanitary Inspector of the Republic of Poland of March 4, 2020, we read

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that: *The virus is covered with a thin fatty layer, which is destroyed by detergents, soap, disinfectants, and UV rays* (*Koronawirus*..., 2020).

At the end of March 2020, the ECDC – the European Centre for Disease Prevention and Control published a technical document with interim guidelines on cleaning procedures in non-health facilities (e.g. offices, public transport, educational facilities) exposed to the coronavirus SARS-CoV-2 and where people confirmed with COVID-19 may have been before reaching hospitals. While no concrete evidence of their effectiveness against SARS-CoV-2 is yet available, cleaning with water and detergents for domestic use and the use of ordinary disinfectants should be sufficient for general preventive cleaning (Oleksy, 2020).

The most effective method that protects users against the action of dangerous viruses, bacteria and microorganisms is, above all, thorough cleaning of hygiene and sanitation rooms. With professional cleaning products and well-trained and protected staff, this task is manageable. When using cleaning chemicals, it is important that the room to be cleaned is well ventilated (e.g. by opening windows) to protect the health of staff.

The following personal protective equipment is recommended for cleaning sanitary facilities and devices:

- filtering face masks;
- glasses, goggles or face shields;
- disposable protective clothing, waterproof clothing with long sleeves;
- disposable gloves.

It is important to be aware that public bathrooms and toilets are used by people with different approaches to personal hygiene and public hygiene. This can cause extra tasks for the cleaning staff. Toilets can be visited by people transporting and using potentially hazardous substances. In the event of contact with such agents, personnel should be familiar with appropriate handling and disposal procedures (*Higiena toalet*..., 2020).

An adequate level of hygiene, safety and protection must be ensured for both users and staff operating sanitary facilities. To this end, the following are important:

- the provision of a safe, professional, easy-to-use, trouble-free cleaning equipment;
- providing regular training of cleaning staff to communicate accurate information on cleaning and disinfecting agents used to maintain the hygiene of sanitary facilities (knowledge of their effectiveness, knowledge about the chemicals contained in disinfectants, their harmfulness and the health impact on cleaners and users of bathrooms and toilets, knowledge about their influence on finishing materials and equipment materials);
- the use of information boards on security and precautionary measures for both staff and users of sanitary facilities.

There are three stages of cleaning public bathrooms and toilets. These are basic cleaning, thorough cleaning and an ongoing service. Each of the stages takes place at a different time of operation of the facilities. Basic cleaning involves removing everyday dirt before or after opening the toilets. Thorough cleaning consists of periodic work aimed at removing difficult dirt that cannot be removed during the basic cleaning. Thorough cleaning is usually combined with the maintenance of sanitary equipment. The ongoing service includes ongoing cleaning and the systematic replenishment of hygiene measures (e.g. soap, paper towels, toilet paper). Due to the frequency of use and other factors, public toilets require frequent repairs and the replacement of various pieces of equipment. Repairs or replacements should be made as soon as required, which ensures the continuous, uninterrupted full operation of the facilities (*Higiena toalet*..., 2020).

In addition to the proper planning of cleaning works and the development of a cleaning system, it is important to select and match appropriate cleaning agents to specific types of surfaces and equipment elements, taking into account the type of materials they are made of. This not only allows for trouble-free

cleaning, it also protects against damage or destruction. Due to the large variety of materials used to finish hygiene and sanitation rooms and their equipment, this task is not easy and requires special attention.

When analysing the issue of disinfecting public bathrooms and toilets, it should be remembered that the specific conditions and microclimate of their interiors favour the growth of microorganisms and the multiplication of bacteria and viruses due to heat, high humidity and a large amount of organic pollutants. Water, especially hard water, and soap residues cause the formation of lime deposits on surfaces and equipment. The use of acidic agents is effective because of the chemical reaction of the decomposition of the limescale to water-soluble compounds. Additionally, by lowering the pH of the surface, an acidic environment can be obtained in which most microorganisms cannot develop. When disinfecting or washing surfaces that come into contact with the human body, it is important to thoroughly rinse the surface, removing any chemicals. They must be completely safe for the health of users (*Higiena toalet*..., 2020).

6. The effect of hard water on hygiene in the bathroom

The scale deposits make it difficult to keep the surfaces and equipment in the bathrooms clean; therefore, when designing not only the sanitary equipment, but also sanitary installations in buildings, the issue of hard water and limescale should be taken into account. Parameters related to water hardness and methods of its softening and filtering should be taken into account in the process of designing and building hygiene and sanitation facilities. This will enable the selection of appropriate filters, softeners and descalers, and will avoid any inconvenience related to use and the maintenance of an appropriate level of hygiene.

The degree of water hardness affects its physical characteristics. This translates into the comfort of its use and the functioning of many facilities, including hygiene and sanitation facilities. The surface tension of water is related to its hardness. As water hardness increases, its surface tension increases. High surface tension causes difficulties in wetting all surfaces. As a consequence, it is very difficult to spread any cleaning agents in hard water. This significantly affects the process of cleaning dirty surfaces and equipment, and the maintaining of an appropriate degree of hygiene in bathrooms and toilets. More detergents are needed for their use to have any effect as the compounds in the hard water react with cleaning agents such as soap and form insoluble salts. As a result of this undesirable reaction, virtually no lather is produced. Additionally, there is an unsightly layer of limescale, which is difficult to remove (*Twarda woda*..., 2019).

The precipitation of hard water scale, commonly known as limescale, can be a persistent problem in the use, operation and maintenance of sanitary facilities. Limescale is comprised of calcium and magnesium carbonate, which are formed as a result of the thermal decomposition of bicarbonates. The high degree of water hardness causes the formation of scale deposits in water installations, pipes, thermostats, heating boilers, and tanks, and on all fittings, equipment and surfaces that come into contact with hard water. Corrosion can also occur under limescale. The scale deposits also generate the growth of bacteria and other undesirable microorganisms due to its uneven, rough and porous surface. The gaseous form of hard water, steam, may also have a negative impact on the equipment of bathrooms and toilets as well as the hygiene and health of users. Among the common problems caused by hard water and limescale deposits, the following can be distinguished:

- reducing the diameter of the pipes, causing blockage of water flow and changes in its pressure;
- growth of corrosion and bacteria in water systems;
- considerable losses of thermal energy in heating devices and an increase in heating costs;
- decrease in device performance and malfunction;

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- the need for frequent repairs or replacement of individual elements or the entire installation;
- high costs due to repair, replacement and maintenance;
- unaesthetic appearance of sanitary equipment and surfaces due to the accumulation of limescale in the form of its rough coating, stains and deposits;
- costs resulting from the replacement of individual elements of equipment (purchase and assembly);
- the inconvenient and laborious process of cleaning and maintaining an appropriate level of hygiene;
- high cleaning costs due to the need to use a large amount of aggressive cleaning agents and detergents;
- the negative impact on hygiene and aesthetics in bathrooms and toilets;
- the negative effect on health – the condition of users' skin and hair – calcium and magnesium salts contained in hard water may irritate the sebaceous glands and dry the skin;
- the harmful impact on the health of cleaning staff due to the need to use large amounts of aggressive cleaning agents and detergents (*Ecoperla*, 2020; *Kraina wody,* 2020; *Metody filtracji*, 2020; *Twarda woda*..., 2019; *Wodar*..., 2020).

In order to confirm the negative impact of hard water on bathroom hygiene, the effect of hard water on surfaces and sanitary equipment was investigated. The study was also intended to indicate which materials commonly used in sanitary facilities are particularly susceptible to hard water and require special protection.

The analysis covered installation elements and surfaces exposed to medium-hard / hard water and steam in a bathroom without window openings, ventilated with a mechanical ventilation system. Thee following were intermittently cleaned with water and natural cleaning agents (ecological and safe for health), occasionally with the use of aggressive detergents, descalers and mechanical agents for several years:

- ceramic coating (tiles, stoneware);
- ceramic coating (toilet bowl);
- acrylic coating;
- composite / granite coating (80% quartz + acrylic, polymers, pigments);
- conglomerate coating / so-called cast marble (a mixture of mineral powder and polyesters);
- glass coating;
- mirror coating;
- tile grout;
- silicone grout;
- stainless-steel sheet (smooth surface);
- aluminium sheet (smooth surface);
- chrome coating (mixer tap);
- oiled solid wood (acacia);
- wood-like veneer;
- gypsum plaster;
- steel elements of lighting fittings;
- acrylic elements.

Discussion

The research described above resulted in the following findings:

1. The ceramic coating is highly resistant to hard water.
2. The glass coating exhibits a relative high resistance to hard water with regular wiping after contact with water. Without regular wiping, stains form on the glass surface.

3. The stainless steel and aluminium coatings are relatively resistant to hard water when regularly wiped after contact with water. Without regular wiping, stains form on the surfaces.
4. Tile grout shows low resistance to hard water. On contact with water, a deposit is formed from limescale combined with soap, which requires mechanical cleaning.
5. On acrylic, composite and conglomerate coatings, the effect of hard water causes the formation of scale deposits in combination with soap, which requires mechanical cleaning.
6. Chrome coatings require regular mechanical cleaning, otherwise contact with hard water contributes to the formation of stains on their surfaces.
7. Silicone grout shows relatively high resistance to hard water. In susceptible places, inaccessible recesses and kinks, scale deposits and impurities accumulate, which can generate the growth of fungi. These irregularities require regular mechanical cleaning.
8. Any material joints and welds, kinks and recesses are sensitive to hard water and susceptible to the formation of scale deposits. The lack of regular mechanical cleaning causes the build-up of a crust and the necessity to use aggressive mechanical cleaners and chemical agents.
9. Warm surfaces, such as parts of taps and fittings through which warm water flows, are more prone to deposit formation than cold surfaces.
10. The use of ecological, gentle cleaning agents, safe for the user's health, turns out to be insufficient for surfaces and elements of bathroom equipment exposed to contact with hard water. To avoid the regular use of aggressive detergents and chemicals, with a view to protecting the health and safety of users, the regular mechanical cleaning of coatings is recommended. Mechanical cleaners should be selected according to the type of coating in order to avoid damage. The places most polluted and threatened with microorganisms (e.g. the toilet bowl) should be cleaned using agents with a strong antibacterial and disinfecting effect. Due to the formation of scale deposits in less accessible parts of the toilet bowl (e.g. under the rim) and in the line where the water level meets the internal ceramic surface of the bowl, it is recommended to use acidic descalers for cleaning the toilet.
11. Wood becomes dull and loses its original appearance in contact with hard water. It is recommended to regularly impregnate and protect wooden surfaces exposed to hard water.
12. It is recommended to avoid the use of materials susceptible to corrosion in hygiene and sanitation areas.
13. It is recommended to use simple forms of lighting fittings due to the ease of keeping them clean.
14. It is recommended to use effective ventilation systems and ensure their regular inspection and maintenance in order to improve the air quality and microclimate in hygiene and sanitation rooms.
15. It is recommended to use efficient plumbing fixtures and drains.
16. Thermostatic taps are sensitive to the effect of hard water.
17. Although manufacturers of sanitary fittings propose various options to counteract limescale, the best solution seems to be the softening of hard water through an appropriate filter system.

In order to soften the water intended for use in bathrooms and toilets, it is necessary to select a filtration method and type of filter system.

The recommended water treatment methods are as follows:

- Reverse osmosis (RO) – osmotic filtration is one of the most accurate methods of water purification. Reverse osmosis removes the tiniest impurities, even bacteria and viruses, from the water.
- Ultrafiltration – this is recommended when there is no risk of bacteria, viruses or microorganisms smaller than 0.1 microns in the water.
- Nanofiltration – this is a process also known as low pressure reverse osmosis, with features of both ultrafiltration and reverse osmosis.

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Previous studies have shown that the nanofiltration membrane is useful in the process of water softening and have confirmed the possibility of obtaining soft water from hard and very hard waters. The use of the nanofiltration process is consistent with the sustainable development of bathrooms and ensures the sustainable management of water and energy in their space. The process is ecological, energy-saving and economical. Only a small amount of water with pollutants is the waste output from the filtration process and this goes to the sewage system, which helps to care for the environment, reduces overall water consumption and reduces related costs (*Metody filtracji*, 2020).

7. Technical and technological solutions favouring the hygiene of sanitary devices

A wide range of cleaning and protective agents includes more and less specialised products that improve the cleaning of bathroom appliances and surfaces. In addition, in the production of bathroom facilities and finishing materials, various technological and design solutions are used to help keep them clean and prevent the accumulation of dirt. The objective is to make them as less susceptible as possible to any kind of contamination. This developing tendency is primarily an expression of care for the user, who has less and less time for household cleaning. It also results from the growing pro-health awareness of contemporary society living at a high level of civilisation. One of the basic principles of preventive healthcare is the need to maintain hygiene in everyday life (Werpachowska, 2002).

Contemporary trends in shaping bathroom equipment, aimed at developing models that are easy and convenient to clean, are clearly visible both in the construction of fittings, sanitary ceramics, bathtubs, shower cubicles and shower panels, as well as in the design of bathroom accessories. Elements with uncomplicated, often oval shapes, devoid of sharp edges, kinks and recesses that are difficult to access and prone to impurities accumulation, are created not only as examples of simple, minimalist, aesthetic design forms but also with a view to keeping them as easy to clean as possible (Werpachowska, 2002).

Design solutions that facilitate user access to critical points in the bathroom are a significant improvement. For example, fixing a toilet seat no longer requires complicated hinges, screws and washers. They have been replaced with easy-to-use latches connecting the lid with the toilet seat and the seat with the bowl. Easy and quick disassembly of the elements of the system, without the use of additional tools, enables thorough cleaning of the toilet seat and parts of the bowl located directly below it (Werpachowska, 2002).

Also in the construction of shower cabins, solutions that facilitate access to its individual parts for cleaning are increasingly used. Special hooks mounted at the bottom of the sliding door allow them to be tilted and, if necessary, even removed. Thanks to this, it is possible to easily reach any point inside the cabin and keep hard-to-reach places clean (Poliszczuk, 2002).

8. Finishing materials recommended for use in bathrooms and toilets

In the process of designing and selecting wall and floor cladding in hygienic and sanitary facilities, it is necessary to take into account the methods and frequency of use of these places, as well as the conditions in their interiors related to the specific microclimate. Frequent contact of wall and floor surfaces with water is also crucial. The most popular finishing material used for the cladding of floors and walls in bathrooms, ceramic tiles, combined with a correctly selected grout, are a good protection against water and moisture absorption into the surface

of the partitions. Glazed ceramic tiles, provided that the glaze layer is properly made and not porous, are easy to clean – particles of dust and other impurities do not penetrate and do not adhere to their smooth surface. By contrast, unglazed porcelain tiles, stoneware tiles and stone-effect tiles are porous. In the process of polishing stoneware tiles, micropores are opened and thus become susceptible to the penetration of impurities; therefore keeping them clean requires much greater care than in the case of glazed tiles. To facilitate cleaning, there are acrylic-based impregnating products specially developed for this purpose. Such products form a protective layer on the tiles, which makes them resistant to abrasion and prevents the adhesion of dirt. Special protective waxes are intended for surfaces finished with natural stone, for example, marble or granite. Both after using impregnating products and waxes, the cladding should be cleaned with special agents that do not damage the surfaces protected in this way (Werpachowska, 2002).

By using ceramic tiles in bathrooms, it is possible to maintain an appropriate level of hygiene thanks to their features, including their resistance to moisture, limescale, impurities and chemicals. In the design process, however, it should be remembered that these materials have different classes with regard to their degree of chemical resistance, including acid resistance, and they also have different levels of stain resistance. In designing the finishing of bathrooms and toilets, the function of protection against moisture is important, but firstly, protection against uncontrolled slipping should be taken into account. Anti-slip is one of the most important parameters in public hygiene and sanitation facilities. The value of this parameter determines the degree of slip braking of the tile, which translates into adequate adhesion to the ground, and thus the safety of people visiting the room (Doleciński, 2020).

Cement grout used for ceramic tiles, in terms of impeccable hygiene, is a relatively "weak point" in the bathroom. It is not resistant to chemicals, limescale or dirt.

Silicone is a material completely resistant to water and moisture, so it is recommended for bathroom finishing. Silicone is produced on the basis of a silicone polymer with the addition of fillers, plasticisers and other agents responsible for adhesion and resistance to chemical and weather factors. Sanitary silicones are additionally enriched with fungicides, which determine proper protection against the deposition of mould and microorganisms on the surface of silicone joints and seals. An impermeable, waterproof skin forms on the drying silicone joint, which is perfectly smooth, so that no dust or other impurities adhere to it. The precision and accuracy of making silicone joints and seals affect their durability and prevent leaks susceptible to the accumulation of dirt and the formation of mould (Werpachowska, 2002).

Epoxy grouts are completely non-absorbent and highly resistant to acids and bases. Also, organic substances do not leave stains or discolouration on them. The top layer of the joint, after it solidifies, becomes perfectly smooth, similar to plastic. For this reason, epoxy grouts are aseptic. No microorganisms grow on their surface and no impurities adhere to them (Werpachowska, 2002).

Modern cement grouts belong to the group of hygienically compliant joints. These are joints based on special hydraulic cements refined with plastics and plasticisers. They are characterised by very high resistance to mechanical and chemical factors. They are flexible joints which protects their surface against microcracks susceptible to dirt. Similarly, the reduced pore volume avoids any kind of contamination and stain (Werpachowska, 2002).

Ceramic tiles, in combination with a properly selected grout, are a safe, hygienic and easy-to-clean solution, recommended for use in bathrooms and toilets as floor and wall cladding. However, not every type of tile material is suitable for every surface. Delicate glazed ceramic tiles are mainly intended for placement on walls. Contrastingly, terracotta, as well as porcelain stoneware, which is resistant to mechanical abrasion and chemical agents, is mainly used for covering floors. In wet areas of the bathroom, it is worth avoiding polished stoneware, which does not show resistance to stains and dirt and loses its aesthetic appearance

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under the influence of water. Glazed clinker, which allows abtaining an interesting effect of its natural irregularities, works very well in the bathroom, both on the walls and on the floor (Nieścior, 2003). Quartz sinters in the form of plates can be used in bathrooms as wall and floor cladding. Additionally, washbasins and washbasin countertops can be made from it. This material has very low water absorption, which makes it perfect for difficult, wet conditions. It also prevents the growth of mould and fungi. Quartz sinter is resistant to chemicals, fire and UV rays. Moreover, its resistance to dirt, scratches, damage and graffiti makes it vandal proof and recommended for use in public hygiene and sanitation facilities. Surfaces made of quartz sinters are free of joints due to the large size of the plates, which makes it easy to keep them clean (*Spieki kwarcowe*..., 2020).

The use of seamless finishing materials (e.g. poured concrete and resin floors) composite materials and polymer concrete provides easy-to-clean, smooth wall and ceiling finishes. A modern material recommended for finishing bathroom floors, walls and washbasin countertops is microcement, i.e. polymer modified concrete. Microcement usually consists of two components: liquid polymer and dry mass. After mixing and binding both components, a material with high abrasion resistance and tightness is obtained. Thanks to a special polymer, the microcement is waterproof and is therefore recommended for use in hygiene and sanitation rooms, also in the formation of washbasins, parts of bathtubs and shower cabins. Additional protection against moisture and dirt can be obtained by covering the microcement with polyurethane varnish. For everyday cleaning, water and a mild detergent with a Ph value over six is enough. However, care must be taken so that the cleaning agent does not damage the varnish (*FAQ: Wszystko*..., 2020).

Among the seamless materials that are recommended for use in bathrooms are composite materials with a high mineral content, supplemented with acrylic resin. A popular group of composite materials are solid-surface materials (Corian is the best known). These are non-porous and homogeneous materials, allowing the countertop and the washbasin to be modelled in one form, without joints. Its resistance to dirt, ease of cleaning and its ability to counteract the growth of bacteria, fungi and moulds confirm the high hygiene attributes of solid-surface materials (*Co to jest Corian?*, 2014).

9. Dirt-repellent, easy-to-clean, antimicrobial and bactericidal coatings used in bathrooms

Modern technologies make it possible to obtain materials in which the micropores are closed. The closure of the micropores means that the surface of the materials does not absorb contaminants, which in turn eliminates or at least reduces the growth of bacteria, viruses and microorganisms. This phenomenon is used in the production of sanitary ceramics and the plastic, Duroplast, from which toilet seats are made. Another way to prevent the deposition of impurities and the growth of bacteria on the surface of ceramics is covering it with a layer of special glaze containing silver ions. Additionally, various types of coatings are used to prevent the deposition of dirt. Glass walls and shower enclosures are covered with special coatings that enable the near complete reduction of the possibility of adhesion of dirt, such as dust, grease and scale deposits to the glass surface. The increasingly high quality of chrome coatings allows the production of bathroom taps that can be easily cleaned and ensure a flawless appearance for many years of use - similar benefits are observed for high-quality metal alloys in the form of steel and brass. All of these metals provide effective protections against corrosion and are scratch resistant (Werpachowska, 2002).

Bathroom taps can also be covered with a PVD (physical vapour deposition) coating, created using the technology of vacuum evaporation. This consists of the several-stage deposition of very thin zirconium nitrate coatings with high adhesion in a very high vacuum. Thanks to the applied coatings, the surface becomes hard and resistant to any scratches, mechanical damage and wear, and

thus is not susceptible to the adhesion of dirt, limescale deposits or the growth of microorganisms (*Baterie z powłoką PVD*, 2010; *Powłoka PVD,* 2017).

Due to the properties of acrylic, it would seem that it is a material that does not require additional anti-soiling protection. It is perfectly smooth and proper maintenance helps to avoid scratches. The protection of the acrylic surface against this type of damage prevents conditions favouring the growth of bacteria and microorganisms. There are also no deposits of grease, soap or lime stains. Furthermore, additional protection has been introduced. During the production process, the cast acrylic plate is enriched with a special antibacterial agent that inhibits the growth of bacteria that cause stains and unpleasant odours. It works by damaging the cell walls of bacteria that settle on the acrylic surface, which prevents their development and reproduction (Łazienkowa kronika..., 2004; Werpachowska, 2002).

In addition to special acrylic coatings, various anti-soiling and bactericidal coatings are used on glass and ceramics. Most often, the effect of such a coating is achieved by eliminating microscopic pores and irregularities on the surface of the material and making it hydrophobic (the surface area of water contact with the material naturally tends to a minimum). As a result, liquid contaminants run off faster. A smoother surface minimises adhesive forces and the water is collected on the surface in the form of large drops. Nanotechnology is used to obtain such coatings. In sanitary ceramics, and increasingly often in the production of ceramic tiles, such an effect is achieved thanks to the use of special glazes during the so-called second firing at reduced temperature. Modern ceramic coatings ensure not only easy cleaning, but a bactericidal effect is also achieved thanks to the content of active silver ions with antiseptic properties. Bactericidal coatings are also used in other elements of bathroom equipment, which are particularly exposed to bacteria and viruses. Examples of such solutions are antibacterial flushing buttons coated with silver ions (Łazienkowa kronika..., 2004).

10. Non-contact use and operation of sanitary facilities

The bathroom and its equipment can be enriched by sensors, actuators, and interactive displays to support useful features in an innovative and more hygienic way. The safe and hygienic use of bathrooms and toilets can be enhanced thanks to solutions and appliances that do not require manual operation and direct contact with them. The application of automatic and electronic facilities controlled by photocell devices is preferable in order to minimise the amount of touch points sanitary rooms. Those are:

- Contactless automatic opening and closing of bathroom and toilet doors – touchless door activation eliminates the need to touch a door handle thus reducing the risk of cross contamination and helps to eliminate bacterial spread among users (*Automatic doors*..., 2020).
- Touchless control of lights – lights can be turned on/off, dimmed and directed upwards or downwards with simple gesture control, making them touchless and intuitive (*Become master*..., 2020).
- Bathroom mirrors with sensors and LED lights with touchless activation of all of their functionalities – thanks to touchless technology, you can switch on the upper and lower LED lighting and activate the demister device with a simple gesture, without having to push any button or leave any marks on the glass (*Bathroom mirror*..., 2020).
- Touchless automatic and sensor-controlled bathroom taps.
- Touchless automatic and sensor-controlled liquid soap dispensers.
- Hands-free paper towel dispensers.
- Automatic hands-free flushing systems that activate automatically when the user leaves the toilet.
- Self-cleaning toilets, with an automatic release for cleaning, rinsing disinfecting and drying the toilet seat after each use.

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11. Application of far-ultraviolet C (UVC) light to reduce pathogens such as SARS-CoV-2 (COVID-19) in bathroom and toilet spaces

Ultraviolet light is used in bathrooms and toilets as a disinfectant for air, surfaces and sanitary equipment. UV light complements the antibacterial effect of automatic hand dryers and air purifiers (e.g. with a HEPA filter). Recent research indicates that far-ultraviolet C (UVC) light technology is an important potential solution for reducing indoor pathogens, including the Sars-CoV-2 coronavirus (*UV Disinfection*..., 2020). UVC light can reduce pathogens but not without an impact on human health – traditional bactericidal lamps emit UVC light with a wavelength of 254 nm, which passes through the stratum corneum, has a cytotoxic effect and destroys DNA (there is a risk of developing skin cancer), so they cannot be used in the presence of unprotected people. This limits their common use in public interiors. Research results confirm that far-UVC light with a wavelength of 222 nm is also bactericidal but without harmful effects on the skin and cornea of the eye. It only reaches the outermost layer of the epidermis and the water layer of the eyes, and consequently has no effect on living cells. Therefore, it can be a safer method of disinfection, unlike conventional UV germicidal lamps. This holds promise for the use of far-UVC 222 nm light to fight coronaviruses, influenza A viruses, and antibiotic-resistant bacteria and superbugs (Buonanno at al., 2017; Fukui at al., 2020).

In cooperation with Columbia University's Centre for Radiological Research, the Japanese company, Ushio, a leading manufacturer of specialised and general lighting solutions, performed research on the effectiveness of far-UVC 222 nm waves using excimer lamps. The possibilities of reducing bacteria and viruses in a public bathroom were investigated. Over the course of three days, researchers collected samples from the floor surface, toilet seat, door handles and light switch panels before, during and after the test, and then analysed them for pathogen development. Scientists also took air samples from each site to check the air quality and the presence of airborne contaminants. The study showed that in the toilet stall treated with the far-UVC 222 nm light, the pollution was noticeably lower than in the other areas. Over time, the levels of bacteria and viruses were reduced even more or kept relatively low in the irradiated room. The use of far-UVC 222 nm light has been proven to be effective in reducing the number of pathogens in spaces with high human interactions. Air-quality results are also promising for pollution reduction, especially as the airborne spread of pathogens is more difficult to control than surface transmission. Airborne particles can also increase surface contamination (*Using far-UVC*..., 2020).

Is far-UVC 222 nm light effective against airborne coronaviruses?

According to scientists at Columbia University Irving Medical Center, very low doses of far-UVC 222 nm light are effective in killing human coronaviruses transmitted by aerosols. A low dose of 1.2 to 1.7 mJ / cm2 inactivates 99.9% of airborne human coronavirus of both alpha and beta species when exposed to far-UVC 222 nm light for twenty-five minutes (Buonanno at al., 2020).

Is far-UVC 222 nm light safe for humans?

A study by Kobe University scientists suggests that far-UVC light filtered and emitted by Care222 modules can be used to reduce pathogens while users are present. In the study, the backs of 20 healthy volunteers were irradiated with far-UVC 222 nm light at 50–500 mJ / cm2 and the induced erythema (skin reddening) was assessed (Fukui at al., 2020).

Can far-UVC 222 nm light deactivate SARS-CoV-2?

Research by scientists from Hiroshima University showed that far-UVC 222 nm light effectively reduced more than 99.7% of surface contamination with SARS-CoV-2 coronavirus (Kitigawa at al., 2020).

How does far-UVC 222 nm light inactivate viruses?

Far-UVC 222nm light inactivates pathogens such as coronaviruses by damaging their RNA, which effectively neutralises them as they are unable to

reproduce or spread causing new infections (Buonanno at al., 2017; Yamano at al., 2020).

Based on research on the use of far-UVC 222 nm light to reduce pathogens in the air and on surfaces, Christie, an audiovisual technology company based in California (a subsidiary of Ushio Inc.) has developed luminaires using excimer lamps that enable effective and safe disinfection of public spaces with various functions (including public toilets). Excimer lamps with Care222's patented filtering technology produce far-UVC 222nm light – they contain a chamber filled with a noble gas that uses no internal electrodes and is mercury-free. The high voltage applied to the outer side of the glass generates a gas inside causing the emission of far-UVC 222 nm light (*Using far-UVC*..., 2020). The Christie CounterAct lighting fixture for public interiors with the patented Care222 filter provides:

- ease of use, installation and maintenance with the application;
- instant on/off at full power output;
- no effect on lamp life of frequent on / off cycles;
- the ability to work in a wide range of ambient temperatures;
- remote monitoring capability for easy programming and troubleshooting;
- safe, continuous operation in the presence of users;
- greater efficiency compared to traditional cleaning, which requires the use of aggressive chemicals that are harmful to the health of users and the environment, and the effects of which are only temporary (*Using far-UVC*..., 2020).

12. Maintaining a proper microclimate in the bathroom

Due to the specific conditions in hygienic and sanitary rooms, it is particularly important to take care of the microclimate, air quality and thermal comfort in their interiors, which may be ensured by the use of an effective heating, ventilation and air-conditioning system, and, if possible by natural ventilation. The ability to easily regulate temperature and humidity as well as quickly get rid of steam from the bathroom are particularly important. The correct microclimate of the bathroom interior should be predicted at the design and construction stage by introducing appropriate technical solutions: waterproofing the walls and floors, proper insulation of walls and foundations, and the elimination of thermal bridges.

The bathroom is a place where a window is desired. The use of windows with different opening parts can significantly improve the ventilation conditions of the bathroom. Windows should be equipped with window ventilators or a micro-ventilation function (*Zdrowy mikroklimat*..., 2020).

Factors that negatively affect the microclimate of the bathroom interior can also be reduced by other methods, such as:

- Filters installed in the toilet seat, attachments absorbing sewage fumes improve the microclimatic properties, which in turn increases the level of hygiene in the rooms (Niedzielko, 1997).
- The installation of air purifiers with fans, HEPA filters and ionisers that remove most pollutants from the air, including fine dust, bacteria, viruses, mites, pollen, mould spores, allergens and smog components.
- The introduction of selected species of potted plants that have a positive effect on air quality, regulate humidity and even have the ability to remove harmful substances, toxins and pollutants from the air. Among the species that purify and moisturise the air is common ivy, which is also suitable for creating "green walls".
- The introduction of ozonation treatments that are recommended for improving air quality in hygiene and sanitation rooms, to removing microorganisms and eliminating unpleasant odours. Ozone disinfection is one of the most effective methods due to the strong oxidising features of ozone. The purpose of the ozonation process is to completely

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eliminate, and not only mask, harmful bacteria, viruses, mites and fungi. Disinfection with an ozonator is an ecological method that is completely safe for humans and recommended to improve the quality of the air and cleanse it of accumulated viruses, bacteria and allergens. Ozone treatment of rooms, as well as ventilation and air-conditioning components, contributes to a significant reduction in the risk of various infections, e.g. respiratory infections. Purified air in bathrooms and toilets can provide adequate hygiene and health conditions while increasing the comfort of their use and contributing to the better well-being of people using them, especially the elderly and children (*Ozonowanie*..., 2018).

13. Separation and disposal of waste

Waste that is either a direct or indirect result of individual hygiene activities can be divided into the following groups:

- dry, relatively clean rubbish (packaging, bottles, etc.);
- razor blades, disposable razors (used);
- dirty, wet garbage (used cotton swabs, tissues, hygiene products, nappies, bandages, etc.).

It is advisable to segregate waste in order to maintain maximum levels of hygiene and user safety. Managing the first two categories of waste is not onerous. The use of a temporary rubbish bin, which is emptied from time to time, is sufficient for them. The third group can be much more problematic given the risk of coronavirus infection. An ordinary rubbish bin, even closed, may not be a safe solution. The simplest answer would be to throw such waste into the toilet bowl, but for technical reasons, this is only possible for a small proportion of them. Another solution could be to use a special mill in the toilet bowl, or to use a small electric furnace to incinerate waste. The hygienic solution is to use airtight bags that can be disposed of through incineration or removal with the rest of the waste. This is especially important in the case of particularly contaminated waste. Even in the case of the common cold, it would be most hygienic to isolate waste and materials such as used tissues, rather than leaving them lying in an open container (Kira, 1976: 183–184).

Special litter bins – containers with protection, designed for hygienic and safe waste disposal – can be an effective solution. Thanks to the skeleton structure in which the removable plastic bag is placed, full visibility of the contents is ensured to increase the sense of security. The containers are made of a durable, chemical-resistant polymer for easy cleaning and long life. The possibility of closing a special dome cover and screwing the bin to the base provides additional security. The bag supporting belt ensures easy handling. Due to the ease of changing plastic bags, the container is an effective solution for the hygienic disposal of waste and impurities in places where safety and hygiene is particularly important, including public bathrooms and toilets (Świat koszy, 2020).

14. Design guidelines for the functional and spatial arrangement of public bathrooms and toilets

In order to ensure the hygienic, safe and comfortable use of public bathrooms and toilets, it is necessary to guarantee a safe distance and maximum privacy for users. This may be influenced by the appropriate functional and spatial arrangement as well as by the selection of equipment and its location in sanitary facilities. There is also a need for a change in the designers' approach to planning usable space for hygiene and sanitation zones.

Design guidelines for the functional and spatial arrangement taking into account the hygienic, safe and comfortable use of bathrooms and toilets should include:

1. Increasing the minimum height of hygiene and sanitation rooms to improve air quality.
2. Providing sufficiently large and properly arranged vestibules with washbasins to enable free use of devices and the simultaneous comfortable and contact-free movement of other people.
3. The use of automatic sliding doors to save space and facilitate their safe, contactless opening – this is particularly helpful for the elderly, the disabled and children.
4. Increasing the minimum usable areas associated with individual devices.
5. Increasing the minimum distances between appliances (e.g. washbasins and urinals) and between appliances and adjacent walls. Increasing the distance between toilet stalls and the opposite walls.
6. The use of partitions separating individual washbasins and urinals.
7. The use of full walls enclosing the toilet stalls and designing each of them with individual ventilation.
8. The application of automatic disinfection of cabins after each use.
9. Designing public sanitary facilities as cabins fully equipped with a washbasin, toilet bowl and complementary elements, with access for all users and with the possibility of cleaning and disinfecting the entire cabin after each use.
10. Use of wall-hung devices, such as a toilet bowl, to free the floor and make it easy to clean.
11. Using as many comfortable hangers as possible, both in vestibules, for example at the washbasins, and in toilet stalls, to ensure that bags and handy items can be hung on them instead of placing them on the floor.
12. The use of a special shower head - trigger spray head, located next to the toilet bowl or bidet. The device can be used for hygiene and convenient cleaning. The length and flexibility of the handheld shower hose would ensure comfort of use (*Higiena w toalecie*, 2017).

15. Conclusion

The presented analyses made it possible to comprehensively address the issues of shaping optimal conditions for the use of hygiene and sanitation facilities, with a particular emphasis on hygiene and health criteria. Factors that should be taken into account in design processes have been identified.

The available knowledge and the most modern technological achievements in the field of technical installations, sanitary devices and finishing materials are not always used in the design and construction of hygiene and sanitation facilities. This fact generates the following problems:

- the rapid ageing of sanitary facilities and their equipment;
- nuisance related to their use and maintenance;
- no possibility to guarantee an adequate level of hygiene and aesthetics;
- health problems of users and cleaning personnel;
- the amount of work involved in cleaning and maintenance;
- financial outlay related to the replacement of devices and equipment;
- repair and maintenance costs.

In connection with the above, it is necessary to optimally use and implement the potential of modern technologies and technically advanced solutions, according to specific principles, criteria and design guidelines. The ergonomic criteria for designing bathrooms and toilets taking into account potential health and hygiene hazards tousers include:

1. Providing safe and easy access to bathrooms and toilets in the context of open and closed spaces.
2. Ensuring the free, safe and hygienic use of sanitary facilities, taking into account the diverse needs of different users.
3. The use of material, installation and equipment solutions that enhance

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hygiene and safety in bathrooms and toilets.
4. The use of material, installation and equipment solutions that facilitate safe cleaning and maintenance of bathrooms and toilets.
5. The use of available knowledge and modern technological achievements in the field of technical installations, sanitary devices and finishing materials in the process of designing and building hygiene and sanitation facilities.
6. Taking into account the characteristics of water and solutions ensuring its treatment for healthy and hygienic use.
7. Ensuring the sustainable architecture of hygiene and sanitation facilities.
8. Ensuring durability and aesthetics of hygiene and sanitation facilities.

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References

Automatic doors and touchless switches: For when hygiene matters most. (2020). Retrieved from https://www.assaabloyentrance.com.au (date of access: 2020/09/01).

Baterie z powłoką PVD. (2010). Retrieved from https://instalreporter.pl (date of access: 2020/08/11).

Bathroom mirror with sensor and LED light: touchless activation of all its functionalities. (2020). Retrieved from http://www.export.roca.com (date of access: 2020/09/01).

Become master of the light with gesture control. (2020). Retrieved from https://www.occhio.de (date of access: 2020/09/01).

Buonanno, M., Ponnaiya, B., Welch, D., Stanislauskas, M., Randers-Pehrson, G., Smilenov, L., Lowy, F. D., Owens, D. M., Brenner, D. J. (2017). Germicidal Efficacy and Mammalian Skin Safety of 222-nm UV Light. *Radiation Research*, *187*(4), 483–491. https://doi.org/10.1667/RR0010CC.1

Buonanno, M., Welch, D., Shuryak, I., Brenner, D. J. (2020). Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses. *Nature, Scientific Reports 10*, 10285 (2020). https://doi.org/10.1038/s41598-020- 67211-2

Co to jest Corian? (2014). Retrieved from https://www.corian.pl/IMG/pdf/dupont-corian-what-is-corian_pl.pdf (date of access: 2020/08/31).

Doleciński, R. (2020). *Vademecum płytek ceramicznych dla Architekta – poznaj najważniejsze terminy i parametry*. Retrieved from https://www.paradyz.com (date of access: 2020/08/08).

Ecoperla. (2020). Retrieved from https://www.ecoperla.pl (date of access: 2020/08/10).

FAQ: Wszystko, co chcielibyście wiedzieć o mikrocemencie i nie baliście się zapytać. (2020). Retrieved from https://www.festfloor.pl (date of access: 2020/08/18).

Fukui, T., Niikura, T., Oda, T., Kumabe, Y., Ohashi, H., et al. (2020). Exploratory clinical trial on the safety and bactericidal effect of 222-nm ultraviolet C irradiation in healthy humans. *PLOS ONE 15*(8): e0235948. https://doi.org/10.1371/journal.pone.0235948

Higiena toalet w miejscach publicznych – czyszczenie i pielęgnacja przy pomocy detergentów dla profesjonalistów. (2020). Retrieved from https://www.clinex.com.pl (date of access: 2020/08/08).

Higiena w toalecie na 3 sposoby. (2017). Retrieved from https://www.lazienkaplus.pl (date of access: 2020/05/24).

Higieniczne ciekawostki. (2004). Retrieved from http://www.kolo.com.pl (date of access: 2004/06/13).

Kira, A. (1976). *The Bathroom* (pp. 183 – 184). New York: The Viking Press.

Kitigawa, H., Nomura, T., Nazmul, T., Shigemoto, N., Sakaguchi, T., Ohge, H., et al. (2020). Effectiveness of 222-nm ultraviolet light on disinfecting SARS-

CoV-2 surface contamination. *American Journal of Infection Control*. https://doi.org/10.1016/j.ajic.2020.08.022
Koronawirus. Czy promieniowanie UV stanie się sprzymierzeńcem w walce z pandemią. (2020). Retrieved from https://businessinsider.com.pl (date of access: 2020/04/25).
Kraina wody. (2020). Retrieved from http://www.krainawody.pl (date of access: 2020/08/10).
Łazienkowa kronika półwiecza. (2004). *Łazienka*, *6*, 2004. Białystok: Publikator.
Metody filtracji. (2020). Retrieved from https://www.filtry-do-wody.info (date of access: 2020/08/10).
Niedzielko, J. (1997). Przewietrzać, wentylować, czy klimatyzować łazienkę? Łazienka, *9,10*/1997. Białystok: Publikator.
Nieścior, M. (2003). Czyste szkliwo bez bakterii. *Łazienka*, *11*, 2003. Białystok: Publikator.
Niewidzialni w domu. (2004). Retrieved from http://www.niewidzialni.com.pl (date of access: 2004/06/25).
Oleksy, K. (2020). *ECDC – Nowe wytyczne dotyczące procedur utrzymania czystości w placówkach innych niż służba zdrowia narażonych na SARS-COV-2 oraz wytyczne dla branży spożywczej opublikowane przez GIS*. Retrieved from https://foodfakty.pl (date of access: 2020/08/08).
Ozonowanie – skuteczny sposób na odgrzybianie i ozonowanie. (2018). Retrieved from http://www.energoelektronika.pl (date of access: 2020/08/19).
Poliszczuk, P. (2002). Anatomia kabiny, *Łazienka*, *2*, 2002. Białystok: Publikator.
Powłoka PVD – kosmiczne rozwiązania na wyciągnięcie ręki. (2017). Retrieved from https://www.dom.pl (date of access: 2020/08/11).
Spieki kwarcowe – zastosowanie w budownictwie. (2020). Retrieved from https://girra.pl (date of access: 2020/08/30).
Świat koszy. (2020). Retrieved from https://swiatkoszy.eu (date of access: 2020/04/25).
Twarda woda – co to za zjawisko? (2019). Retrieved from http://www.krainawody.pl (date of access: 2020/08/10).
Using far-UVC 222nm light to significantly reduce pathogens like SARS-CoV-2 (COVID-19) in indoor spaces. (2020). Retrieved from https://www.christiedigital.com/globalassets/help-center/whitepapers/documents/christie-counteract-with-care222-whitepaper.pdf (date of access: 2020/11/03).
UV Disinfection Technology. (2020). Retrieved from https://www.acuitybrands.com (date of access: 2020/11/03).
Werpachowska, J. (2002). Nieskazitelna łazienka. *Łazienka*, *2*, 2002. Białystok: Publikator.
Wodar – technologie wodne. (2020). Retrieved from https://filtry-wodar.pl (date of access: 2020/08/10).
Wojnarowski, G. (2020). *Doktor Paweł Grzesiowski: Zamiast hasła „Zostań w domu" wolałbym „Nie wychodź, żeby się z kimś spotkać"*. Retrieved from https://sportowefakty.wp.pl (date of access: 2020/04/25).
Yamano, N., Kunisada, M., Kaidzu, S., Sugihara, K., Nishiaki-Sawada, A., Ohashi, H., Yoshioka, A., Igarashi T., Ohira, A., Tanito, M. and Nishigori, C. (2020). Long-term effects of 222 nm ultraviolet radiation C sterilizing lamps on mice susceptible to ultraviolet radiation. *Photochem Photobiol*. https://doi.org/10.1111/php.13269
Zdrowy mikroklimat w domu – jak o niego zadbać? (2020). Dobre Domy Flak & Abramowicz. Retrieved from https://www.dobredomy.pl (date of access: 2020/09/02).