GUIDELINE for Disinfectant choice in feline veterinary hospitals, shelters and cat households

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Synopsis

Regardless of whether a pathogen is viral, bacterial, parasitic or fungal, or an emerging unknown, the mainstay of infectious disease prevention is hygiene, and the cornerstone of good hygiene is effective disinfection. Deficiency of the enzyme UDP-glucuronosyltransferase renders the cat susceptible to toxic effects of phenol based disinfectants (including essential oils tea tree and clove), so these are best avoided in feline environments.

Certain pathogens present a challenge to kill effectively: parvovirus, protozoal oocysts, mycobacteria, bacterial spores and prions resist most disinfectants but can be eliminated through heat, especially steam, which is the only thing which will kill protozoal oocysts.

Heat is the safest, and most effective, disinfectant, but cannot be universally applied, for example, to living skin. Temperatures in washing machines and dishwashers should be at least 60°C to eliminate pathogenic spores and resistant viruses.

Enveloped viruses are susceptible to most disinfectants, and of the non-enveloped viruses parvovirus is universally recognized to be the model most difficult to eradicate. Sodium hypochlorite is recommended for many applications: cleaning of floors, food preparation surfaces and utensils, laundry. Quaternary ammonium compounds (e.g Benzalkonium chloride) are probably best avoided. Skin scrubs and rubs containing alcohols are more effective than those containing chlorhexidine and less subject to contamination. The future of veterinary disinfection may include ultraviolet radiation and more use of silver compounds.

Introduction

Infectious disease is a major challenge for the domestic cat (*Felis catus*). In nature, a solitary creature, the cat has been forced, by domestication, to sometimes live in un-naturally highly dense populations (for example, shelters or breeding households) which results in exposure to un-naturally large doses of pathogens at a time when stress may already be compromising the cat's immune system and ability to deal with it.

Hygienic routines and disinfection are the method of choice for eliminating methicillin resistant staphylococcus aureus (MRSA) or virulent systemic feline calicivirus (VS-FCV) from premises, and is especially important in situations where there is an emerging, or unknown, contagion, when neither vaccination, nor specific testing, can prevent transmission. There are three priorities when choosing disinfectants for use around the cat: the first, obviously, is efficacy. The second, perhaps less obvious, is avoidance of toxicity to the cat: the cat's unique metabolism renders him especially sensitive to many things which are perfectly safe for other species, for example, phenol based disinfectants. Outwith the scope of this article, but also very important, is consideration of the effects of various disinfectant exposures on humans, especially in veterinary hospitals and shelters, where exposure is likely to be a daily occurrence and long term. Cleaning chemicals have been associated with airway irritation, asthma, contact dermatitis in humans and animals, and even, with prolonged exposure, neoplasia. The strongest airway irritants in cleaning products are bleach (sodium hypochlorite) which releases chlorine gas, hydrochloric acid, and alkaline agents (ammonia and sodium hydroxide), which are commonly mixed together (Quirce). Cleaning agents are divided into sensitisers (amine compounds; quaternary ammonium compounds, disinfectants, scents containing terpenes, isothiazolinones, formaldehyde) and irritants (chlorine, ammonia, hydrochloric acid, monochloramine, sodium hydroxide, quaternary ammonium compounds). (Quirce)

Different pathogens require different approaches to effective disinfection, so that recommendation of a single disinfectant for all purposes is not possible. In addition, there is no single solution for all applications: for example, steam cleaning, which is necessary to eliminate protozoal oocysts from a premises, (Ernst) is not feasibly applied to the hands of the veterinary surgeon or the skin of a cat. Thus there is no one single solution to the question of disinfection in veterinary practice. Another question outwith the scope of this review is that of human psychology: hand hygiene is the most important tool in nosocomial infection control ever since Semmelweis observed its immense effect on the incidence of childbed fever (Kampf & Kramer) in 1847, yet obtaining compliance remains a challenge over a hundred years on. (Fuller; Umit) However, apparently people are more willing to use a hand rub than to wash their hands in water. (Kampf & Kramer)

In each class of pathogen certain things have been identified as the most difficult to kill – e.g. of the viruses, parvovirus is the most resistant – so that if a disinfectant kills parvovirus, it is likely to kill most other viruses as well. We are fortunate, as feline microbiologists, in that there are many publications available on disinfecting feline calicivirus (FCV) as it is often used as a surrogate for human norovirus, (Steinmann) which is difficult to grow in cell culture, even though FCV, as a respiratory calicivirus, differs in many essential properties from the human enteric calicivirus. Details of any special disinfection requirement for each particular pathogen are given in their respective ABCD guidelines, while only anything of note is reported in this paper.

Some organisms will die outside the host without any intervention (e.g. feline leukaemia virus, feline herpesvirus): survival times outside the host were presented elsewhere (Mostl et al, 2013; Addie 2008).

This review is intended for the general veterinary practitioner and specialised areas, such as the disinfection of blood for transfusion, bone marrow/organs for transplant, and sensitive specialized equipment, for example endoscopes, will not be covered. For a review of endoscope disinfection, see Greene et al, 2012.

Disinfection – Definition and principles

Disinfection is a potent means to reduce the number of pathogens on a surface. It minimizes the risk of infection for animals and humans that come into contact with that surface.

Disinfection does not result result in sterility, this can be achieved by other methods, and only for very confined surfaces, i.e. on instruments, or liquids, such as infusion solutions.

Disinfection is always non-specific. It does not inactivates specifically pathogens. It will kill most of the bacteria on a surface, including the pathogenic ones. It is therefore important, that a disinfectant is capable of substantially reducing the bacterial burden on a surface. This is defined in most test protocols as a reduction of the number of infectivity by at least 4 log10.

Disinfection can be achieved by various methods, The bacteria, viruses and other pathogens can be damaged and inactivated by physical treatment, which is basically heat and radiation and also by chemical substances. The latter is the most common way of disinfection and can be applied to virtually all surfaces.

Physical disinfection

Heat and steam

Heat is by far the most broad spectrum method of disinfection: moist heat is more effective than dry heat, especially under pressure. When used correctly, steam under pressure (i.e. autoclaves) is the most efficient means of achieving sterility (Greene et al). Steam cleaners are widely available which can be used on soft furnishings (e.g. carpet), as well as floors and work surfaces.

In veterinary hospitals, shelters and the home, heat can be used in dishwashers, washing machines and incinerators to inactivate infective agents. Introduction of a dishwasher (amongst other measures) ended an outbreak of MRSA in a human neonatal hospital (Agca et al, 2014). Household dishwashers modified to achieve a temperature of 71oC were even proposed as a substitute for autoclaving in smaller surgeries (Ebner et al, 2000). However, care must be taken that the dishwasher itself does not become a source of cross-contamination (Ståhl Wernersson et al, 2004). Sterilisation efficacy is dependent on time of exposure of the pathogen to heat, and on whether or not a chemical disinfectant is also used.

Human safety has also to be considered: zoonotic infections may be indirectly transmitted to laundry workers: although from a human source (i.e. not zoonotic), salmonella was transmitted to laundry workers (Standaert). One heavily contaminated item can contaminate an entire laundry load, viruses can be transferred from contaminated laundry to uncontaminated laundry during washing (Gerba;

Honisch); Cryptosporidium oocysts can attach to fabrics during machine washing (O'Toole et al). In a human hospital, a nosocomial outbreak of Microsporum canis infection was linked to laundry contamination (Shah 1988). The temperature needed for decontamination depended on washing time and detergent type. (Honisch) For mycotic contamination, Ossowski and Duchmann (1997) found that reliable decontamination was achieved by laundering at 60oC, regardless of the textiles and detergents used: Nims reports that 60oC (or higher) is also the optimal temperature for inactivating FCV. Temperatures of 56oC and over will kill 99% of giardia cysts. (Mtapuri-Zinyowera) Addition of sodium hypochlorite with detergent significantly reduced the numbers of viruses in laundry (Gerba) and the addition of activated oxygen bleach increased effectivity against a number of bacteria (Honisch).

Microbial size is an important determinant in the fabric attachment-detachment process during the machine washing cycle, with larger microorganisms showing greater transference to, and retention on, fabric swatches than smaller ones. Transfer efficiencies are greater for cotton toweling than for other fabric types both before and after the washing machine spin cycle, indicating that it is not only the properties of the microorganism that influence transfer efficiency but also the properties of the fabric. (O'Toole et al).

Parvovirus can resist temperatures of 80℃ for at least an hour. (Mahnel, 1977)

Ultraviolet-C

Ultraviolet light radiation in the C range (UV-C; typically 254 nm) and the B range (UV-B; 280–320 nm) has been investigated as a method of disinfecting water, food preparation surfaces, (Nims) and hospital rooms. UV-C-emitting devices can decrease the bioburden of important pathogens (Clostridium difficile and vancomycin-resistant enterococci but not significantly Acinetobacter) in real-world settings such as hospital rooms. (Anderson et al).

UV radiation only works on surfaces. It is therefore important that UV radiation is only appled an clean surfaces. UV lamps lose the ability to produce UV light. Most of the commonly used bulbs need to be replaced after around 10.000 hours of use.

The efficacy of UV radiation depends on the intensity of the radiation. For viruses the intensity necessary to reduce infectivity by 4 logs differs between the various viruses, but is in the range of 1000 to 10.000 mJ/cm^2.

Parvoviruses and circoviruses appear to be more susceptible to UV-C inactivation than are the caliciviruses (Nims).

Chemical Disinfection

Both pure active substances and commercial products can be used for efficient disinfection, provided it is adjusted to an effective microbiocidal concentration.

It is therefore advisable to exclusively use commercial products. They usually contain a mixture of various active subtances and the side effects are minimized. Above all, however, they are efficacy tested and the microbiocidal concentration was determined by an independent institution.

Efficacy testing, licensing of biocides

In Europe chemical disinfectants are considered as biocides and as such the need to be licensed according to *REGULATION (EU) No 528/2012 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 May 2012 concerning the making available on the market and use of biocidal products* .All disinfectants will to a varying degree affect the environment and will react with inert materials, such as the various surfaces to be disinfected. The licensing procedure includes therefore tests for the ecotoxicologic effect of the biocide, as well as the potential to harm animals and men and to be compatible with various materials. Another important part of the licensing procedure is the test for efficacy. The complex licensing procedure has started some years ago and the first commercial product of a chemical disinfectants will be licensed and sold in 2015, and others will follow soon.

The complex and expensive licensing procedure will lead to a substantially reduced supply of available products (licensing always masquerades as being for public benefit, but the reality is that it is used as a barrier to entry for small enterprises, reducing competition and stifling innovation, thus the evolution of disinfectants as honed by the natural selection of a free market, will be slowed or stopped). It will be even more important to pick the right disinfectant for the given purpose.

Until that time interim regulations allow the use of the established disinfectants and the voluntary efficacy testing, as performed according to established guidelines, such as those from the German Veterinary Medical Society (DVG, the Verbund für angewandte Hygiene (VAH) or other national or international test protocols.

Chemical disinfectants for use in Veterinary practices

In Veterinary Practice the cleaning and disinfection of the surfaces (floor,walls and tables) in the various areas of the practice have to be performed on a regular basis, up to several times a day.

Alcohol

Rubbing alcohol, USP / Surgical spirit, B.P. is used primarily for topical application, especially following a chlorhexidine or iodine based scrub prior to surgery or is applied immediately after a dog or cat bite (when it stings, but is remarkably effective in preventing bacterial infection sequelae). It is prepared from a special denatured alcohol solution and contains approximately 70 percent by volume of pure, concentrated ethanol (ethyl alcohol) or isopropyl alcohol (isopropanol). Individual manufacturers can use their own "formulation standards" in which the ethanol content usually ranges from 70-99% v/v. It is colorless. Instruments (e.g. thermometers) may be disinfected by immersion in surgical spirits: contamination of alcohol based solutions has rarely been reported (Weber).

Alcohols have a nonspecific mode of action, consisting mainly of disrupting any cell membrane or virus envelope, as well as denaturation and coagulation of proteins. Cells are lysed, and the cellular metabolism is disrupted. (Kampf & Kramer) The following ranking regarding the bactericidal activity has been generally established: *n*-propanol > isopropanol > ethanol. The bactericidal activity is also higher at 30 to 40°C than at 20 to 30°C. In terms of virucidal activity, ethanol is superior to the propanols. (Kampf and Kramer) Taken orally, they are lethal.

Alcohols, and particularly ethanol had poor activity against all non-enveloped viruses (Eterpi). Parvovirus resisted exposure to alcohol for 5 minutes (Rabenau)

Park et al (2010) evaluated the virucidal efficacy of seven hand sanitizers containing various active ingredients, such as ethanol, triclosan, and chlorhexidine, and compared their effectiveness against feline calicivirus (FCV), and a GII.4 norovirus fecal extract. Based on the results of a quantitative suspension test, only one ethanol-based product (72% ethanol, pH 2.9) and one triclosan-based product (0.1% triclosan, pH 3.0) reduced the infectivity of FCV (by ≥3.4 log units). FCV is susceptible to low pH.

Chlorine releaser – Sodium hypochlorite

Sodium hypochlorite has been used as a disinfectant for more than 100 years. It has many of the properties of an ideal disinfectant, including a broad antimicrobial activity, rapid bactericidal action, reasonable persistence in treated potable water, ease of use, solubility in water, relative stability, relative nontoxicity at use concentrations, no poisonous residuals, no color, no staining, low cost (Rutala and Weber), it is easily available, and relatively safe around cats, which is why ordinary household bleach is a widely used disinfectant both in the veterinary surgery and the home. Its rapid inactivation by contact with matter means that items must be first cleaned before they can be effectively disinfected using sodium hypochlorite however this property is a bonus where septic tanks are involved, enabling the houseowner to disinfect freely without the worry that it will harm the flora in his or her septic tank.

The efficacy of sodium hypochlorite in the cleaning and disinfection processes depends on the concentration of available chlorine and the pH of the solution. Hypochlorous acid (HOCl) is a weak acid and dissociates to the hypochlorite ion (-OCl) and proton (H+) depending on the solution pH. It is generally believed that HOCl is the active species in the germicidal action, whereas the concentration of -OCl is a key factor determining the cleaning efficiency. This implies that the optimal pH region of the germicidal activity of sodium hypochlorite differs from that of its cleaning activity (Fukuzaki). Activity is reduced by the presence of heavy metal ions, a biofilm, organic material, low temperature, low pH, or UV radiation. (Rutala and Weber).

HOCl is not very stable in solution and dissociates in Cl_2, H_20, and various components that are hazardous to human and animal health. In particular, low pH leads to the generation of chlorine gas, reaction with ammonium (urine) leads to the formation of chloramine. Oxidation of organic contaminants produces among others chloroform and other trihalomethanes, which are carcinogenic.

Hypochlorites are lethal to most microbes, although viruses and vegetative bacteria are more susceptible than endospore-forming bacteria, fungi, and protozoa. Clinical uses in health-care facilities include hyperchlorination of potable water to prevent Legionella colonization, chlorination of water distribution systems used in hemodialysis centers, cleaning of environmental surfaces, disinfection of laundry, local use to decontaminate blood spills, disinfection of equipment, decontamination of medical waste prior to disposal, and dental therapy. Despite the increasing availability of other disinfectants, disinfectants based on hypochlorites continue to find wide use in hospitals (Rutala and Weber)

Household bleach (0.0314, 0.0933, and 0.670% sodium hypochlorite, pH 8.36 to 10.14) produced a >5-log reduction of Listeria monocytogenes, Escherichia coli O157:H7, and Salmonella Typhimurium after 1 min at 25o°C. (Yang 2009)

Oxidizing agents – Hydrogen peroxide

Often used to flush directly into contaminated or infected wounds where its effervescent action and increased oxygenation retard anaerobic bacteria. Should not be used on closed wounds because of the risk of embolism. (Greene) Used as a disinfectant for nebulizer and anaesthetic equipment. (Greene)

After 1 min at 25o C, 3% hydrogen peroxide (pH 2.75) achieved a >5-log reduction of both Salmonella Typhimurium and E. coli O157:H7. Compared with 1 min at 25 degrees C, greater reductions of Listeria monocytogenes ($P < 0.05$) were obtained with hydrogen peroxide treatments after 10 min at an initial temperature of 55o C. (Yang, 2009).

Hydrogen peroxide is not very stable and dissociates into H_20 and O_2.

Potassium peroxymonosulfate

An oxidizing disinfectant usually combined with a surfactant and inorganic buffer in commercially available preparations. (Greene 2012). Highly bactericidal and virucidal, even against parvovirus (when exposed for 10 minutes). (Greene) However, concern that it can corrode surfaces.

Greatly reduced FCV titres (Nims; Su)

Peracetic acid

Peracetic acid (also known as peroxyacetic acid, or PAA), is an organic compound with the formula CH_3CO_3H, it is generated in situ by some laundry detergents. It is a weaker acid than acetic acid. It is always sold in solution with acetic acid and hydrogen peroxide to maintain the stability of the peracid. Fecal indicator bacteria (*Enterococcus faecium*), virus indicator (male-specific (F(+)) coliphages (coliphages)), and protozoa disinfection surrogate (*Bacillus subtilis* spores (spores)) were tested by Park et al (2014): scanning electron microscopy observation showed that PAA targets the external layers of spores. PAA concentrations of 5 ppm (contact time: 5 min), 50 ppm (10 min), and 3,000 ppm (5 min) were needed to achieve 3-log reduction of E. faecium, coliphages, and spores, respectively.

Peracetic acid is a potent disinfectant which is able to inactivate virtually all known pathogens. It works independent of the temperature is still active around the freezing point. However, due to the acetic acid, it is corrosive. However, additives in some commercial products reduce this side effect.

Aldehydes – Chlorhexidine

Chlorhexidine gluconate is widely used for pre-operative scrubbing of the skin of both patient and surgeon, and for hand hygiene in both wet washing and rubs. Its antimicrobial activity occurs more slowly than that of alcohols. Both chlorhexidine and povidone-iodine cause an immediate reduction in bacteria, however, the reduction when using chlorhexidine is more dramatic. In addition, povidone-iodine shows a lack of cumulative and residual activity in comparison to chlorhexidine (Jarral 2010) Jarral concludes his review of 593 papers thus: “[T]here is no evidence suggesting the use of chlorhexidine during hand scrub reduces surgical site infections, which perhaps explains why guidelines from the World Health Organization, the Centers for Disease Control and Prevention and the Association for Perioperative Practice do not recommend one specific antimicrobial over another for hand scrub.”

Multiple nosocomial outbreaks have been linked to contaminated chlorhexidine. (Weber) Most reports have been traced to the use of contaminated water to prepare diluted preparations and/or the practice of reusing bottles to dispense chlorhexidine without adequate disinfection. Although most outbreaks have occurred with solutions containing less than 2% chlorhexidine, an outbreak has been reported with solutions of 2% to 4% chlorhexidine (Weber)

Resistance to chlorhexidine and a co-selection of resistance against certain antibitotics have been described (Braoudaki and Hilton, 2004; Condell et al., 2012). Chlorhexidine was ineffective against FCV (Park et al, 2010).

Iodine/iodophors

Iodine has broad spectrum activity against gram positive and negative bacteria, fungi, protozoa and, to some extent, viruses (Greene; Weber). Destruction of bacterial spores requires moist contact for more than 15 mins (Greene). It is widely used as a pre-operative scrub on patient’s skin. It has a synergistic effect when combined with alcohol and since it is only slightly soluble in water, it tends to be dissolved in alcohol.

Iodophors are less irritating to skin than iodine compounds (Weber), and are non-staining.

Iodine surgical scrub killed MRSA (Perona) and parvovirus (Mahnel, 1977)

Quaternary ammonium compounds – Benzalkonium Chloride

The quaternary ammonium compounds are chemicals that alter the surface tension of an organism and are classed as cationic detergents. They are used for disinfection but are inactivated by organic material, soap and hard water. They are fungicidal, bactericidal and virucidal against some enveloped viruses at medium concentrations, but there is no evidence that they are effective against parvovirus. (Greene) Scorza and Lappin (2012) claimed that the compound Roccal, Winthrop Labortories, New York) were effective at inactivating Giardia cysts.

Quats are widely used in the area of food production on clean surfaces with little organic soiling. Experimentally resistance against some quats could be induced and ecotoxicologic assessments restrict their use increasingly. Quats are not recommended for general disinfection in the veterinary field.

Benzalkonium chloride was unable to eradicate a mature Salmonella biofilm (though reduced an immature one). (Corcoran)

Bacterial adaptation to quaternary ammonium compounds is documented and, worryingly, exposure to gradually increasing concentrations of this type of disinfectant results in reduced susceptibility to QACs and antibiotics as well as cross-resistance to phenicol compounds (florfenicol and chloramphenicol) in 90% of Escherichia coli strains. Extensive use of QACs at sub-inhibitory concentrations may lead to the emergence of antibiotic-resistant bacteria and may represent a public health risk. (Soumet et al, 2012)

Sodium bicarbonate

Advantages of sodium bicarbonate over the available chemical disinfectants for food contact surfaces are its safety, ready availability and low cost. Sodium bicarbonate at concentrations of 5% and above was found to be the most effective with 4 log(10) (99.99%) reduction in FCV titers on food contact surfaces within a contact time of 1 min. The virucidal efficacy of sodium bicarbonate was enhanced when it was used in combination with aldehydes or hydrogen peroxide. (Malik 2006) However, sodium bicarbonate was ineffective against Listeria monocytogenes, Escherichia coli O157:H7, and Salmonella Typhimurium , even after 10 mins at 55oC. (Yang). Therefore, since bacterial reduction is important in the disinfection of food contact surfaces it is preferable to use a cat safe disinfectant (e.g. sodium hypochlorite) and thoroughly wash it off (preferably with very hot – over 60°C – water).

Acetic acid (household vinegar)

Cheap and readily available, household vinegar (2.5 and 5% acetic acid) can be used for cleaning as well as cooking. After 1 minute at room temperature (25oC) undiluted vinegar (pH 2.58) reduced *Salmonella typhimurium* by over 5 logs and at a starting temperature of 55oC exposed for 10 minutes, it significantly reduced *Listeria monocytogenes.* (Yang 2009). However, acetic acid fumes make it fairly unpleasant to work with and it is unlikely it would be chosen in practice over a commercially available disinfectant.

Citric acid (lemon juice)

5% citric acid solutions reduced *Listeria monocytogenes* after 10 minutes at an initial temperature of 55oC. (Yang). However, little is known about its general disinfectant properties.

Essential oils

Essential oils have been shown to have some effect against *Microsporum canis* in vitro and in vivo (Mugnaini 2012) A mixture composed by 5% Origanum vulgare, 5% Rosmarinus officinalis and 2% Thymus serpillum, in sweet almond oil was administered to seven infected, symptomatic cats: four of the seven treated cats recovered.

Vázquez-Sánchez et al (2014) evaluated the potential of 19 essential oils to remove the foodborne pathogen *Staphylococcus aureus* from food-processing facilities: thyme oil was the most effective. Thosar et al (2013) evaluated five essential oils against four common oral pathogens of the human *Staphylococcus aureus*, *Enterococcus fecalis*, *Escherichia coli* and *Candida albicans*, eugenol oil (oil of cloves), peppermint oil, and tea tree oil exhibited significant inhibitory effect (Thosar). However, the antimicrobial activity of essential oils is due to a number of small terpenoids and phenol compounds (Thosar): since these are toxic to cats, essential oils should only be used under supervision of a qualified veterinary surgeon. Essential oil toxicity has been reported by Genovese et al, by Bischoff (1998) and by Khan (see table 1).

Silver compounds

Silver has been used for centuries for cutlery and dishes, with an implicit understanding of its antmicrobial action. The antibacterial, antifungal and antiviral activities of silver have generated a lot of interest in recent years. A wide range of applications has recently emerged in consumer products ranging from disinfecting medical devices, textiles, cosmetics and home appliances to water treatment. The antimicrobial action of silver or silver compounds is proportional to the bioactive silver ion (Ag(+)) released and its availability to interact with bacterial or fungal cell membranes. Silver metal and inorganic silver compounds ionize in the presence of water, body fluids or tissue exudates. The silver ion is biologically active and readily interacts with proteins, amino acid residues, free anions and receptors on mammalian and eukaryotic cell membranes. Bacterial (and probably fungal) sensitivity to silver is genetically determined and relates to the levels of intracellular silver uptake and its ability to interact and irreversibly denature key enzyme systems. (Lansdown)

Recent advances in nanotechnology have enabled the production of pure silver, as nanoparticles, which are more efficient than silver ions. This has opened up whole new strategies to use pure silver against a wide array of pathogens, particularly multiresistant pathogens which are hard to treat with available antibiotics. (Lara 2011) It is believed that the silver nanoparticles (AgNPs) are able to interact with disulfide bonds of the glycoprotein/protein contents of microorganisms such as viruses, bacteria and fungi. (Lara 2011). AgNPs are attractive because they are non-toxic at low concentrations and have broad spectrum antibacterial action on at least 12 species of bacteria including multiresistant bacteria like Methicillin-resistant Staphylococcus aureus (MRSA), as well as multidrug-resistant Pseudomonas aeruginosa, ampicillin-resistant E. coli O157: H7 and erythromycin-resistant S. pyogenes. (Lara 2011)

There is a growing trend in developing food packaging materials with antimicrobial properties. Martínez-Abad et al (2013) incorporated silver ions into polylactide (PLA) films. The films showed strong antimicrobial efficacy against Salmonella enterica and feline calicivirus (FCV) activity in vitro, with increasing effects at higher silver concentrations. In vivo, antimicrobial activity was very much dependent on the food type and temperature: in lettuce samples incubated at 4 °C during 6 days, 4 log CFU of Salmonella was inactivated for films with 1.0 wt.% and no infectious FCV was reported under the same conditions. On paprika samples, no antiviral effect was seen on FCV infectivity whereas films showed less antibacterial activity on Salmonella.

Advancing biotechnology has enabled incorporation of ionizable silver into fabrics for clinical use to reduce the risk of nosocomial infections and for personal hygiene. (Lansdown) Although veterinary uses of silver have not yet taken off, in 2012, Woods et al reported the use of a combination of nanocrystalline silver dressing and subatmospheric pressure therapy to treat a resistant wound infection, following tumour removal and radiation therapy, in a difficult-to-manage surgical site in a cat

Chemical disinfectants against parasites

In Europe there is no uniform efficacy testing for chemical disinfectants against parasitic infections. The only guideline available is from the German Veterinary Medical Society (DVG), with the test organisms being oocysts of the coccidia species *Eimeria tenella* and eggs of the nematode *Ascaris suum*. This testing aims at the disinfection of large animal housing. The disinfectants that pass this test are exclusively products based on kresols and phenols. Both substances are considered highly toxic for cats. Products based on other active substances such as on aldehydes, peracetic acid, or others have not been tested against these agents or have been shown to be not efficacious.

Antiparasitic disinfection in cat husbandry has therefore to rely on a thorough cleaning and whenever possible heat treatment to minimize the number infectious parasites.

Toxicity of disinfectants to cats

The fastidious nature of the eating habits of the cat results in the cat being involved in fewer toxicity incidents than the dog (Mahdi; Caloni 2012; Forrester 2004; Khan et al, 2014; McLean 2012). Nevertheless, cats spend an estimated 5-25% of their waking time in grooming, so that disinfectants used in the cat’s environment (home, shelter, veterinary surgery, etc) must be safe in case inadvertent ingestion via grooming occurs. Addition sources of toxicity include transdermal absorption; (Dorman;Thompson) inhalation of irritant, or toxic, fumes; caustic burning of the paws or other areas in direct contact with disinfectant, and the tip of the tongue and oesophagus when attempting to groom the toxin off (Abou-Donia; Greene; Malik).

Possible poisoning by household products was the second most common reason (after ingestion of drugs) for telephone calls to the Kansas State University from 2009 to 2012 (Mahdi): 15.5% of 1616 calls were related to possible household product poisoning in dogs and cats, and of that 17 calls related to cats and household cleaners. (Mahdi) However, we would like to emphasise that in most reports on domestic animal poisoning, disinfectants do NOT play a major role: the major culprits being human medications, ethylene glycol, lead, lily, and topical pesticides (Antoniou; Caloni; Curti; Guitart; Hall; Hofstee; Hovda; Malik; McLean; Xavier).

For the cat, deficiency of the enzyme UDP-glucuronosyltransferase results in phenol based products are a problem (see below). Actual case reports of disinfectant toxicity in the literature are few and far between, with most published papers on toxicity in the cat having been deliberately perpetrated in the name of science. Disinfectant toxicity in cats is summarized in table 1.

Phenols

The cat shows remarkable sensitivity to the adverse effects of phenolic drugs, including acetaminophen and aspirin, as well as structurally-related toxicants found in the diet and environment. (Shrestha) This idiosyncrasy results from pseudogenization of the gene encoding UDP-glucuronosyltransferase (UGT) 1A6, the major species-conserved phenol detoxification enzyme. (Shrestha 2011) Glucuronidation is quantitatively the most important of the 6 routes by which xenobiotics (toxins) are conjugated, and therefore eliminated, from the body (Garg). Cats have a uniquely carnivorous diet and, as a result of lack of exposure to plant-based toxins (phytoalexins), have presumably lost the need to metabolise these toxins via glucuronidation, which is common in most herbivores and omnivores (Shrestha).

Table 1 – Reported toxicity of disinfectant use in cats

SUBSTANCE	CLINICAL SIGNS	TREATMENT	REFERENCE
Benzalkonium chloride	Chemical burns when put undiluted onto skin, conjunctiva or mucosae. Cats also developed oral and oesophageal ulceration after licking treated skin.		Greene 2012
Hexachlorophene(Now banned worldwide because of its high rate of dermal absorption and subsequent toxic effects. Kamp & Kramer)	Hindlimb paralysis in 3-5 daysCardiovascular collapse, corneal ulcers, trembling, lethargy, and weakness. Status spongiosis, astrocytosis, and microgliosis of the cerebral and cerebellar white matter and corticospinal tracts	Slow iv administration of 30% urea (2 g/kg in 10% invert sugar)	Hanig et al, 1976;Thompson
Phenol	Dark green urine		Garg
Phenol	Co-carcinogen		Shukla
Pinesol	Unresponsive pupils and extreme ataxia were observed prior to death. Pathologic changes consisted of severe acute centrilobular hepatic necrosis and renal cortical necrosis.		Rousseau
Essential oils in flea treatment	Thirty-nine cats and 9 dogs with history of exposure to natural flea preventatives. Onset time of adverse effects in 39 of 44 animals occurred within 24 hours. The duration of signs in 24 animals ranged from 30 minutes to 149 hours. The products were used as per label in 77% animals (n = 37). Death (1 cat; n = 1/28; 4%) or euthanasia (1 cat and 1 dog; n = 2/28; 7%) was reported in 3 animals.	Of 28 animals with known outcome, 50% (n = 14) recovered with bathing alone while others received intravenous fluids, muscle relaxants, and anticonvulsive medications	Genovese et al, 2012
Tea tree oil	Clinical signs developed within 2-12 hours and lasted up to 72 hours. Increased salivation/drooling, signs of CNS depression or lethargy, paresis, ataxia, tremors, hypothermia, coma, dehydration. Elevated AST, ALT.A significant association with severity of illness was found for age and weight, with higher prevalence of major illness in younger and smaller cats.	Wash off oil, activated charcoal per os, dexamethasone	Bischoff, 3 casesKhan et al, 2014 106 cases

Disinfection Tab.2

Edit

DISINFECTANT	CONCENTRATION/ DILUTION	USES	COMMENTS
Heat and steam	Recommended temperature / pressure-exposure time to produce sterilization with an autoclave is 121℃ at 15 psi for 15 mins or 126℃ at 20 psi for 10 mins (Greene et al). Prions require a heat of 130℃ for 30-60 mins to inactivate (Greene). Washing machines/dishwashers should be set at 60℃ and 30 mins at 60℃ required (Allwood?).	Instruments, floors, work surfaces, dishes, bedding.	The most effective, safe, and broad spectrum of disinfection methods.Steam heat is the most effective for eliminating protozoal oocysts such as Toxoplasma and Isospora.In outbreaks of enteric infections, cardboard litter trays which can be incinerated can be used
Sodium hypochlorite (bleach)	5- 6% bleach diluted at 1:32 or less, depending on use. For a detailed and exhaustive examination of the uses of bleach, see table 93-1 in Greene's Infectious Diseases of the Dog and Cat (4th edition)	Water decontamination, cleaning surfaces, food utensils, litter trays, floors, laundry, instruments and foot baths	The best all round chemical disinfectant.Inactivated by organic debris.One of the few chemicals which will inactivate parvovirus and kill clostridial spores.Loses activity if stored for a long time. [Greene]Caution: can release toxic chlorine gas
Alcohol		Hand rubs are more likely to be used than hand washes (Kampf and Kramer) and reduces bacteria and virus titres more effectively than hand washes.	Contamination of alcohol based solutions has rarely been reported (Weber)Ineffective against parvovirus (Rabenau)
Ethanol	70% to 90% concentration for 1 minute – the higher the concentration, the more effective.Require at least 90% for MRSA control (Perona)	Used along with isopropanol in surgical spirits / scrubbing alcohol and hand sanitisers.	More effective against FCV than isopropanol [Kampf et al 2005] but poor activity against all non-enveloped viruses (Eterpi)No sporicidal activity
Isopropanol	40 to 60% concentration for 1 minute	Used along with isopropanol in surgical spirits / scrubbing alcohol and hand sanitisers.	Less effective than ethanol against FCV (Kampf et al, 2005)
Hydrogen peroxide		Initial flush for wounds for its effervescent action and oxygenation, retarding anaerobes.	Do not use in closed wounds (risk of air embolism).
Sodium bicarbonate	5% for 1 minute effective against FCV[Malik 2006]	Can be used on hands and food surfaces and containers	Cheap and safe, but not effective against some bacteria (Yang 2009) so not recommended.

DISINFECTANT	CONCENTRATION/ DILUTION	USES	COMMENTS
Acetic acid (household vinegar)	Undiluted vinegar (pH 2.58) 2.5 and 5% acetic acid 1 minute at room temperature will reduce Salmonella Typhimurium and at starting temp of 55oC for 10 mins will reduce Listeria monocytogenes (Yang 2009).	Food surfaces and containers	Information not available about activity against viruses/parasites.Unlikely to be used in practice due to odour.
Citric acid	5% citric acid solutions for 10 mins	Food surfaces and containers	Reduced Listeria monocytogenes after 10 minutes at an initial temperature of 55oC. (Yang)Effectivity against other pathogens unknown.
Chlorhexidine (Hibiscrub)	0.5% in water, saline, lactated Ringer's solution or alcohol [Greene]	Pre-operative skin scrub, hand washing. Gives up to 2d antiseptic protection of skin after single application.[Greene]	Does not inactivate FCV [Park] or dermatophytosis (though works with miconazole)Should never be used in the ear (ototoxic) [Lai] or eye [Greene]Skin irritant at 4% or over [Kampf and Kramer]
Iodine / Iodophors	1-10% solution applied topically	Pre-operative patient / surgeon skin scrub.1:50 dilution povidone-iodine for ocular pre-operative surface disinfectionHand rub	Can be skin irritantIodine surgical scrub was effective in killing MRSA (Perona)Synergistic effect when used with alcohol
Potassium peroxymonosulfate(TrifectantÂ®, Virkon-SÂ®)		Cleaning surfaces and instrumentsFootbaths.	Bactericidal, virucidal, even against parvovirus (10 min exposure).Good activity in spite of organic material. Can even be used on carpets. However, can corrode surfaces.Proven effective against FCV.
Quaternary ammonium compounds, e.g. Benzalkonium chloride	Not recommended except possibly where there is Giardia infection.0.001% to 1%	Used as soap and antisepticHas unusual ability to kill Giardia cysts at 4oC and room temp. Greene ref 306	Algicidal, fungicidal, bactericidal and virucidal against some enveloped viruses. Does not reliably inactivate FCV herpes, parvo.Harbours opportunistic bacteria (e.g. Serratia). [Greene; Weber]Has unusual ability to kill Giardia cysts at 4oC and room temp. Greene ref 306Inactivated by organic materials, soap, hard water.Concern about widespread use leading to antibiotic resistance (Soumet Vet Micro 2012) so not recommended

DISINFECTANT	CONCENTRATION/ DILUTION	USES	COMMENTS
Phenol-based, e.g. hexachlorophene, Lysol,® Dettol® FlashÂ® . Essential oil of tea tree or clove (eugenol),.			Not recommended around cats: toxic and caustic
Ultraviolet-C light	influence 30mJ/cm2	For reducing bacterial contamination in whole rooms	FCV more resistant than parvo to UV-C (Nims) Effective against enterococci and Cl. difficile but not Acinetobacter (Anderson)Decreased efficacy in presence of organic material (Nims)
Silver compounds		Impregnated wound dressings	Safe antimicrobial but at present in cats has only been used in wound dressings

Table 2. Recommended disinfection for use around the cat

This table shows disinfectants for use in veterinary practices and around the home, showing the most notoriously difficult to eradicate pathogens as sentinels for effectivity.

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