

NPL's COVID-19 Response

Supporting the national effort



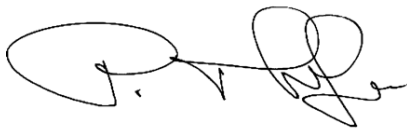
Foreword

A word from our CEO

Back in March 2020, when the UK went into its first lockdown and as coronavirus began to shut down the world, it was clear to see that there would be catastrophic consequences both socially and economically. Whilst the health of citizens around the globe was protected through containment measures, which included closing huge swathes of industry, the economy being closed had instantaneous impacts.

As we came to terms with what this meant for us at NPL, shutting our site for just two days to ensure the safety and wellbeing of our people, we quickly overcame the hurdles of ensuring our laboratories were COVID-secure, as well as moving to new ways of working. We were then able to turn our attention to ensuring critical services were kept running and doing what we could do to support the COVID-19 response and recovery.

I would like to personally thank all those working at NPL for their resilience and hard work through this difficult and challenging time. Together we were able to support UK industry and Government and I am proud of the impact that our science, engineering and technology had. I am delighted to see our work collated in this report.



Dr Peter Thompson FREng FInstP FRSC
Chief Executive Officer



An introduction from the Chief Scientist

The National Physical Laboratory (NPL) is the UK's National Metrology Institute with a strong track record in innovative research with real impact. During the COVID-19 pandemic, we were keen to address the immediate healthcare crisis and support UK companies. By engaging with healthcare contacts, industry and government, we rapidly had a multitude of activities up and running, from helping analysis of health data and giving guidance on fever screening to designing ventilators and advising on manufacturing standards.

We worked with many companies through our Measurement for Recovery programme, looking at how they could automate processes and benefit from innovative technology to boost their productivity. The COVID-19 crisis demonstrated how difficult it can be to get products to market quickly, having ensured that they meet the required standards. NPL is an expert in testing and certification and we worked with organisations across all industrial sectors to help them be more agile in the recovery phase and beyond.

We made our testing and validation services available to companies developing ventilators and face masks so their products met safety and quality standards, as well as additional measurement support to enable them to scale up production. In addition, NPL engineers designed an innovative, low-cost ventilator, the PocketVent, for use in developing countries.

This report brings together the many activities that NPL was involved with during the pandemic. Some were absolutely critical to the safe running of the country, while others were speculative and innovative. We have all had to adjust and embrace new digital ways of working during the pandemic and our experiences highlighted how working with NPL can help organisations adjust to the 'new normal' and benefit from increasing reliance on a robust digital infrastructure.

To deliver all this incredible work, we needed amazing people who were resilient, flexible and responsive. At NPL we have over 1,000 scientists, engineers and skilled professionals who worked together during the pandemic to deliver exceptional science and engineering. I am proud of the work that they did in unprecedented times and how they adapted swiftly to new challenges.

A handwritten signature in black ink, appearing to read 'JT Janssen', with a horizontal line drawn through the middle of the signature.

Prof Jan-Theodoor (JT) Janssen FInstP FIET
Chief Scientist



Contents

Foreword	2
Contents	4
Introduction	5
Providing critical services	6
Measurement for Recovery	7
Ventilators	9
Personal protective equipment	11
Temperature measurement	13
Sterilisation	14
Vaccine development	15
Oxygen supply	16
COVID-19 sensors	17
Air quality in dental surgeries	18
Anti-viral surfaces and materials	19
Data science	20
e-learning	21
Outreach	22

Introduction

NPL provides the measurement standards for science, technology and manufacturing in the UK. Throughout the COVID-19 pandemic we applied our expertise to meet the unprecedented challenges to industry and society. As a national laboratory with thousands of customers in the UK and beyond, it was a natural progression to offer our experience of standards, testing and product requirements. We expanded our Outreach activities to support home schooling, and made skills development for industry a priority.



We made our facilities available to support UK companies, including working with NHS trusts on ventilator provision, oxygen supply and data processing. The pandemic highlighted the vital role that metrology plays in supporting global measurement systems and helping society to function.

Agile and innovative

NPL's depth and breadth of experience helped verify and validate the performance of materials, instruments and sensors, and our state-of-the-art equipment was used to make prototypes and new products. As UK industry turned its attention to recovery, we provided confidence to companies tackling the problems created by new working practices, supply chain changes and product modifications which could impact compliance.

Our expertise allowed us to advise and inform government, companies and research organisations on a wide range of topics, and our extensive professional networks linked organisations with specialist suppliers to overcome manufacturing challenges.

Providing critical services

As a national laboratory, NPL continued to run several critical services to support the UK's infrastructure and vital healthcare provision, whilst following government advice during the first lockdown.

This work included:

- Healthcare services to support the NHS and the medical supply chain
 - Radiation measurements to allow the medical sterilisation industry to operate
 - Calibrating instruments used in cancer treatment
 - Quality assurance measurements and supply of materials to radiopharmaceutical manufacturers
- Provision of timing services on behalf of the government, for example to facilitate reliable high-speed financial trading
- Support to the nuclear sector, declared by operators as critical, to keep power stations operational
 - Calibration activities to allow the acceptance of neutron detectors for use in nuclear power stations as part of safety cases
- Provision of environmental monitoring, declared as critical by the Environment Agency
 - Operation of air particle monitoring network
 - Supporting chemical companies to ensure clean and safe operation and maintain their licences to operate

NPL provided support to critical businesses

- We calibrated thrust load cells for an aviation engine manufacturer, which was critical for the measurement of their products and to keep aircraft flying safely.
- Kindeva Drug Delivery (formerly known as 3M Health Care) manufactures asthma inhaler components and needed their reference stage graticule calibrated. This process is key to the quality and release of their products, which was vital during the pandemic.
- Fluorine-18 is one of the most frequently used radioisotopes in positron emission tomography used for bone scans, prostate imaging and research. NPL analyses samples to make sure they are free of impurities, and this service continued through the lockdown period.
- We run DEFRA's particle network and government flagged the measurement of ambient particulate measurements as crucial during the pandemic.
- Laser Quantum worked with NPL to determine why components in their laser assemblies were losing alignment and how to correct them. These components are key in a range of test equipment which is used for DNA analysis and in the battle against COVID-19.
- NPL offers a calibration service for hydrophones for medical ultrasound equipment. During the COVID-19 crisis the service was briefly paused, but customers requested resumption to ensure the supply of medical equipment to health services, including ultrasound techniques for the diagnosis of COVID-19.

Measurement for Recovery

NPL and our National Measurement System partners supported economic growth and helped UK companies to build back better. The Measurement for Recovery (M4R) programme provided specialist expertise to solve measurement challenges at no charge. Through M4R, we helped companies address the challenges facing their business, including design, production, regulatory compliance and product development. We supported innovation by helping companies bring new products to market, reduce costs and build the confidence required for investment.



NPL launched the M4R programme in July 2020 to ensure measurement science was available to UK industry during the COVID-19 crisis when businesses were facing multiple challenges including cash flow, job security and investment in innovation. Working with our partner laboratories that make up the National Measurement System, M4R was designed to address and solve the challenges by matching businesses with world-leading measurement scientists and engineers, techniques and technologies, and providing up to 20 days specialist science and engineering expertise free of charge.

Enabling innovation

During M4R supported more than 435 UK companies, who have benefited from rapid specialist measurement advice and support, access to world-class laboratory facilities, direct contact with science and engineering technical specialists, and a new approach to solving their measurement and analysis problems. To ensure the accessibility and fair reach of the M4R programme, the application process consisted of a simple online form, and applications were assessed through a non-competitive process.

M4R is funded by the Department for Business, Energy and Industrial Strategy and received over 700 applications, with over 80% of these coming from micro or small businesses. Through the M4R programme, NPL helped to deliver innovation, uncover efficiencies and bring confidence to decision making and investment to drive growth for UK industry. M4R helped to ensure that the UK's measurement infrastructure was utilised in the economic recovery, to unleash innovation and make the UK a great place to work and do business. The programme closed to new applications at the end of September 2021.

What our customers said

“NPL literally leads the world in scientific measurement. It's been a privilege to have NPL put our technology through its paces.”

“With a greater understanding of the data required and the support of the independent analysis provided by the NPL team, we are now able to take the next crucial step in our development.”

“NPL has helped us to become more efficient (time and cost) in our product development by increasing our characterisation process whilst implementing COVID-19 socially distanced and reduced staff working.”

“We are a lot more confident that we will succeed in our CE test, and that's going to impact us significantly because we will get to market sooner and turn over products and revenue sooner.”

“The M4R support will enable us to access the globally recognised scientific expertise at NPL, helping us to accelerate our technology development.”

“The expertise and access to state-of-the-art metrology equipment has allowed us to benchmark each phase of the development and give confidence that we can move on to the next stage.”

Impact of Measurement for Recovery



76% of companies said their commercial opportunity has greatly or moderately increased as a result of their M4R project.



60% of companies expect to secure more investment for their project from either investment or internal sources.



68% of applicants expect to see increased sales in new or existing markets as a result of their M4R project.



37% of applicants expect to see reduced costs through decreased production or material costs as a result of the M4R work.

Ventilators



At the start of the COVID-19 crisis the government launched the UK Ventilator Challenge encouraging manufacturers to re-purpose their assembly lines and support new designs to meet anticipated demand. NPL has a broad team of experts with knowledge on many of the key parameters of ventilator control and operation, including: temperature; humidity; pressure; gases; dimensional measurement; materials and engineering skills. NPL offered advice, guidance and consultancy in the verification, testing and, where applicable, the design and prototyping of parts.

After a few weeks, it became apparent that the additional number of ventilators required for the UK would not be as high as anticipated. The specifications for the requirements also evolved as it became clear that the constant pressure apparatus (CPAP) was often more effective than conventional ventilators. We established a test capability based around a lung emulator loaned from Kings College London to test new ventilator designs against the developing Medicines and Healthcare products Regulatory Agency (MHRA) specification.

NPL offered its support at no cost to companies developing and manufacturing ventilators in the following ways:

- Carrying out validation tests for ventilator designers and manufacturers
- Identifying time savings in the test plans and manufacturing process for several major UK companies who were repurposing their facilities to produce ventilators
- Advising on gas and oxygen sensors given the global shortage of these critical ventilator component
- Helping companies understand and apply product standards

- Providing advice on product modifications or alternative components while still complying with regulations
- Developing innovative testing regimes
- Giving reliable independent advice, particularly for medical devices and the MHRA
- Providing confidence that new ventilators were being assessed accurately

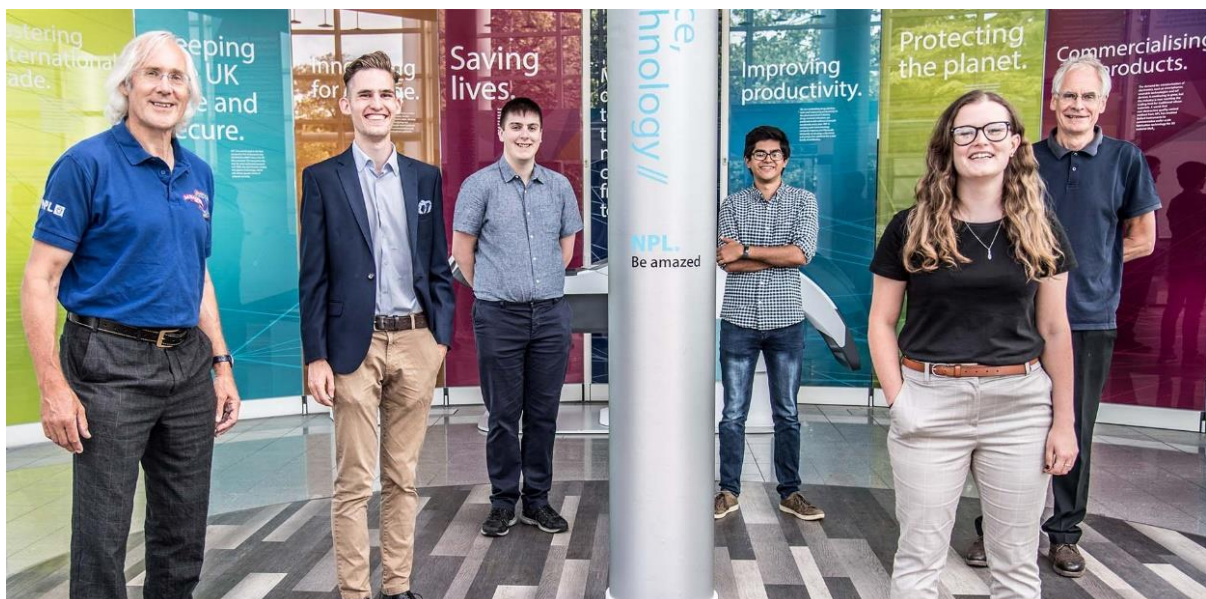
Innovative design

A multidisciplinary team of engineers and scientists pursued several innovative designs which could run on battery, solar panels, wind turbines or mains power, as well as being simple to use and made from widely available parts.

Three low-cost, robust and simple ventilator designs emerged and NPL produced prototypes of each, which were evaluated against the MHRA specification. The PocketVent emerged as an innovative, game-changing design. It is a unique, fan-based ventilator, smaller than a laptop, and expected to cost less than £1,000, compared with the cheapest commercially available ventilator at £8,000 or the more usual £25,000.

The PocketVent is a simple to use device that requires limited training time for healthcare professionals and is made from widely available parts. The design meets the critical functionality and performance requirements detailed in the MHRA specification for ventilation, and costs approximately £1,000 to build. It is compact, has low power consumption and can also be operated as a CPAP respiratory device. It was extensively tested with NPL's dedicated ventilator test facility. It is light, robust, quickly assembled with no major mechanical parts, and can be distributed by plane or drone. It had the potential to be a life-saving ventilator for COVID-19 patients in developing and remote parts of the world.

The PocketVent team was led by Jean Morris, who had only been at NPL for six months. A large part of the work was undertaken by early-career members of the team, including three graduates of the NPL apprentice programme, Joshua Bayfield, Joshua Schofield and Arthur Vie, who designed and integrated electrical, software and mechanical components for the final design. The team was awarded the President's Special Award for Pandemic Service by the Royal Academy of Engineering in recognition of their contributions in helping society to address the challenges presented by the COVID-19 pandemic.



Personal protective equipment

As soon as the practical requirements of COVID-19 became obvious in the UK, NPL started investigating how to utilise its wealth of experience and scientific capabilities to help increase the availability of personal protective equipment (PPE). Medical devices and PPE are regulated in the UK and internationally, this includes requirements for manufacturing and testing (BS, EN and ISO specifications). NPL signposted new manufacturers of PPE and medical devices to relevant standards, and assisted with the interpretation of standards to provide clarity on the requirements for conformity.



Early on, NPL supported several organisations in their production of face shields including companies who were using 3D printing as part of their process. NPL assistance included advice on design, materials and cleaning, as well as modelling of critical design aspects (such as field of vision and area of coverage). We also connected manufacturers and designers with materials suppliers, facilitating collaboration between multiple organisations across numerous projects.

NPL provided support to organisations bringing new face masks and publicly worn face coverings to the market. Initially, this included advice on standards and material selection. NPL then created its own bespoke face mask testing rigs, initially for surgical face masks which had to meet the requirements of British Standards. The tests chosen were those deemed most critical to the performance of these products – breathability, filtration efficiency and liquid penetration resistance. Following on from this, NPL extended its capability to tests associated with FFP-type face masks (filtering facepieces designed to protect from particles in the air), with the provision of tests in which the mask is fitted to a range of test heads. The test rigs were completely designed and built by NPL to provide test data to help demonstrate potential compliance with relevant standards, and also to give additional data to designers seeking to refine and optimise their designs. We aimed to increase the understanding of standards and guidance on PPE and supported the Notified Bodies to maximise their testing capability and efficiency.

Advice and testing were subsequently extended to manufacturers of publicly worn face coverings and novel face mask designs. This predominantly involved modified testing processes to gather useful data about the performance of these products before they were placed on the market. NPL worked with manufacturers throughout the UK, including many SMEs, resulting in the safe introduction of large quantities of PPE including some novel products to satisfy niche requirements.

NPL was also involved in determining whether PPE could be effectively cleaned and re-used, by carefully specifying the cleaning process and protocols. This involved looking at changes in material properties, and hence performance, during and after cleaning, with particular consideration of chemical effects.

Working with UK companies

Protecting Heroes

NPL worked with Protecting Heroes, a not-for profit Community Interest Company, which was focused on the rapid production of high-quality face shields. We assisted with the design and production of demonstrator items, as well as ensuring the product complied to the applicable testing requirements and received CE certification. NPL set up a packing, quality assurance and distribution facility for the face shields at our Teddington site, staffed by NPL volunteers. The face shields are amongst the most highly rated in the world and frontline clinicians say they are the best and most comfortable they have ever used.

Skyrora

Skyrora is a private rocket company which is developing the next generation of launch vehicles for the small satellite market. During the COVID-19 pandemic Skyrora developed a 3D printed design for a face shield. NPL supported Skyrora by giving guidance on full testing and the CE certification process. NPL used its 3D printers in Teddington, Strathclyde and Huddersfield to boost their manufacturing capacity, so that they could rapidly assemble and deliver face shields to care homes in Scotland.

Temperature measurement

NPL is an expert in measuring body temperature and helps develop the standards for fever screening and clinical body temperature measurements. In 2018, we contributed to a United States Food and Drug Administration study on the use of thermal imaging for fever screening. During the COVID-19 pandemic NPL was approached by government bodies, councils, hospitals, transport organisations and measurement companies, for advice and guidance on accurate temperature measurements, the available technology and its fitness for purpose.



Temperature measurements during the COVID-19 pandemic were primarily done using digital electronic thermometers, which are known to have an uncertainty in the reading from 0.5 to 1 °C. NPL contributed evidence to the Department of Health and the Chief Scientific advisers on clinical temperature measurement. Early guidelines on detecting COVID-19 stated that a temperature of 37.8 °C was a critical indicator, but this was later changed to using touch to detect for elevated temperatures. This was particularly important for elderly patients who often have a fever without reaching a threshold 'fever' temperature, and also reflected the accuracy to which a temperature can be measured.

Fever screening had been deployed in certain situations over the past few years but was not regarded as a useful tool for COVID-19 detection, since approximately 80% of carriers were asymptomatic and 10% do not exhibit a fever. NPL advised that many of the thermal imaging systems that had been considered or deployed did not comply with the standards, did not give traceable measurements and, in many cases, were not clinical instruments, so had high measurement uncertainties associated with the data they generated.

Authoritative advice

Although widespread fever screening was not recommended for COVID-19, NPL gave advice on the deployment of reliable temperature measuring systems to hospitals, care homes and other organisations. As the National Metrology Institute and a leading expert in the area, NPL disseminated the current guidelines and information.

NPL are now leading a new Consultative Committee on Thermometry for clinical applications, a working group made up from experts from NMIs internationally. In future pandemics, temperature measurement may be used as a key indicator, and this committee is considering the technology and procedures which will be needed to support it.

Sterilisation

From the beginning of the COVID-19 crisis there was an increased demand for sterilised medical devices, from high volume products, including needles, wound dressings and blood collection tubes, up to more sophisticated products, such as cardiac stents and equipment to maintain blood oxygen levels. Around 50% of single use medical devices are sterilised using ionising radiation, either gamma rays from radioisotopes or high energy electrons and x-rays from machine sources. The industry is highly regulated, and companies must meet specific requirements on the measurement of radiation dose.



NPL provides the essential calibration to the international radiation sterilisation industry, while not carrying out the actual sterilisation. Our industrial sterilisation dosimetry service is based on standard radiation fields and alanine dosimeters, and we are one of the few laboratories in the world providing support and traceability. Usually the calibration is realised on a yearly basis or on-demand if any change is made to the sterilisation process, but there was increased demand during the COVID-19 pandemic.

Calibration of dosimeters is an essential step in the quality assurance process of gamma ray and electron sterilisation. NPL is a 'critical supplier' to many radiation sterilisation companies across the world. We ensured that our calibration services were available during this unprecedented time to support industry as it strived to meet the challenges of maintaining medical device and PPE supply chains, as well as developing new diagnostic tests and treatments.

Our work provided confidence in the quality assurance and sterilisation process, supported by UKAS Accreditation. We offered flexibility and reliability to customers across the world, as well as bespoke expertise to support new processes or improve staff competences.

Vaccine development

There was a massive international effort to develop a COVID-19 vaccine, with over 150 candidates in clinical trials. Vaccines can show variability in their physical and biological properties, and manufacturers must ensure performance consistency from development to batch release. To succeed in this, new reference materials based on prototype vaccine platforms were needed. In addition, effective management and tracing of viral pandemics requires reference materials to ensure accurate and reliable detection.



It is vital to formulate and validate suitable reference standards that exhibit the physical and biological properties of viruses and virus-like structures to benchmark the physicochemical and biological attributes of vaccines. In collaboration with the NHS, NPL set up an inter-comparison to validate virus-like particles using high resolution electron microscopy, so that they could be used as reference materials for the characterisation of vaccines and the diagnosis of COVID-19.

NPL, with VAMAS (Versailles Project on Advanced Materials and Standards) and NIST (the United States' NMI) launched an international call for inter-laboratory comparisons in response to COVID-19, inviting proposals to characterise and validate materials and methods. This activity sits under the VAMAS TWA40 chaired by NPL.

NPL worked on the development of reference virus-like particles exhibiting nanoscale properties and characteristics suitable for accurate, differential measurements of cells, viruses and virus-like structures in clinical samples. The comparison studies helped improve repeatability and reproducibility of proposed methods and materials, and where applicable, validated measurement results with traceability to the SI. These characteristics remain fundamental to ensuring the quality, approval and delivery of safe and effective vaccines.

Oxygen supply

At the beginning of the COVID-19 pandemic there was concern over an adequate supply of oxygen for hospitals and care homes. The oxygen supply chain is from China and the US, so with restricted exports and increased demands the UK was exploring other sources. Shortfalls could potentially have been met by using other grades of oxygen, subject to appropriate validation which NPL could support, or by investigating the feasibility of other methods of oxygen production, such as electrolysis of water. NPL consulted with key suppliers to offer support and expertise.



There were also challenges getting oxygen to the new, temporary COVID-19 beds within hospitals which were not on the existing network of oxygen supply. This was a problem in many countries, and portable devices were required to provide oxygen.

Ventilators require an oxygen sensor to check that the concentration of oxygen in the oxygen/air gas mixture is correct. During the pandemic the supply chain for conventional sensors was exhausted and alternatives were required. NPL developed the concept of a novel electrochemical sensor based on a miniature fuel cell, which had the advantage of not requiring batteries and could be cheaper and more environmentally friendly than current sensors.

NPL has a longstanding relationship with Bramble Energy, a fuel cell manufacturer who were approached by NPL to produce a miniature oxygen sensor. NPL supported Bramble in its bid for funding from Innovate UK and offered laboratory space and resource for the project. Bramble worked with NPL's ventilator team to use this sensor in their novel design.

COVID-19 sensors

Building on previous work to test for hepatitis (B and C) and allergens, NPL has developed a proof-of-concept graphene biosensor for detecting COVID-19. The approach was born from the virus testing procedure at the beginning of the pandemic, which was uncomfortable for the patient, expensive and had limited accuracy. It was also time consuming due to handling and transporting of samples, and required patient travel followed by separate communication of results back.



NPL developed a 10 x 10 mm prototype sensor which gave a rapid result. The sensor is potentially low cost to produce in large quantities, allowing for wide scale population testing. Not only are these sensors very sensitive, they could also be connected to phones, watches or other smart devices. This provides the possibility of real time data to improve our understanding of how a virus spreads and assist healthcare organisations in providing the best response.

NPL then carried out further testing of the technology in partnership with PHE, Ploughshare and NHS laboratories, to understand the performance of the sensor in a clinical setting and begin the process of bringing it into wider use.

The proof-of-concept sensor works by detecting antigens in a sample. The core of the technology is disease agnostic and has the potential to detect a wide range of diseases, pathogens and health conditions.

Optical sensors

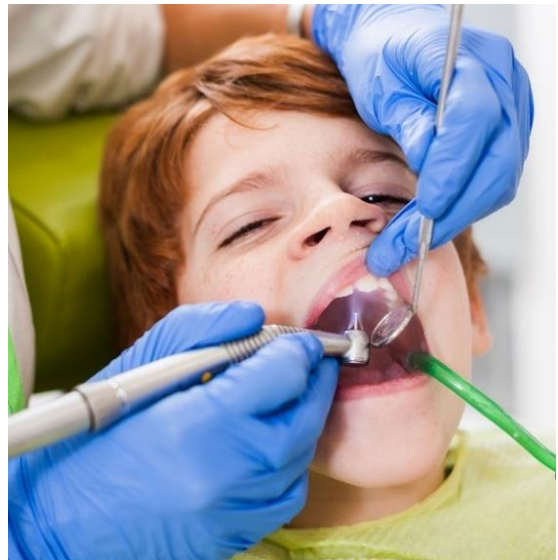
NPL worked with a UK company that detects and helps manage diseases, such as diabetes, through observations of the eye. They use non-invasive sensors which have can deliver quick and accurate tests. NPL extended this research to examine optical methods for detecting COVID-19 using handheld equipment, which require no microscope just sensors to monitor the response.

NPL also investigated developing instrumentation that would use surface enhanced RAMAN spectroscopy to detect COVID-19, or indeed other viruses. The technique can detect singular molecules from samples of blood or saliva and could be exploited using smaller and portable instruments.

As the UK's National Metrology Institute, it is NPL's role to validate new measurement techniques. This means we are ideally placed to collaborate with manufacturers to better understand the performance, repeatability and development of new diagnostic techniques.

Air quality in dental surgeries

Dental treatment involves a range of equipment and 'aerosol generating procedures' which can produce significant amounts of saliva/water-based aerosols in the micron and sub-micron range which present a potential transmission risk for the COVID-19 virus. Before COVID-19 there had been limited studies into the amount, size range and distance spread of dental aerosols. As dentists in England resumed a more normal service, the guidance was to introduce a minimum of one hour 'fallow time' between patients to allow the aerosol particles to dissipate.



During lockdown the number of dental procedures was drastically reduced, resulting in an increase in the proportion of extractions and the number of prescriptions for antibiotics. Dental practices struggled to meet demand for appointments, and the fallow time between patients reduced the number of appointments each day. In addition, the cost of PPE for treating every patient increased significantly. There was an urgent need to improve national dental health and help make dental practices financially viable.

Mydentist, part of the IDH group, is the largest dental provider in Europe and had been in discussions with NPL before the COVID-19 situation about ventilation in dental surgeries. However, in preparation for reopening dental practices for routine treatments, discussions focused on ensuring the safety of clinics for both practitioners and patients. Mydentist asked NPL to perform measurements in a working dental surgery to detect and measure the aerosols produced by a variety of dental procedures and record how they changed over time. NPL used a laboratory optical particle counter instrument to take measurements and compare them with the background levels.

This feasibility study indicated that there was little or no detectable increase in the concentration of aerosol particles for the majority of the 'aerosol generating procedures' carried out by dentists. Aerosols were being effectively captured and reduced by the use of good practice mitigation techniques, such as the high-volume suction tool and rubber 'dams'. This information, along with findings from Newcastle University, was presented to the Scottish Dental Clinical Effectiveness Programme and helped them make recommendations on fallow times and aerosol mitigation procedures.

NPL performed a more detailed study, taking measurements in two dental surgery environments, with varying ventilation levels, instrument types, and for procedures and mitigations, to provide definitive advice. All the information from these tests was shared widely across the dental profession and dental research community.

NPL has also been working with makers of Ultraviolet-C lamps to understand their role in enhancing sterilisation during the fallow time.

Anti-viral surfaces and materials

NPL carried out a comprehensive review of the current state of knowledge, research direction and practices in the area of antiviral materials and coatings. Whilst anti-bacterial properties had been examined closely in the past, the antiviral properties were less well understood and often quite different. We reviewed a range of natural and synthetic surface materials and coatings with documented antiviral properties, including metals, polymers and biopolymers, graphene and antimicrobial peptides, as well as reviewing the properties of surfaces which can influence virus attachment.



The review aimed to understand the mechanisms of antiviral properties at the molecular level and covered the experiences of using these materials. The findings provided an overview of the current practices and applications of antiviral materials and coatings in consumer products, PPE, healthcare and public settings. The information will help the materials selection for future applications, including public buildings and transportation. The work demonstrated the role that material science can play in the development of conceptual and practical measures to slow infectious outbreaks and contribute to the preparedness for future viral pandemics.

The study was carried out with the National Biofilms Innovation Centre and the review article 'Antiviral surfaces and surface coatings and their mechanisms of action' was published in the journal Communications Materials.

We also looked at 3D printing antiviral materials. 3D printing typically involves heating a solid material to approximately 200 °C which reduces any antiviral agents that may be present. NPL developed a resin alternative which has the potential to require less cleaning and hence less abrasion which could reduce the antiviral properties of the material.

Materials used in public spaces are regularly cleaned with antiviral sprays to reduce the COVID-19 risks. NPL is working to understand the impact of using the antiviral chemicals on a range of materials, particularly how often the cleaning is required and how it may influence the material itself from the chemical and mechanical perspective, and in terms of wear.

Data science

During the COVID-19 pandemic, the need for data analysis and support for remote working generated many requests for our experience and knowledge in data science. NPL helped the Royal College of General Practitioners Research and Surveillance Centre to produce their regular updates on communicable and respiratory diseases for Public Health England throughout 2020.



NPL was able to offer help to the Royal Free London NHS Foundation Trust by analysing different kinds of medical data, including:

- extracting the maximum amount of reliable data from biomarkers tests
- analysing the critical pathways in cancer care to meet the anticipated increase in demand after COVID-19
- preparing buildings for safe and efficient movement of patients and staff around hospital sites while adhering to the government guidelines.

We were heavily involved in testing PPE, a process that often involves several testing iterations as designs are refined. Data science allowed certain tests to be simulated, such as field of view tests, so that the computer model could predict if a design would pass the test. This helped streamline the testing and gave confidence that the PPE would pass the tests.

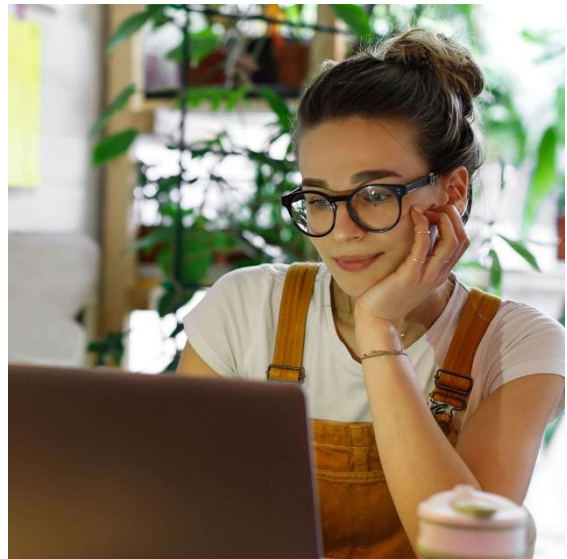
NPL also:

- Worked with the Royal Surrey NHS Foundation Trust to support remote working for as many staff as possible, not something that had been a priority before the pandemic
- Used signal analysis of telephone calls to GPs and 111 to diagnose COVID-19 by analysing the acoustic signals of breathing and coughing
- Analysed the link between mortality or diagnosed COVID-19 cases with air quality data to understand the impact of pollution.

Our work enabled organisations to operate effectively while responding to the pandemic and adhering to government social distancing guidelines. We accelerated the pace of data analysis and enabled complex analysis of data and greater understanding of uncertainty.

e-learning

NPL has always played a leading role in providing training in measurement science, an essential skill for the current and future workforce. At the beginning of April 2020 we made our catalogue of e-learning courses available free of charge to provide training opportunities for UK industry so they could re-skill and respond to changes in business due to COVID-19. The e-learning covered general measurement, dimensional measurement and a range of specialist courses and was designed to accelerate skills development in applied measurement.



Our objective was to help individual's wellbeing and motivation, as well as enhancing their skills and career pathways. The training allowed industry and academia to invest in their workforce and prepare them to play a role in helping UK industry to recover quickly post COVID-19. Nearly 10,000 new learners registered for e-learning and there was a 99% satisfaction rate in the training experience. From October 2020 until the end of 2020 there was a 50% reduction in price.

Outreach

NPL has always recognised the importance of promoting Science, Technology, Engineering and Mathematics (STEM) activities and inspiring the next generation. During the COVID-19 pandemic we became involved in the requirement to educate online about the vital role metrology, the science of measurement. Measurement at Home, NPL's new online STEM initiative, was launched in May 2020. We supported home learning activities, schools and other organisations by providing online activities and high quality STEM and physics information.



Measurement at Home aims to get everyone, particularly school children, engaged and interested in science by creating a measurement community that virtually brings science into households nationally and globally. Regular challenges are posted on the website, and the wider 'measurement community' are encouraged to send in results and share pictures of their tests using the hashtag #MeasurementAtHome. In the first three days, over 70 people submitted results, having measured the strength of breakfast cereal on homemade test apparatus. Measurement at Home remains an important part of our outreach activities.

NPL's annual Water Rocket Challenge became the Space Rocket Challenges and was delivered online, in partnership with the UK Space Agency. Widely shared on social media and mentioned by Tim Peake in his podcast, these challenges had a great response including over 60 designs for rockets, one with 49 pages of detail.

The Virtual Physics Laboratory (VPLab) simulation software proved very popular through lockdown. Webinar demonstrations to groups of teachers were made with over 1,900 downloads of the full resource. Over 50,000 simulation downloads were made by students to use at home, a facility that was not available prior to lockdown. The rate of new users was twice what it was before COVID-19, with the total number well over 6,800.

NPL continued to offer remote presentations and other outreach activities to schools, the Association of Science Educators and other groups. We attended more than 100 online events and 'virtually' met 29,000 people. Staff judged several 'Young Enterprise' competitions, appeared in 'Physics World', attended science festivals and volunteered for 'I'm a scientist get me out of here'.

NPL scientists carried out 15 live presentations for schools, co-ordinated by STEM Learning. These can now be used for other outreach activities and are ideal material to stimulate class discussions and assemblies.

For further information visit
www.npl.co.uk/covid-response

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