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History of disinfection from early times until the end of the 18th century

J. BLANCOU *

***Summary**: The author describes and analyses the methods of disinfection in use until the end of the 18th century, i.e. before the scientific demonstration of the role of pathogenic microorganisms. These methods are classified into three categories: chemical (by derivatives of sulphur, mercury, copper, and also by alkalis and acids), physical (heating, fumigation, filtration, etc.) and biological (burial). The author concludes that, despite their empiricism, these methods were of great value to those responsible for controlling diseases of animals, as in some cases they were able to eradicate diseases while still ignorant of the causal mechanisms.*

KEYWORDS: Animal diseases – Disinfection – Veterinary history.

INTRODUCTION

The purpose of this article is to describe and analyse procedures for disinfection in use before the scientific demonstration, in the 19th century, of the role of pathogenic microorganisms.

To simplify this account and analysis, the 'disinfectants' considered will be restricted to those defined by Block (2): 'A disinfectant is an agent that frees from infection, usually a chemical agent but sometimes may be a physical one, [...] that destroys disease or other harmful microorganisms but may not kill bacterial spores. It refers to substances applied to inanimate objects.'

For convenience, inanimate objects are considered here as including carcasses of animals which have died from contagious diseases, long identified as the principal (or even the sole) source of virulent material.

Disinfectants shall be classified, again for practical reasons, into three major categories: chemical, physical and biological. The third category is not expressly covered by the definition given by Block (2), but such methods were very important in earlier times, and could bring into action both chemical mechanisms (e.g. acidification of the medium) or physical mechanisms (e.g. increase in temperature), thus providing a link with the other two categories.

* Director General, Office International des Epizooties, 12 rue de Prony, 75017 Paris, France.

DISINFECTION BY CHEMICAL AGENTS

Chemical disinfection has been performed using many procedures, although it is sometimes difficult to identify the active principle. The procedures examined below utilised derivatives of sulphur or mercury, alkalis, acids and other products (when the composition is adequately known).

Genuine knowledge of the causes of human and animal diseases was not available until the 19th century. However, since very early times suspicion had fallen on the harmful action of 'animalcules' or living organisms. In the 1st century AD, Marcus Terentius Varro wrote (8): 'There perhaps exist, in marshy places, animals which are invisibly small, and which cause serious diseases by invading the body through the mouth or the nose.' A disinfectant was considered effective if it had a visible corrosive, suffocating or toxic effect on living creatures.

Sulphur derivatives

The oldest reference to disinfection of premises with a chemical product seems to be that described in 800 BC by Homer in book XII of the Odyssey, where the hero, having killed his rivals, demanded that sulphur be burnt in the house which they had occupied (2).

The purifying effect of sulphur dioxide fumes (2) was subsequently employed on many occasions. In India, Susruta (in the 4th century AD), in his book *Susruta-tantra*, prescribed the burning of sulphur in rooms where surgical operations were to take place (5).

In Europe, during the human plague epidemics of the Middle Ages, sulphur was also recommended for disinfecting contaminated premises and objects (2). In 1745, during an epidemic of cattle plague, soiled objects (and persons) were subjected to sulphur fumigation (1).

This use of sulphur probably stems from observations – among the various peoples – of the lethal action of this substance on small animals and plants, the suffocating odour of its vapours and, above all, the ease with which these vapours could be produced by simple combustion.

Mercury derivatives

Mercurial compounds, like those of sulphur, were used in ancient times as disinfectants and as a protective paint or coating in China, India, Egypt and Europe (2, 8). The use of these compounds in medicine was developed by the Arabs, who communicated this knowledge to Europeans, as stated by Mathaeus Platerius in 1140 (2). Mercurial compounds were used subsequently, particularly for combating syphilis in Italy in 1429 (2). In 1705, Homberg treated wood with corrosive sublimate (mercuric chloride) to prevent rot (2). The work of Robert Koch provided a conclusive demonstration of the efficacy of corrosive sublimate on *in vitro* cultures of microorganisms. Later, some organic mercurials (merthiolate, mercurochrome) became widely used in human and veterinary medicine.

As with sulphur, the use of mercury-based products as disinfectants was probably a result of direct observation of their corrosive effect.

Copper derivatives

Since very ancient times, seamen were aware that algae and fungi did not grow on the hulls of boats sheathed in copper. This observation may have inspired the practice whereby French vine growers protect vines against mildew (*Plasmapora viticola*) with Bordeaux mixture, containing copper sulphate (2). This compound was recommended in 1767 by Boissieu and Bodenare to protect wood from rot (2).

Alkalis

The general term 'alkali' (coined in 1509 from the Arab word *al-quali*, signifying soda) comprises all the bases which are capable of neutralising microorganisms, particularly viruses. The earliest such preparations were probably derived from lime.

The highly visible detergent effect of sodium on organic matter and the white traces left by lime (enabling simple verification of the application) probably motivated the use of these two substances as disinfectants from equally early times.

During the epidemics of cattle plague (rinderpest) which raged in the early 18th century, the authorities of affected countries recommended energetic measures to disinfect premises. These measures were often inspired by the original work of Giovanni Lancisi, physician and private chamberlain to Pope Innocent XII and Pope Clement XI. For disinfecting contaminated premises and materials Lancisi, in 1715, advised using concentrated soda lime to wash the fountains, recipients and drinking troughs used by cattle: *Fontes, vasa, ac labra, quo affecti boves potum ire confuerant, acri lixivio ex calce pottisimum parato abstergenda sunt* (6).

In 1730, Emperor Charles VI decreed that stables which had housed glanderous horses should be plastered with quicklime (16). Such arrangements figured in numerous texts published in Europe. In 1745, a decree at Oldenburg prescribed the cleaning with caustic soda of troughs from which cattle with plague had fed, and the cleaning of the woodwork and walls of their houses with lime-wash (1). Similarly, objects which had been in contact with rabid dogs should be treated with undiluted soap solution 'cast in large amounts upon traces of saliva from the rabid animal' (4).

In 1794, Erasmus Darwin recommended that if cattle plague were introduced into England, all cattle within a five mile radius of any confirmed outbreak should be 'immediately slaughtered, and consumed within the circumscribed district; and their hides put into quicklime before proper inspectors' (18).

Acids

The corrosive action of strong acids on hard substances (stone, metal, etc.) and the preserving action of organic acids (vinegar) on fruit and vegetables probably incited embalmers, and medical and veterinary physicians, to propose the use of acids as disinfectants.

The ancient Egyptians (circa 3000 BC) used palm wine and vinegar to rinse the abdominal cavities of human and animal cadavers prior to embalming (5). In the 1st century AD, Celsus recommended the use of vinegar for disinfecting abdominal wounds (2). Meyer, who published a book on the different ways of disinfecting postal items, reported finding a letter dated 1485 which had apparently been disinfected with vinegar (2). In his *Natural History*, published in 1625, Francis Bacon recommended disinfecting drinking water with small amounts of oil of vitriol (sulphuric acid) to keep it fresh (2).

It was not until 1676 that Van Leeuwenhoek offered the first scientific proof of the action of acids on 'animalcules', which he had discovered using the microscope of his own invention. When bacteria recovered from the surface of teeth were covered with wine vinegar, these 'very small objects moving with a swift motion, like eels' ceased their activity (2). Later, in 1693, Edmund King (in England) used a similar method to verify the neutralising action of other acids (e.g. sulphuric acid), or products such as sodium tartrate, wine, ink, blood and salt. However, after application of salt, it was possible to rehydrate the neutralised 'animalcules', restoring them to life (2).

Lancisi in 1715 recommended using vinegar (or vinegar water) for disinfecting objects (and even animals or persons) which had been in contact with cases of cattle plague (6). In 1752, Layard recommended another means of combating cattle plague, as follows: 'After the distemper is over, stables, cribs, mangers, racks, are all to be washed, first with hot soap-suds, and afterwards with vinegar and water. The walls of plaster, or clay, are to be first scraped; then a fresh coat of plaster or clay laid on, and, when dry, the walls are to be washed with lime-water' (7). This method was taken up once more in 1805, also against cattle plague, by Huzard, who recommended that strong vinegar be thrown onto heated stones or bricks to purify the air of cowsheds (16). In 19th century Prussia, regulations stipulated that all objects in contact with a rabid dog (feeding and drinking bowls, bed, bedding, collars) must be disinfected with nitric acid or undiluted soap solution (4).

Other chemical or biochemical products

A number of chemical products – including 'salts' (see above) – were formerly used as disinfectants, although these were sometimes impure or poorly defined. Ancient Egyptian embalmers soaked the cadaver for 70 days in a solution of sodium carbonate, sodium chloride and sodium sulphate (5). They also used resin and tar (5).

DISINFECTION BY PHYSICAL AGENTS

Disinfection by various physical methods was practised in very early times in an empirical way.

During Greco-Roman antiquity the conditions were specified, and later the mechanisms were identified. The methods can be grouped into four broad categories (raising of temperature, fumigation, drying and filtration), as described below.

Disinfection by raising the temperature

When humans first learned to create fire, one of the earliest uses to which they put this new tool was probably the purification of premises, objects, cadavers, etc. suspected of being at the origin of evils affecting humans and their animals.

Recommendations on this subject are numerous in ancient literature. The principal objects for disinfection are considered below.

Water

Soldiers of Alexander the Great followed the advice of the celebrated Aristotle, to boil their drinking water. In Persia, Avicenna (980-1046) indicated in Book III of his *Canon* that water may be rendered drinkable by evaporation and distillation, or simply by boiling (14). The wisdom of these recommendations was acknowledged over the ages, and was proved scientifically in 1776 by Spalanzani, who demonstrated that it was impossible for 'spontaneous generation' of microorganisms to occur once the fluid they lived in had been boiled for an hour (2). Previously, Joblot had demonstrated in 1718 that it was possible to sterilise an infusion of hay by boiling it for fifteen minutes and then sealing the container (2).

Objects and clothing

According to the Bible, Hebrew soldiers returning from war were required to flame all their equipment and clothing capable of resisting this treatment, and to plunge other garments in boiling water (2). In the Middle Ages, the clothing of persons with plague was burnt in order to prevent the spread of the black death (3).

An edict of Frederick the Great, King of Prussia, in 1716, decreed that the clothing of persons who had attended animals affected by cattle plague should be aired and 'exposed to flame'. There were heavy penalties for contravention: branding, forced labour for perpetuity and even flagellation followed by hanging (1).

In 1730, an order of Emperor Charles VI stated that drinking troughs and cribs used by glanderous horses should be burned (16). In 1745, the Oldenburg decree specified steps to eradicate cattle plague, including the burning of contaminated straw (1). Lavoisier in 1782 recommended decontamination by boiling of clothing worn by tuberculous persons (3). In 1784, a decree issued by the Council of the King of France obliged the owners of animals affected by contagious diseases to burn or scald all harnesses, wagons and any other objects which had been in contact with these animals (12). Viborg in 1797 recommended heating to 64-65°C objects which had been in contact with the 'contagious poison' responsible for equine glanders (10).

Cadavers

Incineration of cadavers of human beings or animals affected by disease has long been considered the best means of averting contagion.

Curiously, incineration was not necessarily regarded as being more effective than simple burial. Thus both Leclainche (8) and Smith (13) recall the following verse written by Tusser in 1573, and published in his highly original book entitled *Five hundred points of good husbandry*:

Whatever thing dieth, go burie or burne,
For tainting or ground or a worser it turne
Such pestilent smell of a carrently thing
To cattle and people greate peril may bring.

This book recommended burial **or** burning of all cadavers.

In 1713, Bates specified cremation of cattle which had died from cattle plague in England, followed by disinfection of the premises and leaving the buildings empty for three months (1).

This opinion was shared by neither Mead (in the case of human plague) nor Layard (cattle plague), for 'the infectious particles may be dispersed by the wind', as was observed in Venice during the black death epidemic (7).

Disinfection by fumigation

Fumigation has been used since ancient times to 'purify the air', perhaps due to the observation that smoke chased away insects, which were always suspected of causing human and animal disease. In the year 429 BC, fumigation was recommended by Hippocrates for controlling an epidemic which affected animals and humans in Athens.

The method consisted of burning odoriferous herbs in streets of the city, and was credited with halting the epidemic (5). This means of purifying the air, also useful for disinfecting objects, clothing, etc., was recommended by Vegetius in the 5th century AD for use against *morbus alienatus* (8), in the same century by Hierocles for use against malleus (13), in 1711 by Ramazzini, in 1715 by Lancisi and in 1721 by the Prussians for use against cattle plague (1), etc. During an outbreak of cattle plague at Montpellier in 1745, the Medical Faculty recommended fumigation of cowsheds with juniper wood and vinegar vapour (12). In 1752, during the epidemic of cattle plague ('contagious distemper') in England, Layard recommended the fumigation of stables using the following mixture: 'Wet gunpowder, pitch, tar, brim-stone, tobacco, frankincense, juniper and bay-berries, [...] should be burnt, and the smoke confined in these stables, more than once' (7). The fumigation of kennels contaminated by rabid dogs was also recommended in France, then in England by Jenner, towards the end of the 18th century (18). Chabert, in 1774, also recommended using fumigation in the control of anthrax (18). In 1805, Huzard recommended an alternative recipe for use against the same disease, which consisted of burning 'a good pinch' of a mixture of gunpowder, common salt, and crushed juniper berries and laurel wood (17).

Disinfection by drying

This method often involved the combined action of heat and ultra-violet radiation obtained by exposure to sunlight. Drying was recommended in the 7th century BC in the *Avesta Vandidad*, the Code of the doctrine of Zarathustra, for the purification of land where cadavers had been laid to rest. Drying was also used in ancient Egypt to complete the embalming of corpses, after soaking in a salt solution (5). This practice may have resulted from the observation of cadavers naturally mummified by drying in the desert.

Disinfection by filtration

The history of filtration is very long, for the Egyptians used this method to clarify grape juice by passing it through fabrics (2). This procedure perhaps inspired the mediaeval legend according to which the unicorn possessed the gift of 'dipping his single horn in the spoiled water to make it drinkable' (5). In Persia, Sayyid Ismail Jorjani (1042-1135) observed that filtered (or boiled) water took longer to go stale (15, 16). Filtration was also recommended in 1757 by the British Navy for the purification of water (passage through sand and charcoal).

However, the use of filtration to reduce the burden of pathogenic agents was not examined experimentally until later, notably by Magendie (1783-1855). This author inoculated dogs intravenously with extracts of putrid fish, and noted that the harmful effect of this inoculation was much reduced after the extract had been passed through filter paper (18). These attempts were repeated and refined later, particularly in the study of the pathogenicity of anthrax bacilli, by Tiegel, Klebs, Eberth, Chauveau, etc. It was Davaine, in 1863, who demonstrated conclusively that porcelain filtration retains anthrax bacteria (18).

DISINFECTION BY BIOLOGICAL AGENTS

Examination of the principles of action of biological disinfection necessarily lacks the precision of the two previous sections, as it is rarely possible to establish that a given disinfection procedure acted by a purely biological process without the simultaneous involvement of chemical or physical neutralisation.

Burial

Burial was certainly one of the most common procedures for 'disinfection', particularly of cadavers, by an extremely complex biological process: enzymatic degradation plus changes in oxygen content, pressure, pH, temperature, etc.

This is probably the oldest method of disinfection used by mankind, and it is almost an animal reflex to get rid of evil smelling and decaying material by burial. Thus, according to the book of Deuteronomy, Hebrew soldiers were provided with spades in order to bury their excreta and avert the spread of an epidemic (3). This method seemed to the Romans to be more effective than incineration, to judge by the account given by Virgil (Georgics, Book III) of the epizootic of Noricum, occurring several centuries BC (8). The poet writes of 'animal cadavers decomposed by a hideous rot'. He stated that their remains should be buried in ditches 'because their skins were of no further use, and their viscera could not be purified by water or overcome by flame': *nam neque erat coriis usus nec viscera quisquam aut undis abolere posest aut vincere flamma* (8).

Early in the 5th century, Vegetius ordered the deep interment of horses which had died from contagious diseases, particularly at the time of the invasion by Hun horsemen (4). In 751, Boniface issued written instructions for rabid animals to be buried deep in the ground: *animalia quae a furentibus, id est rabidis, lupis et canibus fuerint lacerati, in foveam proicienda sunt* ('animals which have been caught by raging – that is, rabid – wolves or dogs must be thrown into a ditch') (4).

In 1502, the authorities of Nördlinger were responsible for burying the carcasses of animals which had died from rabies and, in the case of dogs, the grave digger was paid a price of eight pfennigs for this work (4). In 1523, Fitzherbert recommended removal of animals which had died from 'murrain' (anthrax), except the skin (which was sent to a tannery) and the head (which 'was to be placed on a pole to notify to others "that sickness existed in the township"') (13). In 1715, during a cattle plague epidemic, Lancisi recommended collection of milk from affected cows for burial in a trench: *emunctum ex uberibus lac injiciatur in defoffam humum* ('milk drawn from the udders must be thrown into a ditch') (6).

A great number of official publications were subsequently based on the same principle, though with refinements in burial technique. Thus, a decree issued by the Council of the King of France (June 1771) stipulated that 'animals killed or dead from epizootic disease may not be abandoned in forests, thrown into rivers or placed on rubbish dumps, nor may they be buried in stables, courtyards, gardens or elsewhere within the precincts of towns and villages. They must be cut into quarters and transported (not dragged) to the ditches, which must be 8-10 feet (2.4-3.0 m) deep and at least 100 *toises* (approximately 200 m) from the nearest house. The flesh and bones of animals should be buried in these ditches, which are subsequently to be filled in to the previous level of the soil. Owners or farmers must provide carts, horses, harnesses, stretchers or sledges, and even labour if needed, on pain of a fine of 50 francs' (12). This decree was perhaps inspired by the Order of the Privy Council in London (17 October 1747), which stipulated that the cadavers of animals affected with cattle plague should be buried within three hours of death, to prevent the *effluvia* from being carried away by the wind. For the same reasons, in 1752, Layard proffered the following advice: 'I must publickly disapprove of cutting and slashing the hides, to render them unfit for use, and likewise still more of dismembring the carcasses to bury them with greater ease. Such incision, and taking off the limbs, only serve to give vent to all that putrid air observed puffing up the skin in the last stage of the illness' (7).

Other methods

Other biological methods include the following procedures:

– In Chapter 6 of the *Avesta Vandidad*, Ahura Mazda recommended laying fallow (for one year) land on which dogs or humans had died, or (for fifty years) land where cadavers had been buried (14).

– In 581, Gregory of Tours recommended combating cattle plague by driving herds of cattle along streets so that their breath might neutralise the action (of virus). A similar result could be achieved with the breath of goats (11).

– Agostine Gallo (1499-1570) recommended the disinfection of cattle fodder in the case of contagious bovine pleuropneumonia by washing the fodder with water in which aromatic plants had been boiled (18).

CONCLUSION

This review of chemical, physical and biological methods of disinfection is far from exhaustive. Its sole purpose is to recall that long ago, mankind had already learnt to manipulate certain biological processes (fermentation, putrefaction, infection, etc.) by adopting specific procedures. Some of these procedures raise a smile today, but most were thoroughly effective. Coupled with slaughter or segregation of sick animals, these methods for disinfecting objects, housing or cadavers contributed to halting certain major epidemics. It is remarkable that these procedures met with such success, given that they were applied in complete ignorance of the actual cause of these epizootics and in the absence of vaccines or specific therapeutic measures. A large part of this success was due to the ruthless enforcement of regulations in certain countries, demonstrating the advantages of rigourously-applied hygienic prophylaxis.

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