

Comparison of applicable materials for biological disinfection in Hungary

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Abstract. The actuality of our research topic is given by the devastating COVID-19 epidemic which is spreading even today. Without appropriate disinfectants, it is not possible to manage the risk of an epidemic, reduce the spread of infections, and use effective disinfection procedures. During our research, we examined the disinfectants available in Hungary according to their physical and chemical properties and effect spectrum, taking into account the possibilities of use. During the experiments, the evaporation time of the selected disinfectants was examined, and the results were analyzed. With our research, we want to contribute to the management of biological emergencies, and with our experience, we want to promote the effective practical application of disinfectants.

Key Words: biological hazard, epidemic, disinfectant, disinfection procedure.

Introduction. Dealing with biological hazards, epidemics, and infections has always been a serious challenge for humanity and it is no different even today. Looking back at the past, it is clear that epidemics developed during and after the wars at the time, but several records also indicate that serious diseases were caused by naturally occurring pathogens themselves (Grósz 2003). The fight against the already devastating coronavirus (Covid-19) draws attention to the importance of addressing biological threats. Unfortunately, in recent years biological emergencies have become more frequent (Rios et al 2020), in which the risk of infection caused by various pathogens has had to be addressed, thus gaining practical experience. To neutralize or remove biological contaminants, biological decontamination – also known as disinfection – must be performed (Ulinici et al 2006). Disinfection is an extremely important element in the control of biological pathogens, the effective implementation of which requires the use of appropriate disinfectants and procedures (Kuti & Grósz 2016). In our article, we examine the most commonly used disinfectants in Hungary, promoting their practical application.

Basics of disinfection. Before turning to the presentation of disinfectants, we also consider it important to review the disinfection process itself. By disinfection, we mean all the procedures by which pathogens that have entered the environment, persons, and technical devices can be destroyed or their infectivity can be inhibited or eliminated (McDonnel & Russel 1999; Richardson et al 2007; Li et al 2008). In practice, especially in the field, it is expedient to use the classical disinfection and chemical disinfection method, during which solutions, suspensions, or emulsions of chemical disinfectants destroy the vegetative forms of microbes within a short time (Zhang et al 2021). The effectiveness of chemical processes is fundamentally influenced by the survival of microorganisms and the resistance to the selected and available disinfectant. Additional factors may affect the effectiveness of disinfection that should be considered during planning and preparation. These are the followings:

- concentration of active substance applied,
- the amount of disinfectant applied to a given surface,
- temperature of the applied disinfectant,
- ambient temperature,
- pH, application of acidic or alkaline disinfectant,
- selectivity of disinfectant,
- surface activity of the real or colloidal solutions used.

The applied disinfection method can be preventive, continuous, and final disinfection. During firefighting interventions in the presence of infectious substances, efforts should be made to perform continuous disinfection. Creating the conditions and logistical background for effective disinfection requires planning as well as continuous, flexible resource and material management. Once the disinfectant and process to be used have been determined, disinfection work must be continuously coordinated to apply the exact technological sequence in practice, only then can further infections be prevented and the process will be effective (Grósz 1996).

Selection of disinfectants. Training people performing tasks for biological hazards is essential for the use of disinfectants (Halász & Grósz 2000). During the expansion of epidemiological knowledge, it is necessary to know the physicochemical properties of disinfectants, the possibility and requirements of their applicability, and the rules of the application of personal protective equipment.

Continuous disinfection should be pursued in the management of biological emergencies. Creating the conditions and logistical background for effective disinfection requires careful planning (Grósz et al 2016). An important part of the process is the selection of the appropriate disinfection procedure and disinfectant. The most commonly applied disinfection methods in practice are chemical process, disinfection with radiant energy, and thermal energy. In most cases, chemical procedures are used in practical disinfection tasks, so the disinfectants required for them are described in detail below. When selecting the disinfectant to be used to achieve the desired effect, it is important to consider the following requirements (Grósz 1996):

- wide border spectrum,
- fast exposure time,
- excellent disinfecting effect,
- good water solubility,
- reliability,
- chemical stability,
- not corrosive,
- not flammable,
- environmentally friendly,
- economical to use.

Factors influencing the effect of chemical processes:

- concentration,
- pH,
- selectivity,
- capillary active effect,
- mechanical effect.

Categorization of chemical disinfectants by the disinfectant effect (Grósz 1996):

- inhibitory effect on bacterial growth (bacteriostatic),
- bactericidal,
- germ count reducing effect (salivation effect),
- spore killer (sporicide),
- virus inactivating (virucid),
- fungicide,
- parasiticide.

The production of disinfectants that meet the above requirements is a serious task considering the criteria system. As a result, the acquisition of products with a complex mechanism of action is costly, and in everyday practice, several disinfectants do not meet all the conditions (Grósz et al 2016).

The followings are the most commonly used chemical disinfectants:

Oxidized disinfectants (react with water to produce nascent oxygen with a strong disinfectant effect)

Chlorine and its compounds

- o $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HOCl} + \text{HCl}$; $\text{HOCl} \rightarrow \text{HCl} + \text{'O'}$ (reduces, oxidizes protein);
- o Sodium hypochlorite: $\text{NaOCl} \rightarrow \text{NaCl} + \text{'O'}$ (salt, alkaline; the aqueous solution is yellow);
- o Calcium hypochlorite (chlorine lime): Ca(OCl)_2 (water-soluble powder, clear liquid, chlorine gas evolved under the influence of acids);
- o Chloramines: (hydrolysis produces NaOCl) They irritate the skin less. One such substance is Flórasept.

Iodine and its compounds

- o Iodine is a crystalline halogen element. It also irritates the skin and mucous membranes, sublimates. Freely soluble in water, has an oxidizing effect. Iodine mixture is used for disinfection;
- o Iodine mixture: 5% iodine and 4% potassium iodide in 82% alcoholic solution, which inhibits the formation of tissue irritant hypoiodides;
- o Alkaline solution: 5% aqueous solution of iodine in potassium iodide;
- o Iodophores: complexes of elemental iodine with surfactants. The disinfecting effect depends on the elemental iodine released from the complexes.

Hydrogen peroxide (H_2O_2)

- o Colorless, pale blue in a large mass. Denser than water and liquid. Its pH is weakly acidic. It is a strong oxidizing agent and can therefore be used effectively for disinfection.

Potassium permanganate (KMnO_4) (hypermanganese):

- o Violet, a crystalline substance, soluble in water, purple in color, decomposes on the release of nascent oxygen. Its disinfecting effect is excellent because when it comes in contact with the tissues of the body, nascent oxygen is released from it, which disinfects and deodorizes.

Reduced disinfectants

Aldehyde derivatives: broad-spectrum protein precipitating disinfectants that damage the cytoplasmic membrane of bacteria and the enzyme system.

- o Formalin (HCHO) is a 40% aqueous solution of formaldehyde. It is used to disinfect rooms and equipment;
- o Lysoform: an alcoholic solution of formaldehyde;
- o Potassium soap solution 2-3%, antifungal, device disinfectant;
- o Hexamethylene tetramine: an addition compound of formalin and ammonia. Contains virusept, chlorhexidine.

Phenol derivatives

- o Its disinfecting effect lies in increasing the permeability of the cell membrane of pathogens;
- o Cresol: colorless or yellow liquid, less soluble in water;
- o Hexachlorophene: white powder, strong bactericidal, fungicidal, also used in deodorant, disinfectant soaps.

Protein precipitation disinfectants

- o Alcohols: values 1 and 2 are the most effective ones. Effect: the protein is based on coagulation (protein precipitation), it only kills those in the vegetative state, not the latency. It also has a dehydrating effect;

- o Ethyl alcohol (CH₃-CH₂-OH) (spiritus concentricutinius);
- o 96% alcohol: spiritus concentratissimus;
- o 90% alcohol: spiritus concentratus;
- o 70% alcohol: spiritus dilutus;
- o Propanol: solution of 70% is used for disinfection;
- o Isopropanol: isopropyl alcohol (C₃H₈O) at a concentration of 60%;
- o Glycol: alcohol of value 2. It is not used directly on the skin; its vapors are suitable for air disinfection.

Alcohol-based disinfectant gels

- o Disinfectants that can be used primarily for hand disinfection, which, due to their texture, do not run off the hand, so they can effectively exert their disinfecting effect;
- o Disinfectant gels based on ethyl alcohol (CH₃-CH₂-OH), containing 70-73% ethyl alcohol and glycerin (C₃H₅OH₃) as a gelling agent, which is immiscible with ethyl alcohol. According to some recipes, they even contain hydrogen peroxide (H₂O₂). Achieving proper consistency can be achieved by adding distilled water. Some products may contain different colors and dyes;
- o Isopropyl alcohol (C₃H₈O) based disinfectant gels, containing 60% ethyl alcohol and glycerin (C₃H₅OH₃) as a gelling agent. According to some recipes, they even contain hydrogen peroxide (H₂O₂). Achieving proper consistency can be achieved by adding distilled water.

Metals, metal salts

- o Heavy metal salts in particular are prone to protein precipitation;
- o Silver and its compounds: silver nitrate (lapis), still used by veterinarians today;
- o Mercury chloride (HgCl₂): White crystalline substance, freely soluble in water, precipitates proteins, 0.1-0.2 wt.% solution is used for disinfection.

Acids

- o Boric acid;
- o Salicylic acid;
- o Benzoic acid, its salts: sodium benzoates;
- o Paraoxybenzene;
- o Methyl esters: nipagin M;
- o Ethyl esters: nipagin A;
- o Solothio-conservans nipasol M (alcoholic solution of nipagin M) (Halász & Grósz 2000).

Use of surfactants in disinfectant solutions. The various disinfectants are in most cases used in aqueous solutions. The high surface tension of water is not fundamentally advantageous for use in disinfection. The surface tension is the resistance that the surface of the liquid exerts to the force that wants to increase its surface. Surface tension is thus a surface-reducing force acting on a certain length of the surface. Unit: N/m.

The surface tension can be reduced by adding various additives, wetting agents (e. g. surfactants). The additive reduces the surface tension of the water and affects that there will be a greater attraction between the surface of the material to be disinfected and the water molecules than between the individual water molecules. Thus, water adheres to the surface of the materials, penetrating the porous surface parts more easily, thus speeding up the process. This problem also occurs during disinfection work, as drops of solutions applied from different equipment do not sufficiently wet the surface to be disinfected, so more solutions are used to achieve the desired effect. The use of surfactants makes it easier to loosen and remove fats and other organic apolar impurities, thus increasing the effect of the disinfectant, thus speeding up the disinfection process (Grósz et al 2016).

Surfactants can be ionic or non-ionic:

Ionic surfactants

- Anionic substances: They do not have a disinfectant effect on their own, but they dissolve lipids, thus helping to exert the microbicidal effect of disinfectants. Such materials are a variety of soaps or simple dishwashing detergents;
- Cationic substances: They have an inverted molecular structure capable of anionic active surfactants, in which the cation is the surfactant, the lipid-emulsifying part, and depending on their chemical structure, they also have a mild antiseptic effect. Such substances are inverted soaps. Cationic surfactants should not be mixed with anionic surfactants because their effects are neutralized;
- Amphoteric surfactants: Like cationic surfactants, they have a good soil release and cleaning properties, as well as an antiseptic effect. It is used in combined disinfectants.

Non-ionic surfactants. They do not have a disinfectant effect on their own, but due to their excellent degreasing and soil removal effect, they promote the antimicrobial effect of other disinfectants. (Grósz 1996)

Disinfectants for animal epidemics. Animal husbandry, including poultry farming, is an outstanding sector in Hungary, therefore the management of various pandemics affecting animals is carried out under strict supervision. In Hungary, disinfection tasks related to epidemics and accidents affecting animals are supervised by the Veterinary Authority. The use of effective disinfectants is also essential in animal health, as epidemics also appear in Hungary, which in many cases are not only dangerous for animals but can also lead to zoonoses. In such cases, infectious diseases can also spread from animal to human. The task of the veterinary authorities is, among other things, to detect and investigate various animal diseases and epidemics, as well as to order control against them, in which disinfection plays a key role. For the prevention and control of infectious animal diseases, the law (Ministerial decree 1997) contains a disinfection guide that regulates the disinfectant to be used for different diseases and the concentration to be used. The most commonly used disinfectants in veterinary medicine are:

Alkalis

Lime milk

- 2-4% solution of sodium hydroxide,
- 2-4% solution of potassium hydroxide,
- 3-6% solution of sodium carbonate,
- 1% solution of sodium metasilicate.

Carboxylic acids

- 0.4% citric acid solution,
- 1-2% solution of lactic acid,
- 1-2% solution of formic acid.

Chlorine-containing disinfectants

- Hypochlorites–Sodium hypochlorite, (active chlorine content 9-12%) in 3-6% solution,
- Chlorine lime (active chlorine content 25-30%) in a 2.0% solution,

Aldehydes

- Formalin (36-40% solution of formaldehyde) in 1-6% solution. Below 15°C, its effect is moderate, so its use in that temperature range is not recommended.

Other disinfectants

- Iodophores, 1-5% solution pH: 2.5–4.0,
- 0.2% solution of sulfamic acid (Ministerial decree 1997).

For effective disinfection, we need to recognize and identify the cause of the pandemic emergency, which is essential for developing an appropriate prevention and management strategy (Rudnai 1993). One element of the process is the selection of the appropriate disinfectant. A disinfectant that kills all pathogens is not available, the acquisition of broad-spectrum materials requires a significant financial outlay, which unfortunately is not always available, so the available disinfectants are used in combination.

Experimental and Discussion. We performed two series of experiments with commercially available disinfectants. First, we examined how long it takes for the applied disinfectant to a furniture surface at a temperature of 20°C to evaporate. Second, we examined the evaporation time of disinfectants from the human hand. Some of the disinfectants used for the experiments were purchased ready-made, and others were mixed according to the concentrations described above. Prior to application to the surface, in the case of the ready-made product, the mixture was poured from the factory container into the hand-pumped, spray head container. The mixed mixtures were also delivered to the designated surface from a vessel with the same hand pump and nozzle. Each experiment was performed three times, and the average of the measured results was as the following.

Experiment 1. During the experiment, the evaporation time of the disinfectants applied to the horizontal furniture surface to be disinfected was investigated. An area of 10x10 cm was selected, which was drawn around so that it was easier to monitor the drying process. The surface temperature was measured with a laser thermometer, which was 20°C in each case. The disinfectant mixtures were then applied and the evaporation time was measured with a stopwatch. Since the same application vessel was used for all materials, the amount applied to the surface was the same. The average of the measurement results is given in the Table 1.

Table 1
Evaporation time of disinfectant mixtures applied to the surface (compilation of authors)

<i>Applied disinfectant</i>	<i>Evaporation time (sec)</i>	<i>Comment</i>
Prefabricated alcoholic disinfectant with 70% ethyl alcohol (C ₂ H ₆ O) content	71	
An aqueous mixture of ethyl alcohol (C ₂ H ₆ O) mixed by us with 70% ethyl alcohol content	44.6	
An aqueous mixture of isopropyl alcohol (C ₃ H ₈ O) mixed by us with 70% isopropyl alcohol content	50.2	
An aqueous 2% NaOCL.mixture of HYPO mixture	286.5	The disinfected surface faded slightly after evaporation.

Analyzing the results, it can be stated that the HYPO solution remained on the surface of the furniture for the longest time, but the disadvantage of its application is that it faded the surface of the furniture. Of the alcoholic disinfectants, the prefabricated material remained on the surface for the longest due to the addition of an evaporation-reducing additive. The solutions we mixed evaporated 20-25 sec earlier because no material other than alcohol and distilled water was mixed into them. If all parts of the surface to be disinfected come out of the solution, it will be able to disinfect properly even during this time. However, it should not be forgotten that disinfections must be repeated, depending on the usage of the equipment or room. It is important to know that our own disinfectant mixture is also effective, because this way we can produce a disinfectant mixture even when it is not commercially available. During the COVID-19 epidemic, the disinfectant

mixtures were in short supply in Hungary several times. HYPO mixture is also effective, which is significantly cheaper than alcoholic disinfectant solutions, but it is better to use it on walking surfaces in water blocks.

Experiment 2. In the second experiment, the evaporation time of disinfectants applied to human hand was investigated. Disinfectant mixtures and a disinfectant gel were applied to the entire palm surface. The evaporation time of the materials was measured with a stopwatch. The subject's hand temperature was measured with a laser thermometer, which was 36.4°C in each case. The same application vessels used in the previous experiment were used to apply the mixture, and the application tube for the disinfectant gel. The measurement was started when the entire palm surface was covered with disinfectant. The measurement results are shown in Table 2.

Table 2
Evaporation time of disinfectant mixtures applied to the hand surface (compilation of authors)

<i>Applied disinfectant</i>	<i>Evaporation time (sec)</i>	<i>Comment</i>
Prefabricated alcoholic disinfectant with 70% ethyl alcohol (C ₂ H ₆ O) content	22.4	
An aqueous mixture of ethyl alcohol (C ₂ H ₆ O) mixed by us with 70% ethyl alcohol content	14.6	After evaporation of the disinfectant mixture, the skin dried slightly.
Aqueous mixture of isopropyl alcohol (C ₃ H ₈ O) mixed by us with 70% isopropyl alcohol content	15.2	After evaporation of the disinfectant mixture, the skin dried slightly.
An aqueous 1% NaOCl-mixture of HYPO mixture	114.3	After evaporation of the disinfectant mixture, the skin is dry and got discomforted.
Disinfectant gel with 72% ethyl alcohol (C ₂ H ₆ O)	32.2	

Analyzing the results, it can be concluded that the HYPO solution remained on the hand surface for the longest time. However, it dried the skin and caused discomfort to the subject, although the concentration was reduced to 1%. In our experience, if no other hand sanitizer is available, the HYPO solution can be used, but it is recommended to use a hand cream after treatment. Of the alcohol-based disinfectants, the disinfectant gel remained the longest on the human hand due to the gelling agent (usually glycerin). The prefabricated alcoholic disinfectant has evaporated sooner and needs to be repeated more frequently. The substance we mixed evaporated the fastest, as they did not contain any other additives, but these caused a slight dryness of the skin. It is also recommended to repeat the application of these in practice, and after that it is also recommended to use a hand sanitizer cream to prevent dehydration.

Being aware of the effects of the disinfectants used on the environment is essential for carrying out environmentally and safety-conscious biological disinfection activities. To some extent, all disinfectants pose a risk to the user and the environment, so their application requires caution. The groups of substances that have the most significant impact on the environment are examined below.

Chemical disinfectants, including those containing chlorine (Cl), are still used in Hungary today. The advantage of these materials is their wide applicability, but at the same time they pose a heavy burden on the environmental elements, especially calcium hypochlorite Ca(OCl)₂. This disinfectant is corrosive, oxidizing and poses a great risk to the aquatic environment. It is also harmful to human health, so it is mandatory to use the required protective equipment during application. A common feature of alcohol-based disinfectants is that they remove moisture from their environment when applied and exert their disinfecting effect due to their ability to dehydrate. However, depending on

their alcohol content, they are also flammable. Their use also requires caution, in addition to the surfaces to be disinfected, release into the environment should be avoided. In case of hand disinfection, skin care products should be used after application in order to avoid dehydration. In addition to increasing efficiency and spectrum of impact, the use and development of disinfectants should also focus on the protection of the natural and human environment.

Summary. The spread of the various viruses must be constantly monitored, but at the same time, we must have the appropriate professional training and tools to prevent the spread of outbreak viruses. An important element in the management of biological emergencies is disinfection, the efficiency of which must be continuously improved. In our article, we presented the most commonly used disinfectants in Hungary, describing their physical and chemical properties, the advantages and limitations of their use. We have carried out experiments on the use of the disinfectants available to us, and the results are intended to facilitate their practical application. It is important always to select the disinfectant required for the target task, as this will also make the disinfection process effective. If the desired disinfectant is not available, mixtures of adequate effectiveness can be mixed at home, but they must be used with care to protect human health. The advantage of most of the materials used in Hungary is their wide applicability, however, some disinfectants have a serious load on the environmental elements, especially calcium hypochlorite. International processes also provide an incentive to replace environmentally harmful disinfectants with disinfectants that are superior in both effectiveness and applicability. With our research, we wanted to draw attention to the importance of the topic, the use of disinfectants presented in the article can help those performing disinfection tasks.

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