Decontamination of Technical Rope Rescue Equipment in the COVID-19 Novel Coronavirus pandemic

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Abstract

The SARS-CoV-2 novel human coronavirus, also known globally as COVID-19 and HCoV-19, emerged in late 2019 in Wuhan, China, and is now is causing a global pandemic. At time of writing this pandemic has resulted in 4,170,424 confirmed cases, and, 287,399 deaths (World Health Organisation, 2020b). Despite the risk of contagion, especially from body products as a result of injury, Technical Rescue activities cannot be ceased.

We have incorporated the existing literature on both anti-viral decontamination in general, the known persistence of SARS-CoV-2 on various surfaces and the construction and usage of rescue equipment to consider if effective and safe protocols for the preparation and decontamination of Technical Rescue equipment are available. The importance of continuing Technical Rescue activities, and therefore the importance of determining effective cleaning protocols is discussed, and future work on the impacts of decontamination agents on Technical Rescue equipment is called for.

KEY WORDS: *COVID-19, Technical Rescue, Decontamination*

Introduction

On the 31st of December 2019, Chinese authorities notified the World Health Organisation (WHO) of an outbreak of pneumonia of an unknown aetiology in Wuhan City, in the Hubei Province. In January of 2020 the Chinese had identified a novel Coronavirus, (SARS - CoV2) which was later designated as COVID-19 (coronavirus disease 2019). There is lack of clarity on how the initial outbreak started, although there is some evidence that the source may have initially been a zoonotic transmission at a seafood market in Wuhan city before developing into person to person transmission. (Wu & McGoogan, 2020)

The disease symptoms appear after a median incubation period of 5.1 days and the development of symptoms in the majority of cases appears to be within 11.5 days. (Lauer et al., 2020). The most common symptoms are fever, cough and fatigue although the range of other symptoms is wide and varied.

Information from published studies suggest that transmission of the virus is primarily through respiratory droplets, although there is evidence that symptomatic patients may also have some intestinal symptoms. For the most part, it is believed that person to person transmission occurs through droplet transmission from an infected host (Rothan & Byrareddy, 2020).

There have been a range of governmental responses to the pandemic. Hale et al (2020) describe the Oxford COVID-19 Government Response Tracker (OxCGRT), which uses 11 indicators of response, relating to public gatherings, financial indicators, and COVID-19 testing and contact tracing. Comparing the 149 countries listed in the OxCGRT, across 5 of the indicators (from April 2020) it can be seen that 95% of countries had required schools to close and 75% had required workplaces to close. 95% of countries had cancelled public events, 56% of countries had closed public transport and 87% of countries had put restrictions on internal movement in place.

Wilder-Smith & Freedman describe the practicalities of isolation, quarantine, social distancing and community containment. Ideally for social distancing to be effective it requires a distance of >2m to be maintained between individuals (Blocken et al., 2020) at all times. However, first responders will find that difficult to maintain perfectly throughout the working day, and effectively impossible in the majority of rescue operations.

Although there is some disagreement in the effectiveness, necessity or ethics of public health restrictions (Allcott et al., 2020; Williams et al., 2020), there is a significant school of thought who maintain that these restrictions (or forms of them) will be in place until a vaccine is produced (Leung et al., 2020).

As a result, most branches of emergency services in the developed world face some sort of enforced change, either as a result of precautionary measures, (including the wearing of face coverings, distancing, reduced levels of response) to halt the spread of infection, or as a result of diminished numbers of personnel, making standard operations impossible. One group of emergency responders, falling within both the Ambulance and Fire & Rescue sectors, is that of Technical Rescue.

Technical Rescue can be described as a lifesaving activity using skills, equipment and techniques exceeding those normally used in firefighting or other emergency response (Vines & Hudson, 2004). The term originates with various Fire Services, to differentiate between these activities and mainstream firefighting, but is now in common use across a range of allied sectors, such as Mountain Rescue and Coastguard teams. In particular, it is often described as requiring the rescuer to commit their safety to specialist equipment, during the rescue, and should that equipment fail it could be expected that death or severe injury would occur. This reliance means that any contaminated equipment must be cleaned, or replaced as rescue activities cannot proceed without it.

Although numerous activities, such as Hazardous Materials response (HAZMAT), Animal Rescue, Urban Search and Rescue or extrication from vehicular accidents could be considered Technical Rescue, for the purposes of this paper we shall limit the scope to rescue from height (see Table 1). To this end, the equipment being considered is rope (referred to typically as “line”), climbing harnesses, work clothing, helmets, rescue harnesses, stretchers and various other hardware components (such as karabiners, pulleys, slings, ascending and descending devices and portable frames for creating height). Cliffs, buildings, span structures (bridges), cranes, sewers, mines and caves are all environments that might require use of Technical Rescue equipment.

Equipment used in Technical Rescue is required to be of a sturdy construction, typically over-engineered to provide a safety margin. This is known as the safety factor of the item and for example, in the United Kingdom, equipment used to support human life in a work environment must on average break at force 10 times greater than the expected load. The commonly accepted figure for a rescue load is 200kg (Vines & Hudson, 2004) so an item must not break at a load lower than (10x200kg) 2000kg, or at a safety factor of 10:1. Despite this high level of redundancy, much of the equipment regularly used in Technical Rescue is even stronger than this.

Some items are designed to be used in a way that reduces their strength. For example, a simple straight piece of rope when tied into a knot may lose up to 50% (Atiyah, 1990; Delaney, 2015) of its strength due to the constrictions on the strand of rope created in the knot. Furthermore, equipment deteriorates from wear and tear. Mechanical friction, internal and external, exposure to chemicals and exposure to sunlight can all reduce the working strength of fibres and, therefore, Technical Rescue equipment (Davis, 2005). Incorrect decontamination could potentially reduce the working strength of the components, and in isolation or in combination with wear and tear, could create a potentially fatal failure.

In the course of treating and rescuing casualties, equipment may come into contact with body products that may expose it to pathogens. Often, the contamination will be visible or witnessed by a team member allowing the equipment to be removed from service and quarantined according to standard procedures. However with SARS Cov-2, equipment may be contaminated in the course of a rescue, training session, routine testing, inventory or any activity where the equipment comes into contact with a person.

Therefore, in order to be of use for emergency response, the equipment should be treated as if it was confirmed as contaminated. The decontamination process needs to be carried out in a way that leaves that equipment completely free of active virus, does not damage or adversely affect the equipment (making it potentially unsafe to use) and leaves the equipment ready to be used immediately, in the event of an emergency response.

Kernmantle rope (the most commonly used climbing and rescue rope, consisting of an outer sheath and inner core) is typically made from nylon and climbing harnesses made from a combination of steel, aluminium alloys, nylon, Dyneema and polyester. Some line is constructed from aromatic polyamide (Aramid) which is similar to Kevlar. These materials provide a high strength to weight ratio, which allows for significant redundancy in the tensile strength of the equipment, but with relatively low weight. Given that much of the equipment needs to be carried to a scene of operations, or worn, the advantages of this are self-evident (Table 2).

In the sampled literature, the manufacturers recommended a luke-warm (<30*) detergent solution for decontaminating harnesses and line, and specifically warned against the use of bleach, stating that this could weaken the nylon in the outer sheath of lines and the fabric components of harnesses, which are considered Technical Rescue equipment here (Beal, 2019, 2018a, 2018b; CAMP, 2019, 2018a, 2018b, 2018c; CMC, 2018a, 2018b, 2018c; Heightec, 2020a, 2020b, 2020c, 2020d, 2017; Petzl, 2019, 2019, 2018, 2014a, 2014b, 2014c; Teufelberger, 2020). Teufelberger (2020) describe experiments conducted on rope which was exposed to a solution of 70% isopropanol and 30% distilled water, and air dried for 48 hours. They report a 2-4% decrease in breaking strength, but a decrease in flexibility. Lawson et al also (2002) also describe a number of methods for decontamination after CBRNe exposure, but focus on decontamination only, and not re-use afterwards.

	Rope	Harness	Helmet	Hardware / connectors	Breathing Apparatus	Respirators	Liquid or Gas-tight suits	Shoring
HAZMAT					✓	✓	✓	
USAR - collapsed buildings or major transport accidents	✓	✓	✓	✓	✓	✓	✓	✓
Rescue from Mud or Ice	✓	✓	✓	✓				
Rescue from Machinery						✓		✓
Rescue from Vehicles						✓		✓
Cliff Rescue	✓	✓	✓	✓				
Animal Rescue (large or small)			✓					
Confined Space Rescue	✓	✓	✓	✓	✓	✓		
Rescue from water - moving and still	✓		✓	✓				
Rope Rescue	✓	✓	✓	✓				

Table 1: Activities potentially considered "Technical Rescue", with typically associated equipment or techniques

Equipment Type	Construction Materials
Metal connectors and other hardware (Karabiners, pulleys, rope grabs)	Stainless steel, high tensile steel, anodised aluminium, bare aluminium, Titanium alloy
Metal wire anchor slings	Stainless steel with swaged eyes and a pvc outer
Textile woven and sewn anchor slings	Nylon (including polyamide), Polyester, Dyneema, Aramid or a mixture of some of these.
Textile woven and sewn harnesses with metal attachment points	
Textile ropes and other cordage/lines	
Stretchers	Plastic and metal for "basket" stretchers Plastic for spine boards / extraction boards Canvas Fabric for USAR / some line rescue stretchers (Cooper, 2018)

Table 2: Construction materials of TR Equipment

Nylon is considered completely unsuitable for exposure to sodium hypochlorite, as it will break down bonds in the polymer and significantly compromise the tensile strength of the harness. Polyester is more resistant to bleach, as a stronger polymer, but is still susceptible to degradation when exposed to sodium hypochlorite at higher temperatures (Campo, 2008).

Beal's tests on Aramid line suggest that it maintains 98% of its tenacity, (defined as tensile strength (Cordage Institute, 2020)) after 100 hours exposure to a 20% hydrochloric acid solution at 20°C. No information is given regarding bleach specifically, and so it is difficult to predict without proper testing what the impact of exposure to bleach would be. Aramid is also used in ropes with a greater heat resistance, which may be of value when treating any contamination.

Table 3 details the current methods by which organisations respond to a contamination event, from complete disposal of equipment, to various decontamination processes. Most relevant equipment cannot be stored wet, and so must be dried before being stored ready for use; which is all time when it might not be available for use (it can be used while wet, but may not be accessible while drying, or easily stowed for deployment). Table 4 shows a sample of current manufacturers' advice on decontamination in normal conditions, and where applicable specific advice for the COVID-19 pandemic.

It is clear that Technical Rescue activities cannot cease for the duration of the COVID-19 pandemic, and in many cases, for safety reasons, cannot be substantively changed. Therefore, the only reasonable solution is to continue with rescue activities, but to reduce the risk of infection to or from the rescuer by adopting protection and decontamination procedures, and by following where possible WHO guidelines (World Health Organization, 2020c). This is to ensure confidence both that the exposure of rescue personnel to infection is reduced, as well as limiting the risk of the rescuers infecting vulnerable people in the process of rescue.

No.	Name	Description	Positives	Negatives
1	Total Disposal	Some teams experience contamination rarely and are comparatively well funded. In cases of gross contamination the equipment is disposed of and replaced.	Simple, low risk of continued contamination	Potentially very expensive
2	Temporary Quarantine	Equipment is quarantined until sufficient time has passed to render any pathogens inactive.	Confidence in decontamination, inexpensive.	Equipment off the run whilst in quarantine.
3	Mild Bleach Wash	Equipment is washed in a mild bleach solution, typically 0.05% sodium hypochlorite in water.	Bleach is readily available, is recognised as a good decontaminant.	Potential for weakening / damaging equipment.
4	Pure Soap Wash	Equipment is washed at max 30°C in pure soap (this is also a standard method for general cleaning) and dried.	Aligned with some manufacturer's recommendations. If done thoroughly, good chance of effective decontamination.	Relies on availability of pure soap.
5	Specialist Cleaner	Equipment is washed in a proprietary cleaner as above eg Beal rope cleaner or Ecolab.	Aligned with some manufacturer's recommendations. If done thoroughly, good chance of effective decontamination.	Relies on availability of specific products.
6	Air Dry	Equipment is washed, air dried and quarantined for sufficient time for any pathogens to become inactive.	Confidence in decontamination, relatively inexpensive.	Relies on availability of specific products. Equipment off the run whilst in quarantine.
7	Hot Water Bath	Equipment is placed in a water bath at 55°C for at least 20 minutes and then allowed to dry naturally.	Demonstrated to be effective against white nose (Throop & Kees, 2016), whilst not initially reducing tensile strength of equipment. Even the lowest breaking strengths for treated lines were well above required minimum breaking strength. There is some risk however that continued washing would weaken lines further.	Exceeds some manufacturer's recommendations.

Table 3: Existing Options for Decontamination, across organisation types

In addition to the direct risk of either infection, or unavailability of equipment due to quarantine or cleaning, logistics systems, staffing and general support functions are severely stressed by lockdowns. This stressing, plus unavailability of staff due to widespread illness, or being seconded to other duties, means that normal replacement services may also be affected. This could be seen to apply to both the equipment itself, or specialist cleaning products (see Table 3).

	Harness		Rope		Helmet		Carabiner		COVID-19 SPECIFIC ADVICE
	Temp	Products	Temp	Products	Temp	Products	Temp	Products	
Beal	≤30°C	Delicate Fabric Cleaner Disinfect only using materials that have no effect on the synthetic materials used.	"cold" water	Agent for delicate textiles Disinfect only using materials that have no effect on the synthetic materials used.	"cold" water	appropriate products, which are not harmful to the wearer (soap).	≤20°C	Disinfectant containing quaternary ammonium salts.	NO
Camp	≤30°C	pH Neutral soap.	≤30°C	pH Neutral soap.	≤30°C	pH Neutral soap.	≤30°C	pH Neutral soap.	NO
CMC	"Cold" water.	"Mild Detergent safe for nylon and polyester".	None given	"Mild Detergent safe for nylon and polyester".	Shell: Cold water Padding: =<30°c	Mild soap.	None "clean and dry"	None.	YES
Edelrid		70-100% Isopropanol.		70-100% Isopropanol.		70-100% Isopropanol.		70-100% Isopropanol.	YES
Heightec	Approx. 25°C	Non detergent soap disinfectant compatible with polyamide and polyester.	Lukewarm	For disinfection, only use substances that have no influence on the synthetic materials used.	Approx. 25°C	disinfectant compatible with polyamide and polyester.	Approx. 25°C	disinfectant compatible with polyamide and polyester.	NO
Petzl	≤65°C	Ph neutral soap (household face and body soap).	≤65°C	Ph neutral soap (household face and body soap).	≤65°C	Ph neutral soap (household face and body soap).	≤65°C	Ph neutral soap (household face and body soap).	YES
Singing Rock	≤55°C (Polyamide, polyester or metal, not for HMPE, Dyneema®, Spectra®, Dynex® or similar).	83% of denatured 95% ethanol; 11.3% of distilled water, 4.2% of 3% hydrogen peroxide and 1.5% of glycerol. Maximum 3 times.	Not stated	83% of denatured 95% ethanol; 11.3% of distilled water, 4.2% of 3% hydrogen peroxide and 1.5% of glycerol. Maximum 3 times.	Not stated	83% of denatured 95% ethanol; 11.3% of distilled water, 4.2% of 3% hydrogen peroxide and 1.5% of glycerol. Maximum 3 times.	Not stated	83% of denatured 95% ethanol; 11.3% of distilled water, 4.2% of 3% hydrogen peroxide and 1.5% of glycerol. Maximum 3 times.	YES
Singing Rock	≤30°C	Pure soap (e.g. Lux soap flakes, stergene) at the approximate dilution, with pH range 5.5 and 8.5. Disinfection is necessary, use weak (1%) dilution of Potassium permanganate.	"Lukewarm"	clean water disinfection use weak (1%) dilution of Potassium permanganate.	≤30°C	pH-neutral soap.	≤20°C	disinfectant containing quaternary ammonium salts in warm water one hour.	NO
Teufelberger	N/A	N/A	cold	70% Isopropanol 30% Distilled water.	N/A	N/A	N/A	N/A	YES

Table 4: Manufacturer's instructions for cleaning contaminated rescue equipment, both generic and COVID-19-specific (Highlighted rows).

Literature Review

The COVID-19 novel coronavirus was declared a Public Health Emergency of International Concern (the highest level of infectious disease response categorised by the WHO) on 30 January 2020. At the time of writing less than 4 months have passed since that declaration, which means that much of the information about the virus, its survivability, life cycle, transmission and destruction are still not entirely known. As a result, the literature that does exist is understandably focused on the immediate epidemiology and characteristics of the disease, rather than secondary issues, such as equipment decontamination.

Furthermore, with incomplete data, it is hard to be certain of many of the key factors pertaining to transmission;- incubation period, shedding, R-number and modes of transmission (Cascella et al., 2020; Peeri et al., 2020). However, it would seem to be the case that the SARS-CoV-2 virus is similar in morphology to known coronaviruses in many ways, and as such this (plus what we do know about the novel form) allows us to develop decontamination procedures suitable for rescue equipment (Wu et al, 2020).

To this end, there is both some early work specifically on COVID-19, and generally on viruses (and coronaviruses) and their survivability or persistence on different surfaces and materials, that is relevant to this matter. Kampf et al (2020) conducted a review of 22 existing papers, (Kampf et al., 2020) and concluded that the virus can survive on inanimate surfaces (such as metal or plastic components of rescue equipment) for up to nine days. However, it can be reliably inactivated in around one minute using simple surface disinfectant measures, using ethanol, 0.5% hydrogen peroxide or 0.1% sodium hypochlorite.

van Doremalen et al (2020) compared the surface stability of COVID-91 with SARS-CoV-1 and found that it was similar under the conditions of the test. Specifically, they found that the virus can remain active on plastic, stainless steel, copper, or cardboard for a number days (depending on conditions, such as the inoculum shed) (van Doremalen et al., 2020).

Nogee et al 2020 recommended investigating the widespread use of ultraviolet germicidal irradiation (UVGI) to sterilize clinical PPE such as masks, and this could be effective with rescue equipment, but often requires specialised UVGI rooms, lamps and air conditioning equipment (Varaine et al., 2014).
Throop and Kees (2016) conducted a series of experiments on decontaminating climbing equipment, relating to pathogens such as the fungus that causes white-nose syndrome in bats. Climbing equipment, practically identical to rescue equipment, used by bat researchers and cavers required decontamination after use, and the extent to which that decontamination affects equipment strength was investigated. The equipment was subjected to a hot (55°C) bath, 30 times, and dried naturally each time. Line and harnesses were then tested to industry standard breakage strength tests. The line was calculated to have between 0.2 percent to 2.0 percent less strength than untreated line. The harnesses all passed

the European Standard EN 12277 (Bright, 2014) and the authors could find no evidence that the decontamination had any impact on the integrity of the harnesses.

(Phillips, 2014) for the US national Park service, details cleaning carabiners, harnesses, rope and helmets using warm soapy water, with household soap for harnesses and helmets and ph neutral soap for rope.

Discussion / recommendations

Having established that it is not feasible to cease use of rescue climbing equipment during the pandemic (unlike recreational climbing), it is therefore imperative to establish an effective decontamination protocol. Ultimately, any rescue equipment that is potentially contaminated with the COVID-19 virus must be decontaminated before reuse, but the practicalities of that are not entirely clear from existing literature.

On one hand, the manufacturer's recommendation of lukewarm soapy water will maintain the nylon components of the equipment without question, and should be sufficient to kill the virus (World Health Organization, 2020a, 2014). On the other hand, some agencies are reported to use a weak (<0.05%) sodium hypochlorite solution (which will almost certainly kill a coronavirus), or soapy water at circa 60□C (Throop & Kees, 2016) but potentially puts the wearer in contradiction of manufacturer's recommendations, and so the potential practical decontamination protocols are somewhat limited.

Quarantining equipment for a period beyond the typical persistence of a virus is likely to be effective, but will result in equipment being unavailable for a minimum of 96 hours. Organisations with sufficient quantities of equipment could set up a quarantine rota and replace contaminated equipment with fully quarantined equipment when required. Organisations could consider reducing the number of responding Technical Rescue units, to increase the relative amount of equipment per unit.

According to most available evidence or technical documents. warm soapy water can be used to decontaminate line and harnesses, at a temperature of 30-60°C, using a mild detergent. This would appear to be a sensible and pragmatic approach, although it would be advisable to wear appropriate PPE, during the decontamination. Even mild bleach solutions should be avoided, as a result of the potential catastrophic weakening of polymer-based materials. However, PMI (2014) and McCurley 2009 interpret the NFPA standards as requiring the using of a mild household bleach to decontaminate effected rope, although this is not advocated as a long term solution.

There is a case for further investigation into the use of UV to decontaminate equipment, and in particular, UVGI could potentially be used, with the aid of local medical facilities. However, this investigation must pay heed to any potential damage to rescue PPE resulting from it’s exposure to high concentrations of UV.

This work has identified an urgent case for a dedicated program of research concerning decontamination of rescue equipment, as well as workwear and other PPE, beyond existing work on high-toxicity CBRNe contaminants. In short, the emphasis in the technical and academic literature has been towards weaponised or industrial scale contaminants, and decontamination for viruses or bacteria has, to some extent, been overlooked. A laboratory-based investigation into effective disinfectant measures for rescue equipment, incorporating disinfectant types, concentrations and applications, would be a welcome development. This should incorporate two strands: Firstly, effective removal of contaminants across a viral, bacteriological and blood-borne pathogen spectrum, and secondly, tensile strength and usability of equipment after treatment.

We are aware that this paper offers a limited range of solutions to contaminated rescue equipment, but hope that by bringing what literature does exist together, and indicating further research opportunities, we have contributed to the safe continuation of vital emergency services work across the world, during the COVID-19 crisis and into the future.

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