DECONTAMINATION WITHOUT MONITORING IS LIKE SHOOTING IN THE DARK

On 25th January 2020, two days after the Wuhan lockdown, instrument manufacturer ATi received a phone call from China requesting a very large order of hydrogen peroxide sensors…

As Covid-19 raged around the world, governments and citizens became increasingly aware of the importance of testing and monitoring – something that readers of IET already knew. For example, healthcare workers need to believe that their working environment is safe, which means that they need to know if they or their colleagues have Coronavirus. Similarly, when a room is being decontaminated, staff need to know that effective concentrations of decontaminant gas have been reached, and when levels are low enough for safe re-entry. Physical biological indicators can help, but swab testing takes too long to check that decontamination has been effective because the treated room would be out of operation until the results are known.

As a provider of monitoring technology, ATi specialises in the development of instrumentation that delivers vital data which improves industrial processes, and protects health and the environment. ATi Executive Director Garry Tabor says: "The application of our oxidant-based electrochemical sensors in decontamination equipment is a prime example of the way in which monitoring data is crucially important to the success of a measure that helps to protect health and save lives.

"For us, the urgent call from China was the first indication that something very significant was about to happen."

Background – disease transmission

In 1841, Hungarian Dr Semmelweis, a Vienna hospital obstetrician was alarmed by the number of women dying from puerperal fever. He noticed that mortality was three times higher in the ward where the medical students were delivering babies than in an adjacent ward, staffed by midwifery students. The medical students were also working with dead bodies, so he supposed that the medical students may be infecting the women after labour. He therefore implemented mandatory hand-washing in May 1847 - and infection rates dropped dramatically. Thereafter, the connection between microorganisms and disease transmission was established.

The word decontamination means the removal of dangerous materials such as hazardous chemicals, radioactive substances and infectious diseases from equipment and environments. Decontamination can be a combination of processes, including cleaning, disinfection and sterilisation, but the effectiveness of decontamination can only be determined when there is a defined objective and a suitable means for measuring against that objective. So, for example, the level of decontamination required in an operating theatre will normally be higher than that for a care home.

ATi UK's D16 PostaSens III portable gas detector

Disinfectants destroy micro-organisms and the aim of disinfection is to reduce the numbers of viable micro-organisms to a level that is not harmful to health.

Healthcare-associated infections (HAIs)

According to the World Health Organisation (2016), hundreds of millions of people are affected every year by avoidable infections in healthcare. The determinants of HAI are influenced by a complex combination of gaps in policies, infrastructure, organisation and knowledge, healthcare workers' behaviour, and patient-related factors. Through knowledge, best practices and infrastructure improvement, infection prevention and control aims to prevent harm from HAI to patients and health staff. Nevertheless, due to the rise of antibiotic-resistant bacteria and failure to implement best practice infection control, HAIs remain one of the biggest causes of death in most countries.

In the UK, the number of death certificates mentioning MRSA doubled from 487 to 955 between 1999 and 2003. Resistant to conventional antibiotics, MRSA was the most common cause of HAI in England in 2005. Similarly, the incidence of C difficile in England declined by about 80% after 2006, following the implementation of national control policies. In addition to measures such as hand cleansing, which prevent the transmission of infection from one area or patient to another, decontamination techniques were also developed. For example, hydrogen peroxide (H_2O_2) vapour was employed to disinfect spaces that could be evacuated and sealed. This method is capable of delivering 6-log broad-spectrum kill of microorganisms.

Logarithmic reduction is the standard used for quantifying disinfection. So, a 1-log reduction in colony forming units (CFUs) represents a 90% reduction and 2-log represents a 99% reduction. 6-log reduction therefore represents a reduction of CFUs by 99.9999% which may not seem like much of a difference to, say, 99.9% (3-log) kill, but if 3-log disinfection is conducted on a surface with one million bacteria, around 1,000 viable bacteria will remain, whereas a 6-log reduction would leave just one bacteria.

Garry Tabor believes that target disinfection rates are critically important. "The Coronavirus pandemic has resulted in a multitude of newcomers to the disinfection market," he warns. "We have seen a wide variety of fogging devices being used almost everywhere, with no real measure of their effectiveness. During a pandemic it seems that doing something is better than doing nothing, but going forward there needs to be more regulation to ensure that products and services are fit for purpose."

As a manufacturer of disinfectant, Adrian Gee-Turner agrees: "During the pandemic we saw large numbers of organisations hurriedly creating almost home-made disinfectants, with no real measure or proof of efficacy. Many of them may have helped, but with no testing or monitoring, no one really knows. In fact, they may have led to a dangerous false perception of safety."Our

Nemesis eH$_2$O broad-spectrum 6-log disinfectant complies with European Biocidal Products Regulations

disinfectant, Nemesis eH$_2$O, is fully compliant with European Biocidal Products Regulations and has been independently tested with proven 6-log efficacy against dangerous pathogens, including enveloped viruses (Coronaviruses are enveloped viruses), as well as C Difficile, which is an important cause of HAIs that many disinfectants do not kill. This is why further regulation will be necessary to raise standards – during and after a pandemic."

Why monitor Hydrogen Peroxide

In order to be effective at delivering a 6-log kill, the concentration of vapour has to be maintained above a certain level for a specific period of time. However, there are a number of variables – the level of microorganism kill required, the type of room, and surfaces within it. In addition, both temperature and humidity affect the activity of hydrogen peroxide.

The toxicity of hydrogen peroxide is due to the oxidation of proteins, membrane lipids and DNA by the peroxide ions. Inhalation causes irritation to the respiratory tract. In very severe cases bronchitis or pulmonary oedema may occur, which can be fatal. Contact with the skin causes bleaching and possibly permanent scarring. Ingestion results in abdominal pain, foaming at the mouth, vomiting, fever, lethargy unconsciousness and in severe cases, can result in death. In the UK, the Workplace Exposure Limit (WEL) for airborne hydrogen peroxide is just 1ppm as an 8-hour time weighted average and just 2ppm as a 15-minute time weighted average. In the past, instances where staff have not been adequately protected have resulted in legal action against NHS Trusts.

Clearly, traces of hydrogen peroxide must be removed before staff and patients are allowed to re-enter a treated room, and this is the second reason for monitoring – to protect health and safety. Garry says: "It is not uncommon for decontamination equipment manufacturers to connect our sensors to traffic light warning systems that provide a visual indication of when an area is safe for re-entry."

Monitoring technology

With a focus on instrumentation for monitoring disinfection in air and liquids, Garry Tabor reports a doubling of turnover during the pandemic. The company's electrochemical sensors are made in small batches by hand in its Pennsylvania factory, which has been designated part of the State's critical supply chain. In response to the emergency, the factory has been operating 16 hours/day, 6 days/week.

The hydrogen peroxide sensors are factory calibrated using hydrogen peroxide vapour, and rather than re-calibrate with a toxic surrogate span gas, these low cost sensors are simply replaced every year.

As outlined earlier, fogging systems need to be able to monitor high levels of hydrogen peroxide to check efficacy, but also to check at very low levels to allow safe return to a treated room. Individual sensors would not be able to function satisfactorily across such a broad dynamic range, so these devices are generally fitted with two sensors; a high-range version and a low-range. Portable versions of the same monitoring technology (as recently demonstrated on the BBC's 'One Show') can be employed to assist with safety checks, and permanent monitors can be installed in rooms that are frequently decontaminated with hydrogen peroxide.

Looking forward

Are there lessons that can be learned from the pandemic? Garry Tabor believes that more organisations will implement Business Continuity planning – identifying all the major risks that potentially affect them, and documenting appropriate mitigation procedures. From an instrumentation perspective, he also believes that current and emerging developments will help protect assets and society better in the future. "In the age of Big Data, there is concern with the possibility of being a 'DRIP' (Data Rich and Information Poor) organisation. Data collection should focus on issues that matter, so that the results of monitoring can deliver useful insights.

"IoT sensors are becoming increasingly common and this is delivering the significant advantages that can be gained from networks of smart sensors. For example, the latest smart sensors

ATi UK's Isomon dual channel gas detection system

can operate independently of localised data storage, and are able to not only communicate live data, but also supply metadata indicating whether they are in calibration and operating as normal. The main advantage, however, is speed – when a sensor detects a problem it can immediately alert the right people, which enables prompt effective action.

"By operating networks, users benefit from the 'Power of Pattern' which means if one sensor is showing an unusual value, this may be due to a false positive, damage or a fault, but if a cluster of sensors are showing the same values, there is more likely to be an issue of concern. Alarm systems are then able to assign an appropriate level of risk and implement a pre-designated response."

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Following the global Coronavirus pandemic, there will be a heightened sensitivity to cross-infection, and a greater emphasis on decontamination. Garry says: "We are already seeing an expanded range of applications for monitoring decontamination – in pharmaceutical facilities, isolators, transfer hatches, cleanrooms and ambulances for example. We have also been pleased to see work on the decontamination of PPE equipment for re-use."

In summary, it is vitally important that decontamination should not be a 'shot in the dark' – instead, there should be a regulatory requirement for decontamination activities to be monitored for both efficacy and safety with full traceability of data.

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