HSE

SARS-CoV-2 (COVID-19) Transmission in Meat Processing Factories: Evidence Summary to 27 July 2020

Prepared by the **Health and Safety Executive**

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Evidence Report

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Scientific evidence about COVID-19 is vital to inform decision making by HSE and across Government. The national and global scientific evidence base about COVID-19 (SARS-CoV-2) continues to develop. Evidence summaries give the best available evidence on specific questions at the time of their preparation in order to inform the COVID-19 response. Subsequent HSE guidance and advice may therefore have been updated.

This rapid evidence summary considered three questions about SARS-CoV-2 transmission in meat processing factories including abattoirs. The context is concerns about outbreaks in the UK meat processing industry. Similar outbreaks have been seen in other countries. The summary was completed on 27 July 2020. HSE scientists carried out the summary to inform decision making by HSE policymakers. The questions are: (i) Is there evidence that working in cold conditions increase the infection risk? (ii) Is there evidence that SARS-CoV-2 survives longer on stainless steel than other surfaces? (iii) Is there evidence that pressure washing of surfaces increase the infection risk? HSE chose these questions following discussion with the Food Standards Agency (FSA). The summary gives conclusions about these three questions only. Many other factors influence both the risk of SARS-CoV-2 transmission within food processing factories and outbreaks of infection.

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SARS-CoV-2 (COVID-19) Transmission in Meat Processing Factories: Evidence Summary to 27 July 2020

Key messages

Evidence Summary

This evidence summary was prepared to inform decision making by HSE policymakers in relation to outbreaks of COVID-19 infections in employees in meat processing factories. The evidence summary considers three factors that may contribute to the transmission of the virus and risk of infection. These factors are temperature and humidity, the type of surface used in meat processing, and use of pressurised washers to maintain food hygiene standards. The evidence summary was completed on 27 July 2020.

The summary concluded:

- Experimental and epidemiological studies reported evidence that COVID-19 remains infective from hours to days at temperatures below 20^{o}C. Above this temperature infectivity declines, and above 65^{o}C the virus infectivity is inactivated.
- COVID-19 infectivity was prolonged on inert smooth surfaces such as stainless steel, glass, and plastic. It declined rapidly on surfaces such as copper or absorbent paper and at temperatures above 20^{o}C and 40-65% relative humidity.
- Employees using high-pressure hoses to clean in meat processing factories may be at risk of inhaling small water droplets containing COVID-19. Food Standards Agency guidance recommends that high-pressure washers should not be used during food processing. Their recommendation is that high flow low-pressure hoses should be used for cleaning work.

HSE guidance

COVID-19 workplace control measures:
https://www.hse.gov.uk/coronavirus/index.htm

Safe working in the manufacturing sector during the pandemic:
https://www.hse.gov.uk/coronavirus/working-safely/manufacturing/index.htm

Executive summary

Background

Scientific evidence about COVID-19 is vital to inform decision making by HSE and across Government. The national and global scientific evidence base about COVID-19 (SARS-CoV-2) continues to develop. Evidence summaries give the best available evidence on specific questions at the time of their preparation in order to inform the COVID-19 response. Subsequent HSE guidance and advice may therefore have been updated.

Aim

This evidence summary considered three questions about factors affecting COVID-19 outbreaks in UK meat processing factories. The questions were agreed with the Food Standards Agency (FSA). The questions are: (i) Is there evidence that working in cold conditions increase the infection risk? (ii) Is there evidence that COVID-19 survives longer on stainless steel than other surfaces? (iii) Is there evidence that pressure washing of surfaces increase the infection risk?

Method

A literature search was undertaken with relevant search terms using public and academic search engines. These searches included government guidance documents. The research studies were ranked for relevance and quality of the study design and methodology. This took a structured approach to sifting and summarising evidence for each research question.

Conclusions

The evidence summary was completed on 27 July 2020. The conclusions are:

- Experimental and epidemiological studies reported evidence that COVID-19 remains infective from hours to days at temperatures below 20^{o}C. Above this temperature infectivity declines, and above 65^{o}C the virus infectivity is inactivated.

- COVID-19 infectivity is prolonged on inert smooth surfaces such as stainless steel, glass, and plastic. It declines rapidly on surfaces such as copper or absorbent paper and at temperatures above 20^{o}C and 40-65% relative humidity.
- Employees using high-pressure hoses to clean in these factories may be at risk of inhaling small water droplets containing COVID-19. FSA guidance recommends that high-pressure washers should not be used during food processing. At other times high-flow but low-pressure hoses should be used.

The evidence summary reaches conclusions about these three questions only. Many other factors influence both the risk of COVID-19 transmission within food processing factories and outbreaks of infection.

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1. Overview

1.1 Issue

HSE has concerns about outbreaks of COVID-19 (classified as SARS-CoV-2) infection in workers in meat processing factories. HSE Policy makers asked HSE scientists to undertake an evidence summary about the transmission of SARS-CoV-2 in these factories. Three questions were discussed and agreed with the Food Standards Agency (FSA), which considered environmental circumstances that may enhance SARS-CoV-2 transmission. This summary includes an overview, key conclusions and a methodology section.

1.2 Background

Evidence about the transmission and infectivity of SARS-CoV-2 is being published on a daily basis. This summary mostly considered findings from peer-reviewed published studies but it was necessary to include emerging findings from a few pre-publication studies. There were few studies of SARS-CoV-2 transmission in workplaces other than healthcare settings. However, additional evidence from epidemiological studies about the effect of temperature and humidity on SARS-CoV-2 transmission was available.

1.3 The three research questions

To address uncertainties about the transmission of SARS-CoV-2 in food processing factories, three research questions were chosen after discussion with the FSA

- Is there evidence that working in cold conditions increases the SARS-CoV-2 infection risk?
- Is there evidence that SARS-CoV-2 survives longer on stainless steel than other surfaces?
- Is there evidence that pressure washing of surfaces can increase the infection risk from SARS-CoV-2?

- These are not the only factors influencing the risk for transmission of this virus within food processing factories. Other occupational factors include:
- work activities involving aerosol-generating activities
- employees working in close proximity
- environments with reduced air ventilation
- recirculating air-cooling systems
- generation of bioaerosols
- surfaces coated in organic matter.

Social factors are also likely to contribute to outbreaks of SARS-CoV-2 infection in food factories, such as employees living in high occupancy accommodation and sharing transport to work.

2. Evidence summary for temperature effects

2.1 Question

Is there evidence that working in cold conditions increases the SARS-CoV-2 infection risk?

2.2 Overview

A small number of published studies have examined environmental variables that may alter the survival of infective SARS-CoV-2. These studies were often different in design and methodology and many investigated Betacoronavirus associated with other pandemics such as severe acute respiratory syndrome (SARS) and Middle East Respiratory Syndrome (MERS). Some experimental studies were based on surrogate viruses as models for SARS-CoV-2. Only a few studies had directly investigated the transmission and infectivity of SARS-CoV-2.

2.3 Conclusions

There are no studies in occupational settings, other than healthcare, where environmental factors that affect transmission and infection of SARS-CoV-2 have been investigated. Published experimental studies provided consistent evidence that below 20^{o}C, SARS-CoV-2 virus survives and remains infective for longer periods. Above 20^{o}C the survival of the virus declines linearly until above 65^{o}C when it is almost completely inactivated within minutes.

Epidemiological studies have provided evidence that SARS-CoV-2 infections and deaths are reduced at high ambient temperatures and humidity after accounting for variables of population density and movement. However, the relationship between environmental temperature and humidity and viral survival is complex and influenced by many variables.

2.4 Supporting evidence

The contamination of surfaces by SARS-CoV-2 from exhaled droplets (termed fomites) is one possible route for transmission involving contact with surfaces and transferring the virus to the mouth, nose or eyes. Other routes of transmission include the inhalation of aerosols containing droplets of different size. The largest droplets deposit in the nasal passages and upper airways, and the finest droplets of respirable size (with a modal diameter around 4.0 μm diameter) travel into the deeper parts of the lung. Both large and fine droplets are expelled much further when infected individuals cough, sneeze, sing, or talk loudly. Even light breathing and quiet talking may generate a fine aerosol containing the virus.

Infectivity is critical for the spread of the virus and many factors influence this including whether the viral membrane is damaged and can no longer fuse to cells in the airways, nose or eyes. Viral infectivity can be reduced or sustained by variables such as temperature, humidity, the presence of biological materials, and interactions with different surfaces. For example, on hard non-absorbent and non-reactive surfaces like steel, plastic, etc., SARS-CoV-2 viability is sustained longer than on other surfaces. Tests to determine how these factors affect viral infectivity are typically based on recovering the virus from the surface of the test material and incubating the sample with, for example, cultured lung epithelial cells. After a suitable period of days the epithelial cells are examined to identify opaque plaques where virus replication has taken place. The number of the plaques is then quantified as a measure of infective virions that survived the test treatment(s).

2.5 Experimental investigations

Review by Kampf, et al. (2020a)

Kampf, et al. (2020a) discussed the results from 10 separate studies into the effects of thermal disinfection in solution on the infectivity of SARS, MERS, Transmissible Gastroenteritis Virus (TGEV), Mouse Hepatitis Virus (MHV) and Porcine Epidemic Diarrhoea Virus (PEDV). Complete loss of infectivity for these viruses generally occurred after 30 minutes at 60^{o}C, after 15 minutes at 65^{o}C, and after one minute at 80^{o}C. The higher temperature treatments reduced SARS infectivity by at least 4 $Log_{10;}$ at 4^{o}C, or 20^{o}C, there was either no, or negligible, loss of viral infectivity.

Review by Kampf, et al. (2020b)

Kampf et al. (2020b) also reviewed published studies of different Coronavirus including a surrogate (HCoV-229E) for SARS-CoV-2. These studies examined the effects of temperature and humidity on infectivity of these viruses plated onto different surfaces (steel, aluminium, glass, wood, plastic, paper and protective glove materials). They concluded that at 4^{o}C viral infectivity persisted up to and beyond 28 days. In contrast between 20^{o}C, 30^{o}C and 40^{o}C the infectivity was retained only for a few hours to days depending on the type of substrate, level of humidity, or numbers of virus particles in the fomite. On most of these inert materials at ~20^{o}C SARS-CoV viruses survived from 2-9 days with a starting inoculum as low as 10^3 infectious virions per millilitre. At temperatures >30^{o}C viral infectivity was typically retained for shorter periods up to 4 days.

Experimental investigation by Kratzel (2020)

Kratzel et al. (2020) added 1.58×10^7 infectious dose per millilitre of SAR-CoV-2 (a clinical isolate) to metal discs in a solution containing 0.3% bovine serum albumin to simulate surface biological contamination. They investigated incubation at 4^{o}C, 20^{o}C or 30^{o}C up to 214 hours. Within the first hour at all three temperatures as the liquid samples dried viral infectivity reduced ~100-fold (from ~10^7 to 10^5). After this point, the number of infective virions declined progressively until the lower detection limit of the assay was reached between 96 and 168 hours later. Overall the temperature did not reproducibly affect the time that some viral particles remained infective. Certain caveats apply to this study. A large number of infective virions were added to the metal discs in this test in which the maximal test temperature was 30^{o}C. The solution in which the virus was dispersed also contained an additional carrier protein, which is likely to have enhanced viral survival.

Experimental investigation by Biryukov (2020)

Biryukov, *e*t al. (2020) evaluated the effect of temperature and humidity on the stability of SARS-CoV-2 diluted 1:10 in simulated saliva and deposited onto stainless steel, acrylonitrile butadiene styrene (ABS) plastic, or nitrile rubber glove coupons. Material coupons were placed in an environmentally controlled testing chamber which maintained RH and temperature at set points They compared temperatures from 24 to 35°C and relative humidity (RH) from 20-60%. For changes in RH at 24^0C the mean half-life of the virus fell from ~15 hours at 20% RH to ~9.0 hours at 60% RH. At the higher temperature of 35^0C, the mean half-life of the virus fell from ~7.0 hours at 20% RH to ~2.0 hours at 60% RH. The different test materials did not significantly differ in their effect on virus infectivity but temperature and humidity were significant variables. The test materials did not include surfaces shown to inactivate rapidly this virus, such as Copper.

Experimental investigation by Darnell, et al. (2004)

Darnell, et al. (2004) investigated the inactivation of SAR-CoV-1 at higher temperatures (56^oC, 65^oC and 75^oC) in solution. These tests were based on a very high loading of virus particles and examined temperature and time on viral infectivity. At 56^oC most of the virus was inactivated after 20 min but some remained infective after 60 minutes. At 65^oC most of the virus was inactivated after 4 minutes with residual infectivity detectable after 20 minutes. At 75^oC the virus was completely inactivated within 15 minutes.

Review by Dietz, et al. (2020)

Dietz, et al. (2020) reviewed evidence that temperature and humidity play a role in the survival of infective SARS and ARS-CoV-2 viruses within build environments. At typical indoor temperatures a relative humidity above 40% was detrimental to the infectivity of SARS-CoV viruses (Kim et al. 2007; Noti et al. 2020). It was concluded that a high relative humidity in buildings (between 40 and 60%) limited the spread and survival of SARS-CoV-2 partly through sustaining larger aerosol droplets that deposit quickly (Kim et al. 2007; Marr et al. 2019; Xie *et al*. 2007).

Experimental investigation by van Doremalen, et al. (2020)

van Doremalen, et al. (2020) undertook an experimental study to investigate the survival up to 7 days of SARS-CoV-1 and SARS-CoV-2 on different surfaces at 21-23°C and 40% RH, and in an aerosol at 21-23°C and 40% RH. They concluded that the virus remained viable at room temperature up to 3 hours but the overall titre reduced by ~25% for SARS-CoV-2 and ~20% for SARS-CoV-1.

2.6 Epidemiological and environmental studies:

Study by Pequeno, et al. (2020)

Pequen*o,* et al. *(202*0) studied 27 cities in Brazil during the first month of the pandemic and the interaction between meteorological conditions (temperature, solar radiation, air humidity and precipitation) and cumulative confirmed SARS-CoV-2 cases. This analysis included variables such as SAR-CoV-2 test data, arrivals at airports, population density and the proportion of elderly people and social factors such income. The variables that mostly accounted for the trends in infection were numbers arriving at local airports and the city's population density. After accounting for these variables ambient temperature accounted for the greater number of cases in colder cities and on cold days. Their evidence indicated that a 1^{o}C increase in ambient temperature was associated with an 8% decrease in confirmed cases.

Study by Eslami and Jalli (2020)

Eslami and Jalili (2020) reviewed the published evidence about environmental variables on SARS-CoV-2 infectivity. They noted epidemiological studies reported a general association between a decreased prevalence of infection and increased ambient temperature. This was consistent with WHO (WHO 2020) advice that heat, high or low pH, and sunlight reduce the infectivity of Coronaviruses.

Study by Xu, et al, (2020)

Xu, et al. (2020) investigated environmental factors associated with the incidence of SARS-CoV-2 in different regions of China during the pandemic which included air quality and other meteorological variables. Modelling the data demonstrated that increased viral infections were associated with poor air quality, temperatures from 10°C to 20°C, and relative humidity from 10% to 20%. These results are consistent with the experimental findings that viral infectivity declines less quickly at lower temperature and reduced humidity.

Additional experimental studies

The effects of temperature and humidity on viral infectivity are thought to be due to removal of structural water molecules from the viral capsid (Yang et al. 2012). This causes surface tension, shear stress, and rearrangements of the viral membrane. Enveloped viruses such as SARS-CoV-2 with a lipid membrane survive better at lower relative humidity (Xu et al. *2020*). It has been found that infection from MERS virus is more likely to occur under dry conditions (Gardner, et al. 2019). Exceptions to this relationship have been reported (Lakadamyali, et al. 2003; Laliberte, et al. 2011).

3. Evidence summary for surface effects

3.1 Question

Is there evidence that SARS-CoV-2 (COVID-19) survives longer on stainless steel than other surfaces?

3.2 Overview

A small number of studies were published about the effects of different surfaces on the infectivity of SARS-CoV-2 but used different methods to assess viral infectivity. They mostly investigated Coronavirus such as, SARS and MERS, or a safe surrogate virus model for SARS-CoV-2. Some studies in clinical environments investigated the survival of SAR-CoV-2 on surfaces to determine the efficacy of disinfection and cleaning methods.

A very recent published article (Goldman E, 2020) drew attention to deficiencies in many of published studies of virus survival on different surfaces. The author's main concern was the very high number of virus particles added to these materials in these tests. In comparison, studies of SARS-CoV-2 contamination on surfaces in hospital wards had generally failed to detect high numbers of virus except close to the patients during their early stage of infection.

3.3 Conclusions

SARS-CoV-2 virus can survive for longer on smooth and inert surfaces including metals such as stainless steel, aluminium, glass, plastics and polymers. In contrast it declined rapidly in minutes to hours on reactive metal surfaces such as copper and nickel and absorbent materials such as cellulose. Other factors that decreased viral survival rates on surfaces included higher ambient temperature (above 20^{o}C) and relative humidity (above 50%). Estimates suggested that on smooth inert surfaces at low temperature and humidity, SARS-CoV-2 remained infective for several days. There was insufficient evidence that stainless steel performed more poorly than other inert smooth materials used in food processing factories. It is probable that the presence of proteins on work surfaces in food processing plants increases the survival of the SARS-CoV-2.

3.4 Supporting evidence

Review by Fiorillo, et al. (2020)

Fiorillo, et al. (2020) undertook a review of published evidence on the survival of Coronavirus and SARS-CoV-2 on different surfaces**.** The review was based on systematic principles but the authors were unable to complete a full systematic analysis because of the small number and inadequate quality of many studies. Of 25 studies considered relevant to their research questions only four met international criteria for inclusion in a systematic review.

Experimental investigation by Warnes, et al. (2015)

One of these studies (Warnes, et al. 2015) incubated Coronavirus on different materials, including stainless steel, at 21^{o}C up to five days. On stainless steel, polyfluorotetraethylene (PTFE), polyvinyl chloride (PVC), ceramic tiles and glass, viral infectivity persisted for 5 days. This was reduced to ~3 days on silicon rubber but rapidly inactivated in less than two hours on brass, copper and nickel.

Experimental investigation by van Doremalen, et al. (2020)

Another study by van Doremalen, et al. (2020) investigated different materials on the infectivity of SARS-CoV-2 and SARS-CoV-1 at 21-23^{o}C and 40% RH. This included stainless steel, plastic, copper, and cardboard. They reported that SARS-CoV-2 and CoV-1 were more stable on stainless steel and plastic than on copper and cardboard. Virus infectivity was detected up to 72 hours but after 48 hours reduced ~1000 fold on stainless steel and after 72 hours on plastic. SARS-CoV-2 and CoV-1 infectivity was completely lost within 4 to 8 hours on copper surfaces. On cardboard, no viable SARS-CoV-1 was detected after 8 hours and for SARS-CoV-2 after 24 hours.

Review by Kampf, et al. (2020)

Kampf, et al. (2020) reviewed 22 published studies that examined different materials on the infectivity of Severe Acute Respiratory Syndrome (SARS) coronavirus, Middle

East Respiratory Syndrome (MERS) coronavirus and endemic human coronaviruses (HCoV). They found evidence that high titres of infective viruses persisted on steel, glass or plastic for many days. On steel these viruses persisted for 48 hours at 20^{o}C, and between 8 and 24 hours at 30^{o}C. For some of these viruses infectivity was retained beyond 28 days at 4^{o}C.

Review by Scully (2020)

Scully (2020) reviewed evidence about the rapid effects of reactive metals such as copper, nickel and brass in inactivating Coronavirus and SARS-CoV-2. They stated that the primary mechanism of damage to the virus envelope was free radical generation from the surface of the metals driven when water was present, or as an oxidative process in relatively dry environments.

Experimental investigation by Biryukov, et al. (2020)

Biryukov, et al. (2020) undertook tests on the stability of SARS-CoV-2 in a simulated and clinically relevant fomite matrix dried onto nonporous materials. SARS-CoV-2 decayed more rapidly when either humidity or temperature was increased but not when the volume of the test droplet increased. The different materials such as stainless steel, plastic, or nitrile glove did not alter the rate at which viral infectivity declined. Depending on the RH at 24°C the half-life of the virus ranged from 6.3 to 18.6 hours; at 35°C it ranged between 1.0 and 9.0 hours. These findings suggested that on non-porous and non-reactive surfaces this virus might persist indoors from hours to days.

Experimental investigation by Chin, et al. (2020)

Chin, et al. (2020) undertook an investigation of the stability of SAR-CoV-2 in clinical environments on different material surfaces. They found that infective virus could not be recovered from tissue paper after 3-hours but on treated wood surfaces, or cloth, it could be recovered up to 2 days. The virus was more stable on smooth surfaces and infectious virus was detected on glass after 4 days and stainless steel and plastic after 7 days. They concluded the greater reduction of viability on porous surfaces such as tissue paper might be an experimental artefact due to inefficient extraction of the viral particles from these materials.

3.5 Pre-publication research

Experimental investigation by Liu, et al. (2020)

Liu, et al. (2020) reported an investigation into the survival of a clinical isolate of SARS-CoV-2 on different materials. They found that SARS-CoV-2 added to stainless steel, plastic, glass, ceramics, wood, latex gloves, and a surgical mask, retained infectivity up to seven days. There was a rapid loss of infectivity within 1 hour after incubation on paper and cotton clothes.

Experimental investigation by Guillier, et al. (2020)

Guillier, et al. (2020) collected data from 26 published studies on the survival of different Coronavirus in surface fomites. Five different mathematical models were fitted to this data and the most appropriate model incorporated the effects of temperature and relative humidity. These findings supported a conclusion that Coronaviruses persisted better at low RH and less well at intermediate RH. At low RH the virus was more resistant to thermal inactivation (Sauerbrei *et al*. 2009). Above 20^{o}C viral infectivity reduced linearly and above 60^{o}C viral infectivity was almost completely inactivated.

4. Evidence summary for pressure washing

4.1 Question

Is there evidence that pressure washing of surfaces can increase the infection risk from SARS-CoV-2 (COVID-19)?

4.2 Background

The Food Standards Agency (FSA 2020a) good practice guidance for hygiene and cleaning in food processing states:

"If cleaning while production is in progress is unavoidable, food must be protected from splashing, aerosol spray or other contamination. **Do not use high-pressure hoses,** disinfectants and other cleaning chemicals on equipment, structure and fittings while food is present."

Recently updated guidance by the Welsh Government (Welsh Government, 2020) on reducing SARS-CoV-2 infection risks in food processing states:

"Avoid generation of aerosols as much as possible. **Power washing should be high throughput/lower pressure rather than low throughput/high pressure** to minimise the risk of spray and aerosol generation"

Whilst high-pressure washers should not be used near food production lines, they may remain in use for deep cleaning tasks after food-processing tasks are completed.

4.3 Overview

There was no published evidence on the use of pressure washing in cleaning facilities contaminated by SARS-CoV-2. There was evidence from occupational studies and FSA guidance on appropriate cleaning methods for meat-processing factories.

4.4 Conclusions

There was no published research on pressure washers for cleaning in meat processing factories and whether this increases the transmission of SARS-CoV-2. Studies in other occupational settings found that pressure washers generated an aerosol of fine droplets containing bacteria and endotoxin. Employees using them also suffer symptoms of irritancy and inflammation in their airways. If pressure washers are used in meat processing factories this could increase the risk of worker exposure to SARS-CoV-2. However, FSA guidance recommends that they should not be used around food processing activities. If there is requirement for deep cleaning, current good practice guidance recommends high flow low-pressure washers. The requirements for RPE should be considered as part of the overall work risk assessment.

4.5 Supporting evidence

Study by Burfoot, et al. (2003)

Burfoot, et al. (2003) investigated several cleaning operations in food factories that produces aerosols carrying microorganisms. They used lasers to measure the size, fluxes and concentrations of airborne droplets >1.0 μm. The low-pressure hosing produced ~$1.4 \times 10^{7}.m^{-3}$ droplets compared to a floor scrubber which produced ~$4.6 \times 10^{6}.m^{-3}$ droplets. The background particle count in the room was $6.0 \times 10^{5}.m^{-3}$. Using low-pressure hoses increased the risk of generating respirable droplets compared to the other cleaning methods**.**

Study by O'Shaughnessy, et al. (2012)

O'Shaughnessy, et al. (2012) investigated employee exposure to dust and bacterial endotoxin when power washers were used to clean pig units. Median personal inhalable mass concentration of 7.14 mg m^{-3} and median endotoxin concentration of 12,150 $EU.m^{-3}$ were measured. Expressed as 8-h TWA samples, one of 19 samples exceeded a US OSHA regulatory dust limit of 15 $mg.m^{-3}$. The median personal exposure to endotoxin was estimated as 40,350 $EU.m^{-3}$ greatly in excess of a health based recommended occupational exposure limit (HBROEL) for endotoxin of 90 $EU.m^{-3}$. The HBROEL was proposed by DECOS the Dutch Expert Committee on

Occupational Safety committee (Health Council of the Netherlands: Endotoxins 2010).

Review by Madsen and Matthiesen (2013)

Madsen and Matthiesen (2013) reviewed occupational studies that investigated exposure to bio-aerosols and chemicals generated by high pressure cleaning (HPC) washers some of which are summarised below.

Study by Braymen (1969)

In one study of cleaning in a public health setting, Braymen (1969) investigated use of a HPC unit operated at 6-litres per minute and a nozzle pressure of 500 psi. This generated an aerosol containing a larger number of airborne microorganisms in droplets of ~2.0–3.5μm diameter.

Study by Larsson, et al. (2002)

In another study by Larsson, et al. (2002) of HPC cleaning in a pig barn the median exposure to inhalable dust and bacterial endotoxins rose to 0.94 $mg.m^{-3}$ and 830 Endotoxin Units (EU).m^{-3} respectively. The respirable dust levels were 0.56 $mg.m^{-3}$ and the respirable endotoxin levels were 230 $EU.m^{-3}$.

Study by O’Toole, et al. (2009)

O’Toole, et al. (2009) studied HPC washing of cars and reported this produced respirable aerosol droplets of 0.2–2.0 μm diameter as well as larger 3–10 μm droplets.

Study by Haas, et al. (2020)

Haas, et al. (2020) compared high and low pressure washing for cleaning in a sewage treatment plant and found that exposure to bacterial endotoxin was higher with HPC. However, the emissions were strongly influenced by the shape of the object being cleaned (Visser *et al.* 2006). Stationary air sampling at another sewage treatment plant found significantly higher concentrations of Coliform bacteria (1×10^3 colony forming units (cfu).m^{-3}) and Mesophilic bacteria (4×10^4 $cfu.m^{-3}$) in areas where HPC was used compared to areas of the plant not cleaned by HPC

Study by Langworth, et al. (2001)

A study by Langworth et al. (2001) in Sweden showed that when HPC was used to remove graffiti from surfaces there was an increased personal exposure to Pseudocumene (1,2,4-trimethylbenzene) a hazardous chemical. This exposures occasionally exceeded the Swedish national exposure limit but only for work carried out in poorly ventilated spaces such as in lifts. These exposures were generally 20% lower than the Swedish permissible exposure limit for total solvent (measured as a 8-hour time-weighted average). Nevertheless the employees reported more non-specific irritation of the respiratory tract compared to non-exposed individuals (Nieuwenhuijsen *et al.* 1999).

Study by Larsson, et al. (2002)

Larsson et al. (2002) investigated volunteers cleaning a horse stable using HPC and showed acute inflammation of their upper airways. These symptoms were reduced when they wore respiratory protective half-masks fitted with a Sundströms p3 filter

Study by Anundi, et al. (1993)

Anundi et al. (1993) investigated workers removing graffiti by HPC and exposed to organic solvents. They reported symptoms of irritation in the workers upper respiratory tract and this was reduced when they wore respiratory protective half-masks

5. Methodology for literature searches

5.1 Literature search approach and study ranking

The literature searches were based on specific key search words that related to the three research questions (Table 1). The search period included publications between 2000 and July 2020 covering the period when most investigation took place in relation to SAR, MERS and the recent SARS-CoV-2 pandemics.

These searches for peer-reviewed studies were undertaken using the search engines Web of Science™, SCOPUS™ and PubMed™. Additional 'grey literature' searches for government guidance and studies' in press were identified using Google and Google Scholar search engines. The citations and abstracts for relevant studies were imported into the Endnote V9.0 bibliographic database and organised into thematic topic folders.

Each study was ranked based on criteria for the relevance and quality of the study in terms of:

- The research provided evidence to answer the research questions (i.e., effects of temperature, surface of materials and use of pressure washers)
- The paper was written in English (limited time prevented translation of other languages)
- Where possible the paper had been accepted after peer review for publication in an established scientific journal
- The methodology used was clearly described and traceable.
- That in addition to their conclusions the authors had identified uncertainties introduced by their methodology or constraints on the research.

Given the urgent requirement for this summary a full systematic review was not undertaken but a structured approach to searching, sifting and summarising evidence was adopted. Each paper was assessed in terms of the clarity of the research question, the adequacy of the methodology and data analysis, and whether the results were likely to be relevant in the context of meat processing units in the

UK and EU. Some studies were published as short rapid publications and therefore did not provide detailed explanation about methodology or results obtained.

5.2 Caveats

- There was limited published evidence to address the question about use of pressurised hoses and transmission of Coronaviruses. Consequently studies in other parts of industry that examined risks for transmission of other infective agents were considered.
- There is very limited published evidence from occupational settings about the effects of ambient temperature on the viability of Coronaviruses, and specifically SARS-CoV-2. Most research was undertaken in healthcare settings where environmental air management systems typically are in place. This means that studies on the viability of SARS-CoV-2 in healthcare setting are likely to reflect controlled environmental variables less representative of other workplace settings.
- Given the very recent history of the SAR-CoV-2 pandemic the number of studies specifically relevant to this virus was limited. Whilst many new studies continue to be submitted for publication the results of unpublished studies are being made available on-line. Some of these studies have been included in this summary but clearly highlighted as pre-publication and caution should be applied to the findings until full peer review has been completed.

Table 1. Key search terms (bold headings) and terms related to these

Materials	**Pressurised washers**	**Food industry**	**Environment**	**Coronavirus**	**Surfaces**
Stainless/	Pressure/s	Meat	Temperature	SARS	Bench/es
steel	Bar	Abattoir/s	Cold Heat	SARS-CoV	Worktop/s
Bronze	Cleaner/s	Processing	Humidity	MERS	Floor/s
Nickel	Washer/s	Poultry	Moisture	MERS-CoV	
Plastic	Low/High	Chicken	Light Sunlight	SARS-CoV-2	
Glass	HPC	Cow/s	Ultraviolet	COVID-19	
Polymer	Lance	Pig/s			
Paper		Swine			
Cardboard		Hogs			
Copper					

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Scientific evidence about COVID-19 is vital to inform decision making by HSE and across Government. The national and global scientific evidence base about COVID-19 (SARS-CoV-2) continues to develop. Evidence summaries give the best available evidence on specific questions at the time of their preparation in order to inform the COVID-19 response. Subsequent HSE guidance and advice may therefore have been updated.

This rapid evidence summary considered three questions about SARS-CoV-2 transmission in meat processing factories including abattoirs. The context is concerns about outbreaks in the UK meat processing industry. Similar outbreaks have been seen in other countries. The summary was completed on 27 July 2020. HSE scientists carried out the summary to inform decision making by HSE policymakers. The questions are: (i) Is there evidence that working in cold conditions increase the infection risk? (ii) Is there evidence that SARS-CoV-2 survives longer on stainless steel than other surfaces? (iii) Is there evidence that pressure washing of surfaces increase the infection risk? HSE chose these questions following discussion with the Food Standards Agency (FSA). The summary gives conclusions about these three questions only. Many other factors influence both the risk of SARS-CoV-2 transmission within food processing factories and outbreaks of infection.

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