July 2020

DAE TECHNOLOGY Bulletin

(COVID Special)

Government of India

Deparment of Atomic Energy

के. एन. व्यास
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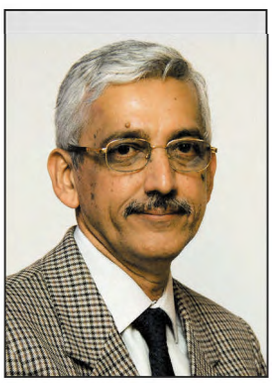
सत्यमेव जयते
भारत सरकार
Government of India

अध्यक्ष, परमाणु ऊर्जा आयोग
व
सचिव, परमाणु ऊर्जा विभाग
Chairman, Atomic Energy Commission
&
Secretary, Department of Atomic Energy

Chairman's Message



Department of Atomic Energy(DAE) has been an important contributor to the fight against cancer and treatment of various other diseases using radiation therapy and nuclear medicine procedures. The ongoing pandemic caused by the Novel Corona Virus is unprecedented in recent memory and has thrown up a fresh challenge to humanity.DAE with its highly multi-disciplinary expertise and a wide technological bandwidth has made efforts in contributing towards the fight against the pandemic.

DAE has been proactive in adapting technologies available in the nuclear sector to devise solutions for some important aspects connected with combating the pandemic.

TIFR is in the midst of a Serological survey led by Niti Aayog in Mumbai. Clinical trials of the chlorophyllin, a phyto-pharmaceutical developed in BARC to treat cancer, have shown promise as a "repurposed" drug in treating COVID patients due to its antiviral properties. Power respirators developed for personnel working in radiation and nuclear fuel facilities have been adapted as personal protective equipment for doctors treating COVID patients. Other developments include use of radiation technology for sanitisation of PPEs, design of high quality masks for medical professionals and common users as well as the development of a low cost test kit for COVID-19.

I congratulate my DAE colleagues who have worked during the last three months and risen to the occasion to develop or adopt technologies which can help in the fight against the pandemic. I dedicate the contributions of our scientists and technologists brought out in this brochure to the nation and humanity. We recognize that these technologies are far from mature. This bulletin is in the spirit of recognition of their efforts during these testing times and to remind us of the goals ahead.

(K. N. Vyas)

राष्ट्र की सेवा में परमाणु
प ऊ वि
DAE
ATOMS IN THE SERVICE OF THE NATION

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FOREWORD

COVID-19 is the most devastating pandemic since the 1918 influenza pandemic that has hit the globe. Caused by the novel coronavirus SARS-CoV-2 virus originating from China, it spread rapidly across the world claiming many lives. With no vaccine to protect against and no antibiotics to treat the disease, we have been left with the only option of adopting various control measures limited to interventions such as isolation, quarantine, personal hygiene, use of disinfectants, limitations of public gatherings and other social distancing measures to retard the spread of the infection. Large parts of the world had been forced to lockdown in order to slow down the spread of the pandemic. The economic loss inflicted by the lockdowns across the world is unprecedented.

Despite being highly vulnerable through constant exposure to the viral infection, the medical fraternity was more than busy combating the deluge of patients infected by the coronavirus. Both developed and developing world had come under immense pressure in providing not only the equipment required for the treatment of patients but also to supply the basic gear required for medical professionals to protect themselves from the infection. In the early days of the pandemic, the country was critically dependent on imported test kits, of questionable reliability, at a great expense. In this backdrop researchers in the Department of Atomic Energy developed a test kit with highly promising results. Radiation technology has been harnessed to develop protocols for sanitizing Personal Protection Equipment (PPEs) for their re-use. Plasma technologies developed for radioactive decontamination were tweaked to produce cost effective solution in the fight against COVID. Technologies developed for Nuclear waste management have been adopted to make high quality masks. These are just few examples of our scientists moulding their knowledge and technical expertise acquired over the years to innovate and improvise within their own domains and contribute to the current emergency as well as to various measures that are needed to adapt to the New Normal. Several solutions have been developed for maintaining hygiene and implementing social distancing measures. This bulletin is a compendium (compilation) of various products and technologies born out of the timely efforts of our scientists in the fight against COVID-19. This is indeed a tribute to their scientific spirit and temper.

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IN THIS ISSUE

Public Health Measures in DAE for COVID Pandemic

COVID-19 is a major crisis to have hit the globe in recent memory. While there exists no remedial measures to cure the decease, we are left with various steps that are recommended for prevention of the infection. Social distancing measures, wearing a mask and use of sanitizers to maintain hygiene have become the first line of defence against the spread of COVID-19. These measures are essential to ensure the safety of employees required for sustaining the minimum essential operations in an organisation. In the event a vaccine or a credible treatment is delayed further we may have to imbibe these measures for much longer time to come.

All the units of the Department of Atomic Energy (DAE) including autonomous institutions have diligently implemented the above measures and largely succeeded in curbing the spread of COVID-19 among the employees and in the residential colonies.

To maintain overall hygiene in the official premises, sodium hypochlorite is sprayed periodically to sanitize offices, plants and buildings including housing colonies Automatic hand sanitizer dispensers are installed at all entry points of buildings and plants. The entry of essential staff has been staggered to avoid crowding at the gates. Employees are thermally scanned before they are allowed entry into the office premises.

The DAE units have chosen to produce the sanitizer in house not only because it is economical but also to ensure reliable and consistent supply, especially during the lockdowns. For instance, Chemistry Group has been producing sanitizer using Ethanol or Isopropanol based on WHO formulation. No fragrances and colour were added to avoid the risk of any kind of allergy. A precautionary note indicating that the ingredients are flammable was pasted on the containers.

Nuclear Fuel Complex (NFC) has installed a number of foot operated wash basins and soap dispensers in all the plants, change rooms, entry gates, office buildings, etc. Existing wash basins have been converted into foot operated wash basins. Foot operated liquid soap dispensers were installed at each wash basin.

Plants, public places, offices, wash rooms, entry gates, vehicles, etc. are sanitized at regular intervals. Vehicles entering the campus are disinfected before entering the campus. Tractor mounted units are employed to disinfect plants and public buildings.

Heavy Water Board (HWB) has ensured minimum manpower at its plants for keeping the emergency systems in operation while complying with various statutory guidelines to curb the spread of COVID-19 at the Heavy Water Plants (HWPs) in Manuguru, Kota, Thal, Hazira, Talcher, Tuticorin, Baroda, and a facility at Technology Demonstration Plant, RCF (Chembur), Mumbai. Roster duty has been implemented as per the guidelines of respective State Governments. Transportation is provided for essential services personnel. HWPs at Thal & Hazira, which are parasite to fertiliser plants of RCF and KRIBHCO, were operating under essential services. All

On-site Sodium Hypochlorite Electrolyser

BARC developed a Sodium Hypochlorite (NaOCl) Electrolyser Plant (SHEP), which is ideal for on-site production of NaOCL. The Plant has a single pair of electrodes along with several auxiliary instruments such as water purifier, gas sensors, flow-meters, temperature sensors, etc., all housed in a single enclosure. The plant produces consistent solution strength of NaOCl in required volumes by electrolysis of common salt dissolved in water.

The SHEP has competitive energy efficiency & foot-print area as per industrial standards. Entire spectrum of the product concentration (0.1 to 1%) has been mapped and operating time is optimized accordingly. Hence, this plant can be operated for various virus loads. Further, product spraying system developed has unique feature of very long jet (upto 10 m distance), which can penetrate all the corners thus safe-guarding the user.

The plant is ideal for use in Micro, Small and Medium Enterprises, offices and hospitals, use in hospitals and offices, in addition to its application for water treatment plants.

employees were advised to bring their own food and requested to avoid gathering in canteens. Situation at the HWPs and the compliance of the guidelines issued by DAE were frequently reviewed through video conferencing.

In the residential colonies of the HWPs, immunity booster Homeopathy medicines, 'Arsenicum Album-30' recommended by Ayush Mantralay, have been distributed to the residents. Employees were advised to report visits of their relatives from outstation and they were kept quarantined for two weeks. In some colonies, door to door surveys were conducted to ascertain the health of families and visitors. Employees contributed their might in distribution of essential commodities to the needy in nearby villages.

HWP, Manuguru (HWPM) started functioning with full strength from 09.05.2020 and XU (Exchange Unit)-I was restarted after obtaining necessary permissions from State Government. MTA Work commenced on 27.04.2020 with contract labourers and local contractors. HWPM has provided shelter, food and sanitation to immigrant labourers from Gujarat, who were stranded for the entire period of lockdown. COVID-19 awareness programs were conducted for contract workers and masks and sanitizers were distributed to them.

UV Based Key Bunch Sterilizer

Board of Radiation & Isotope Technology (BRIT) developed a non-contact UV based system to sterilize personal belongings such as keys, watches, belts, etc.

A sensor is built into the system to detect the presence of an object placed in the sterilizing chamber. The chamber automatically rotates in the direction of the UV-C light and is turned on for a pre - programmed time of exposure. After the UV – C lamp is turned OFF, original position of the chamber is restored for the user to collect the items. The user is not at all exposed to UV-C rays. The unit will be deployed for regular use once it passes the QA test.

UV Cabinet for Sanitizing Office Stationery

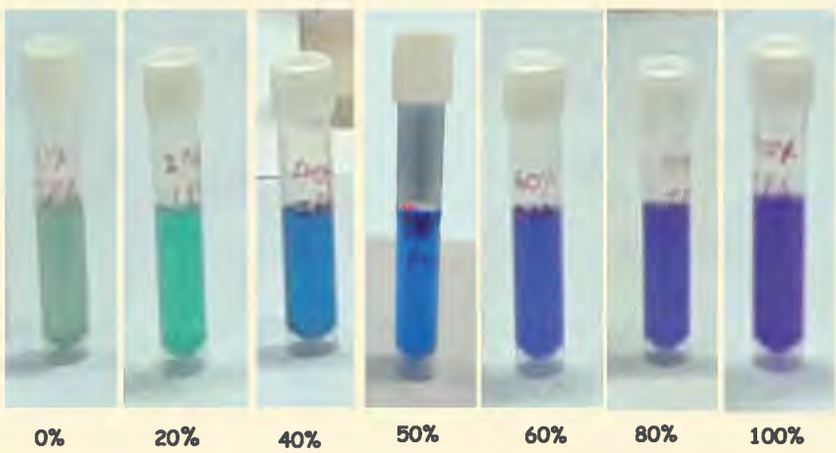
BRIT routinely analyses samples for radioactivity. There is a possibility that the surface of these samples are contaminated by SARS-CoV-2 virus.

BRIT developed a UV cabinet for Sanitizing Files/folders & Sealed samples. They are exposed to UV-C light in the UV cabinet for 15 minutes. Adequate precaution is taken to avoid exposure of human body parts, especially eyes, to UV radiation.

UV based key bunch sanitizer

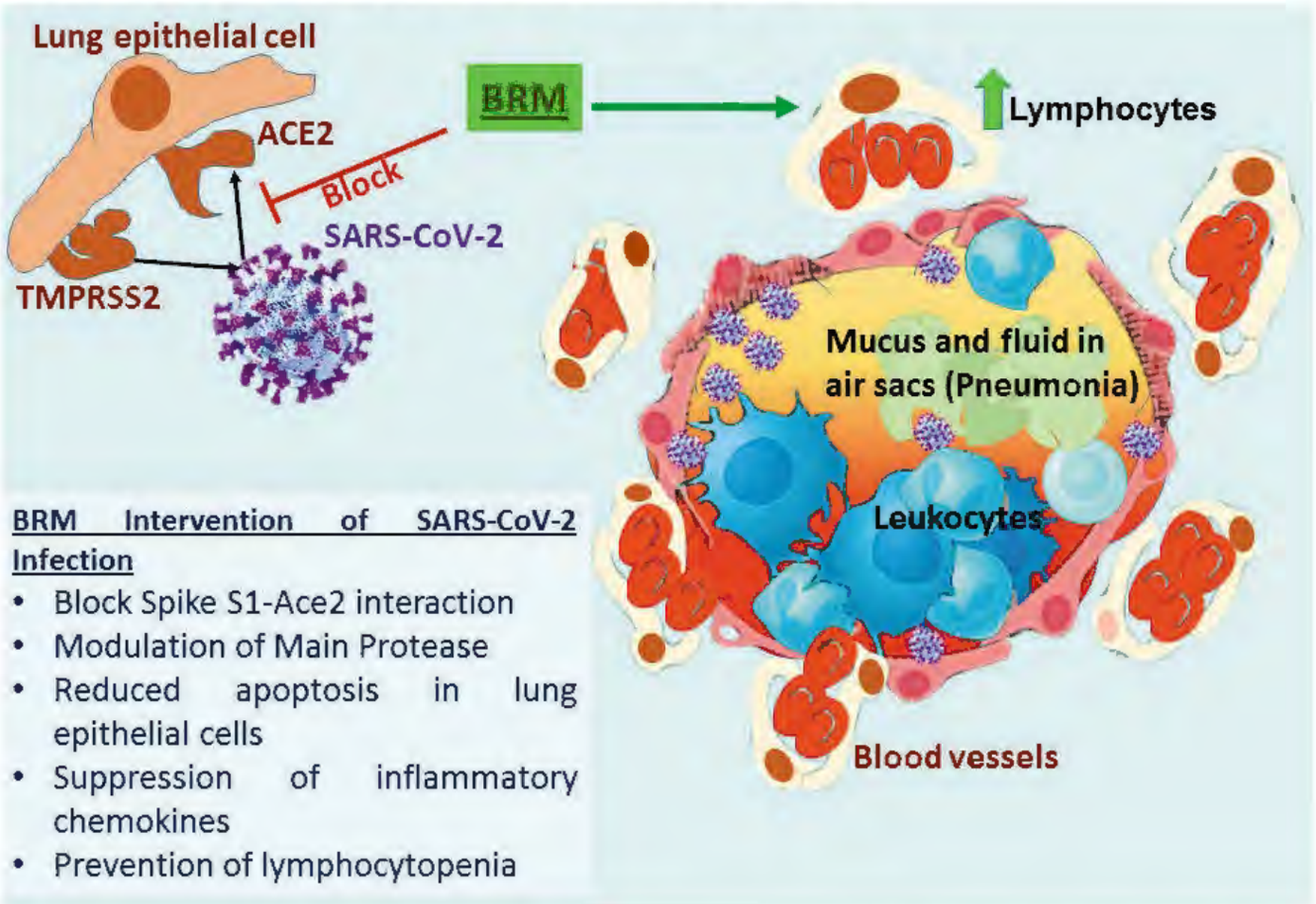
Test Kit for Alchohol Based Hand Sanitizers

National Centre for Compositional Characterisation of Materials (NCCCM), BARC, Hyderabad developed a simple test kit which can rapidly check ethanol or propanol content in hand sanitizers. The test kit consists of two chemicals which are sequentially added to a small sample of sanitizer in a 10 ml glass or plastic vial. The solution acquires a distinct color depending on the alcohol concentration, irrespective of the presence of additives such as glycerol or hydrogen peroxide. The colours remain stable for more than 10 minutes. Sanitizers that differ by 10% in alcohol content exhibit distinctly different colours in the test. The method is equally effective for ethanol or isopropyl alchohol based sanitizers and also for those bearing sky blue or mild pink colour. Furthermore, the test kit costs only one rupee per five.



Colours observed after the addition of test chemicals for sanitizers containing isopropyl alcohol in different volume proportions

Chlorophyllin for Treatment of COVID-19



Chlorophyllin is a water-soluble derivative of green plant pigment chlorophyll. Research at Bio-Science Group, BARC has shown that chlorophyllin specifically protects normal cells and organs like lymphocytes, stem cells and lungs against ionizing radiation induced toxicity in mice. It is found to be very effective against radiation induced killing of human breast cancer derived xenograft tumors (US patent No 10183026B2 dated 22nd Jan 2019). It has been proposed for use of chlorophyllin as an adjuvant to cancer radiotherapy. In a toxicity study conducted in rats and mice, chlorophyllin was found to be well tolerated up to a dose of 5g/kg body weight. Based on its safety and efficacy in animal models, Phase I clinical trial of chlorophyllin was carried out in healthy human volunteers with approval from DCGI. Chlorophyllin tablets were manufactured by M/s IDRS Labs Pvt Ltd, Bengaluru under technology partnership with BARC. Chlorophyllin was well tolerated in healthy human subjects, reduced inflammation markers and improved immunity by increasing the abundance of immune cells (lymphocytes and neutrophils) in blood. These effects pointed towards possible therapeutic application of chlorophyllin for treatment of patients who cannot fight infections due to weak immune system.

COVID-19 is associated with severe depletion of immune cells, increased inflammation and death of lung epithelial cells (pneumocytes). Since chlorophyllin was shown to improve immunity, reduce inflammation, prevent death of lung epithelial cells and also inhibit other viruses like hepatitis C virus, poliovirus and HIV, it was proposed for possible treatment of COVID-19. Structure based docking studies also indicated possible inhibition of SARS-CoV-2 virus multiplication by chlorophyllin. We have started Investigator initiated clinical trials of chlorophyllin in COVID-19 patients with approval of Ethics Committees of Kasturba Hospital for Infectious Disease (KHID) Mumbai, and Tata Memorial Hospital (TMH), Mumbai and after obtaining a 'No objection certificate' on behalf of Director General Indian Council of Medical Research. The trials are initiated in 76 mildly symptomatic COVID-19 patients and in 64 severe cases like pneumonia due to COVID-19. Preliminary results indicate positive outcome in terms of faster recovery of immune system in mildly symptomatic patients after Chlorophyllin treatment as compared to those undergoing standard treatment. Early intervention with chlorophyllin also prevented deteriorating symptoms indicating its ability to prevent COVID-19 associated death.

Another clinical trial of chlorophyllin has been initiated at TMH, Mumbai involving COVID-19 patients suffering from cancer in both mildly symptomatic patients and those with pneumonia due to COVID-19.

Plasmas – in Fight Against COVID-19

Most matter around us occurs in solid, liquid and gaseous states. Plasma, the fourth state of matter, is not seen naturally in our immediate environment. However, man-made plasmas are everywhere. For example plasma is the source of light in a fluorescent lamp. Plasma is a collection of positive ions and free electrons produced in a gas discharge. Usually it is a rarefied inert gas which is ionised in a fluorescent lamp. Sun and stars are big balls of plasma at such high temperatures, where all the atoms are ionised. Plasmas occur in a wide spectrum of temperatures. While fluorescent lamp is an example of cold plasma, stars are made up of very high temperature plasma. Department of Atomic Energy works with plasmas across the temperature spectrum for applications ranging from radioactive decontamination to futuristic fusion energy generation. Following are some plasma devices with profound applications in the fight against COVID-19 developed or improvised using the knowledge and expertise acquired over the years.

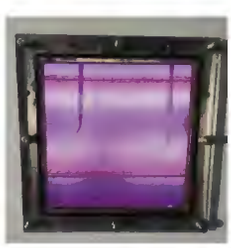
Portable Plasma Sterilizer

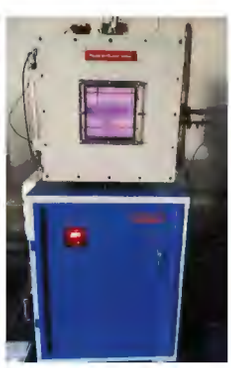
Institute for Plasma Research, Gandhinagar (IPR) has been working on various applications of plasmas, especially for medical and health sector. IPR developed atmospheric pressure plasma jet (APPJ) - also referred to as *pencil torch* and is exploring the possiblity of using it in cancer & skin treatment.

IPR has now developed an array of APPJs by modifying the pencil torch for sterilizing non conducting surfaces from pathogens, which may be of great significance during the current COVID-19 pandemic. A portable plasma sterilizer developed by IPR can be used to sterilize mattresses, cushions, floor, walls, tables, etc., in hospital ICUs. It is established in collaboration with Nirma University that a 15 minute exposure to the pencil torch causes a 6-log reduction of Bacterial load (Staphylococcus Aureus, E-Coli, Pseudomonas Aeruginosa). However, effectiveness against Viruses, including SARS-CoV-2, is being studied in Centre for Cellular and Molecular Biology, Hyderabad. The product design is presently being improved with respect to handling and ergonomics.

Plasma Sterilizer

IPR patented a plasma sterilizer to sterilize small and medium size surgical instruments such as scalpel, forceps, scissors etc., and personal protective equipment (PPEs such as gloves, masks, etc.). A study conducted in collaboration with B.V. Patel Pharmaceutical Education and Research Development Centre (PERD), Ahmedabad revealed that one hour exposure to plasma yields a 6 log reduction in the bacterial species such as S. Aureus, E-Coli, P. Aeruginosa, and Salmonela Abony. IPR is working out an arrangement with C-CAMP, Bengaluru (an organization under Department of Biotechnology) for validation and commercialization of plasma sterilization system against viruses including COVID-19.





Cold Plasma for Sterilisation

Cold Plasmas have long been used for cleaning up surfaces suspected of radioactive contamination. Now a team of scientists from Beam Technology & Development Group (BTDG) have demonstrated that the cold plasmas are also very effective against surfaces contaminated by *Aeromonas* bacteria and Bacteriophage virus – considered to be a tougher virus to destroy than the Coronavirus. The team has made the Cold Plasma Torches in two versions – one, operating at microwave frequency (2.45 GHz) is particularly suited for small areas. For instance, a 2 mm^2 area can be sterilized in 2 minutes. The second version operates at radiofrequency (13.56 MHz) and is ideal for larger surfaces and can disinfect a 40 cm^2 area in less than 4 minutes. The team has shown that N-95 masks can be disinfected from the two test-pathogens using the RF plasma device without affecting the quality of the filter material or its aerosol capturing efficiency.

(a) N-95 mask being treated under Cold plasma (b) Cold plasma disinfection set-up in BARC Hospital, (c) Disinfection of personal belongings under cold plasma treatment in BARC Hospital.

Plasma Pyrolysis for Disposal of Bio-Medical Waste

While the authorities are mainly preoccupied in controlling the COVID-19 pandemic, the volume of the biomedical waste (BMW), generated from infected and suspected patients and COVID dedicated hospitals and quarantine centres treating them, is swelling by the day. Mixing the waste, which includes used masks, gloves, personal protective equipment (PPE), etc., with regular medical and household garbage poses a grave public health hazard.

IPR has patented a plasma pyrolysis system for safe and environment friendly disposal of BMW. Based on the evaluation carried out by the Central Pollution Control Board for its emission performance, the system has been accepted & included in the Gazette of India, Bio-medical Waste Management Rules 2016 for safe disposal of BMW.

M/s Ankur Scientific Energy Technologies Pvt. Ltd., Baroda; M/s Crimson Energy Experts Pvt. Ltd., Pune; and M/s Indiahub E-Governance Pvt. Ltd., Noida have been recommended for grant of license against the expression of Interest floated by IPR for licensing of the plasma pyrolysis technology for safe disposal of BMW. Process for technology transfer is underway.

Model of the plasma pyrolysis system.

Plasma for Environment Friendly Disposal of COVID Waste

Thermal plasma torches offer environment friendly mechanism for disposal of hazardous wastes such as electronic and nuclear wastes. BTDG, BARC developed a high temperature (>8000K) air plasma jet capable of gasifying COVID infected PPE and other wastes rapidly with negligible residue and no harmful emissions. On the contrary, low temperature incineration generates highly carcinogenic compounds like dioxin, furan in addition to other pollutants and ash. The plasma process produces mainly CO, H_2 and N_2 which are made to combine with excess air to be converted into CO_2 and H_2O. N_2 mostly remains unaffected.

Thermal plasma system for complete destruction of COVID infected wastes

Hydrogen Peroxide from Tap Water Using Plasma

Hydrogen peroxide has gained importance as a highly effective disinfectant in maintaining hygiene during these COVID times. Commercial production of H_2O_2 following traditional wet route is complex and energy intensive needing costly equipment and large space. Moreover, start up and shut down times are long. BTDG, BARC came up with a portable cold atmospheric pressure plasma unit for onsite production of hydrogen peroxide from tap water.

The system is based on a very simple principle. Strong synthesis of H_2O_2 occurs through two parallel routes. Highly energetic electrons in the cold Atmospheric Pressure Plasma Jet (APPJ) breakdown the oxygen molecules into atomic oxygen which reacts with water to form H_2O_2. In a parallel process, energetic electrons break water molecules into atomic hydrogen and OH radicals. While H combines to form molecular hydrogen, OH radicals combine to form H_2O_2. Concentration of H_2O_2 can be varied by controlling flow rate of water. Typical production rate achieved is 750 ml/h with an H_2O_2 concentration of 25 ppm.

The portable unit for H_2O_2 production

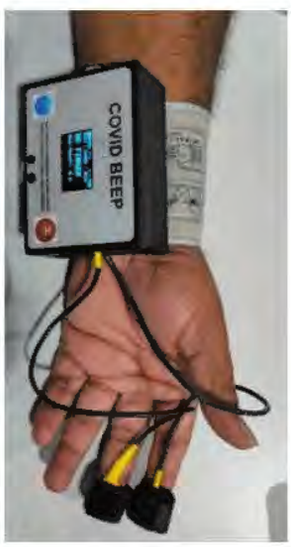
Electronics & IT Applications

IoT Based COVID BEEP

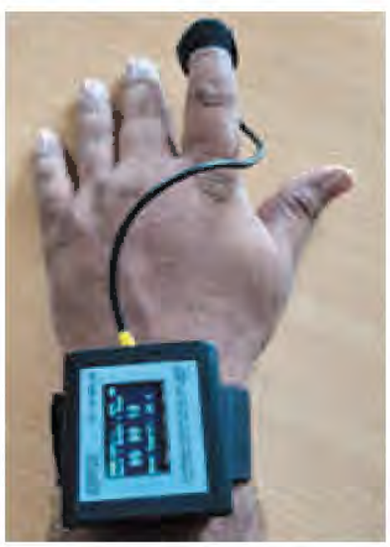
Electronics Corporation of India Limited (ECIL) developed a watch-like wearable device COVID-BEEP for remote monitoring of COVID-19 patients. The prototype was tested on different patients in Employees' State Insurance Corporation (ESIC) Medical college, Hyderabad. COVID-BEEP essentially helps the frontline healthcare personnel to monitor the health condition of the COVID patients remotely without being exposed to them. A GPS module built-into the device helps in identifying the location of the patient either using Google Maps or from BHUVAN – the Geographic Information System (GIS) developed by Indian Space Research Organisation (ISRO). ECIL worked closely with the National Remote Sensing Center (NRSC), Hyderabad for incorporating this feature.

COVID-BEEP on the wrist of a COVID patient measures vital health parameters of the patient such as body temperature, blood oxygen level (SpO2), heart beat, respiration rate, ECG and Blood Pressure and transmits them to an IoT (Internet of Things) gateway. IOT gateway in turn sends the data to a cloud/private server in an appropriate format. The data can then be accessed by the doctor on his mobile phone or computer through wifi, LAN or WAN. The gateway is equipped with huge memory and can back up the data during loss of connectivity. For the home-quarantine patients placed in remote locations where internet is not available, COVID-BEEP, incorporated with an in-built GSM / GPRS network, can directly communicate to the cloud or server in the device.

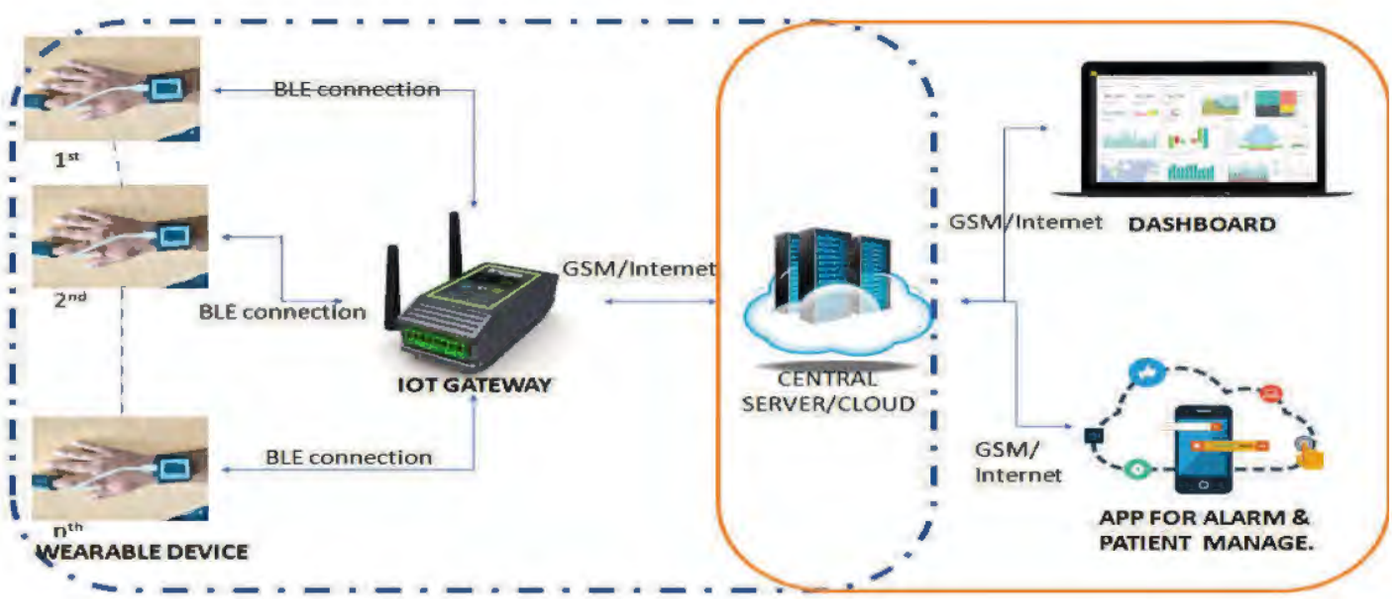
An IoT gate way can simultaneously serve a maximum of 20 patients wearing COVID-BEEP devices. Doctors and healthcare workers treating COVID-19 Patients are alerted when the health parameters of a patient exceed a preset value to enable them to respond immediately.



Wearable device



AROGYAVANI device



Remote Wearable Health Monitoring System with IoT

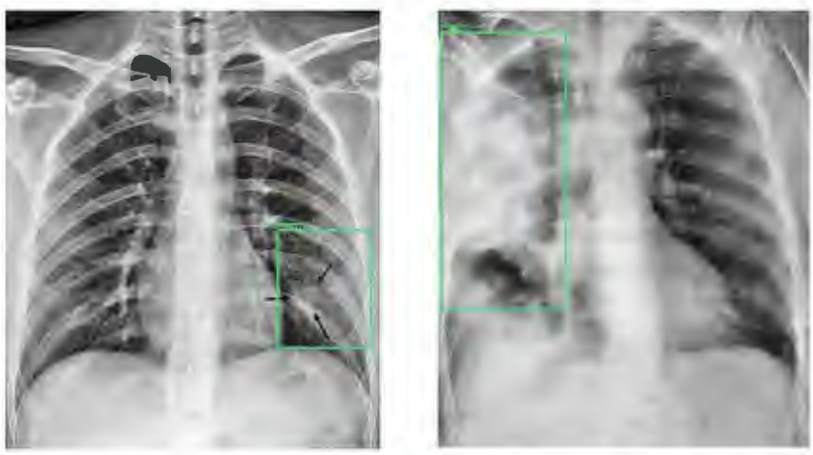
AI Model for Arogya Setu Safe Zone Detection

IPR has developed an artificial intelligence based deep learning software which is extended to analyze health safety from arogyasetu app. The employee/visitor needs to run the app on their mobile phone and point in the direction of camera, the camera scans the image and finds the low risk or you are safe in the image. The software is implemented in IPR entry gate security and shows an accuracy of 95%.

Deep CXR System for Chest X-ray Analysis

IPR has developed an artificial intelligence (AI) based deep learning software (DeepCXR) for prediction of abnormal chest ailments in the chest X-Ray images. This is being extended for detection of COVID-19.

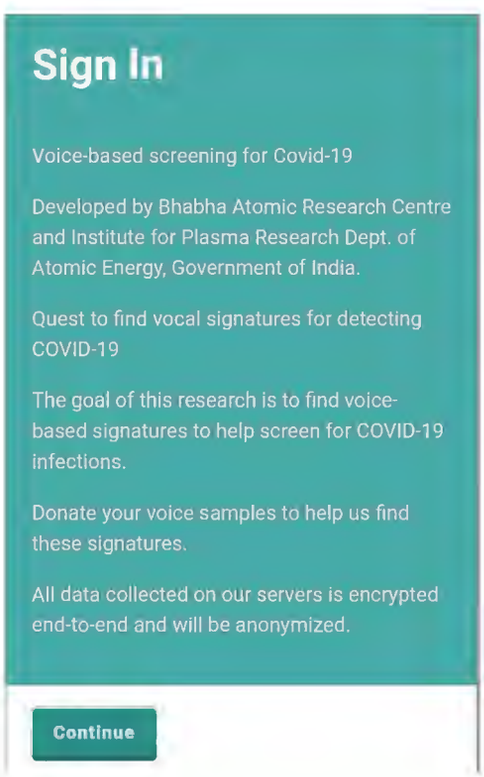
The software has a current prediction accuracy of 97% and is further being improvised with the help of Civil Hospital Ahmedabad & Govt. of Gujarat, Dept. of Health & Family welfare. An MoU has been signed with ICMR Delhi & NIRT Chennai for use of this software in national TB eradication programme. This MoU also considers extending this software for use in analysis of COVID-19 symptoms.

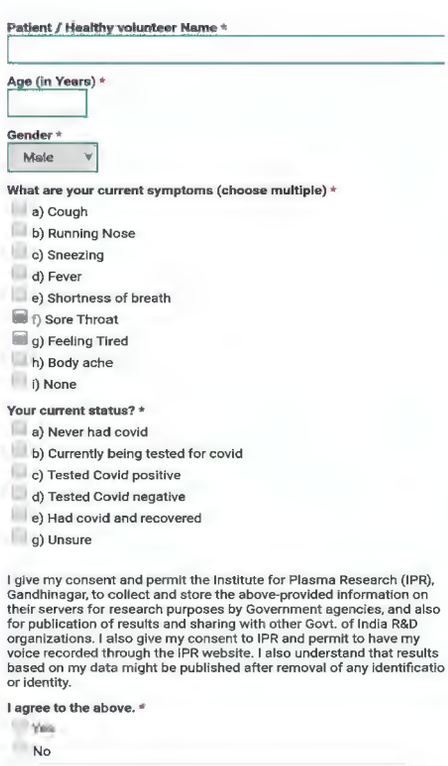


True Positive Images with areas of abnormality marked on Images

Voice Based Screening for COVID-19

IPR and BARC Vizag in collaboration with the Government of Gujarat, Dept of Health and Family Welfare are jointly developing a web application to detect COVID-19 by analyzing voice recorded remotely. Voice samples of COVID-19 patients (through doctors) and healthy individual volunteers are collected through web based mechanism. Individuals can login/register by opening the link https://covid19-icmr.ipr.res.in. After filling a questionnaire about the health status, he/she is directed to record his/her voice and cough samples. The algorithm works on the premise that the tonal quality or the frequency composition of voice and cough samples from a COVID affected person will differ from that of a healthy individual. The software is being trained to improve prediction accuracy.





Development of Mechanical Ventilator

IPR developed prototype of a big valve mask (BVM) type mechanical ventilator (with mechanized compression), needed for the treatment of critical COVID-19 patients. The prototype with electronically controlled flow meter with feedback loop is functional. The optimization process in consultation with medical practitioners and validation trials are being carried out for end use.

About the product:

The product is a mechanical ventilator of BVM.

Power	*: < 1000 W (@230V AC, 50 Hz, 4A)*
Tidal volume	*: 300 – 800 ml*
Breath per minute	*: 8-40 BPM*
I/E ratio	*: 1:2 – 1:4 (variable), default at 1:2*
Footprint	*: 0.5 sq. m*
Modes	*: CPAP & PEEP modes capability*
Feature	*: Variable BPM, Oxygen inlet & tidal volume with feedback loop control*

Video Conference Application

In order to maintain social distancing during COVID-19 pandemic, meetings are required to be conducted online as far as possible. VECC has installed a browser based and user friendly open source video-conferencing software on a server, configured and tested successfully. The facility supports 120 concurrent users in a virtual room and can be extended to individuals from different DAE units to participate in a meeting from their desktops through Anunet. The tool can be very useful for on-line classroom as well.

Quad Copter for Surveillance

VECC, Kolkata has developed a quadcopter (drone) at a cost of Rs. 30,000/-. It can be programmed for autonomous aerial surveillance following pre-specified GPS locations including take-off point and landing points. It will be very useful for aerial surveillance of people staying in quarantine centres, crowded market places etc.

Masks and PPEs

Face masks are the first defense against COVID-19. It is imperative that they are affordable to a wide spectrum of the population of India and preferably reusable without compromising the effectiveness against the infection. While masks are the protective gear for the general public, medical professionals working at the forefront of the COVID fight need protection at much higher level. Personal Protective Equipments (PPEs) are critical gear to protect healthcare professionals from direct exposure to body fluids (blood, saliva, plasma, serum, urine, spit, etc.) from COVID-19 patients. BARC, BRIT and TMH have developed sterilization processes for masks and for PPE kits. Testing protocols are evolved not only for assessing the quality of the masks and PPEs but also to qualify the sterilization procedure developed for their reuse.

High Quality Face Masks from Indigenous HEPA Filters

HEPA filters are typically randomly arranged mat of fiberglass fibres of diameter 0.5 to 2.0 μm. At least 99.95% of particles of diameter 0.3 μm are removed from the air that passes through these filters. Commercialized in the 1950s, HEPA filters find applications in high tech areas such as manufacture of disk drives, medical devices, semiconductors, food and pharmaceutical products, and in nuclear, aviation, automobile sectors and hospitals.

Large scale manufacture of HEPA filter

Nuclear Recycle Group, BARC had acquired indigenous capability to produce HEPA filters required for special applications in Nuclear Waste Management. Responding to the current pandemic, BARC exploited this knowhow to develop High Quality Face masks using the indigenous HEPA filters with filtration efficiency in excess of 99.97%. Masks were manufactured using automated machining and ultrasonic sealing process. Key advantages of these filters are low breathing resistance and high tensile strength and they can be sterilized either by heating at 60°C or gamma irradiation without compromising their efficiency.

Mask configuration

Mask made by automated process

Tests carried out by National Institute for Occupational Safety and Health (NIOSH) at BIS approved lab revealed a filtration efficiency of 98-99% and that by South India Textile Research Association (SITRA) lab reported better than 99%. All other parameters such as breathing resistance, splash resistance and flammability are equivalent to those of N99 and Filtering Face Piece (FFP)-3.

Evaluating Efficacy of Face Masks

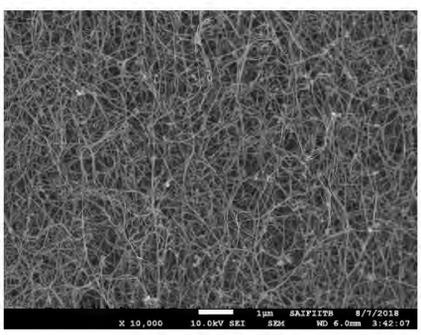
Radiological Physics & Advisory Division (RP&AD), BARC developed a setup in a very short time to test effectiveness of face masks. The test involves evaluating how effectively aerosols are captured by the filter material used in making the mask. NaCl particles of size ranging from 10 nanometers to 20 micrometers generated by aerosol atomizer (TOPAS ATM226) are used as test particles. About 100 samples of different filter media, before and after subjecting them to steam sterilization, gamma irradiation, thermal and cold plasma treatments, were tested. While this test provides a measure of the intrinsic efficiency of the material used in making a mask, test procedures are developed to evaluate how well a ready-to-wear mask performs and how it fits to the face as well. Finally pressure drop test evaluates the resistance offered by the material to air flow, thereby provides the comfort level to the person wearing the mask.

Instrumentation to test by efficacy of masks

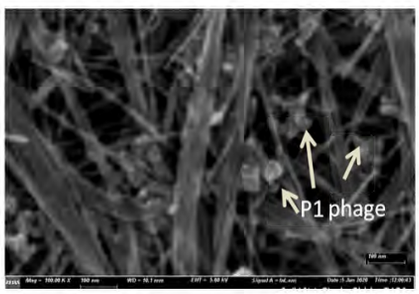
Capture of Virus by Self-Assembled Carbon Nanotube Based Filters

Carbon nanotubes (CNT), by virtue of their high specific surface area, find novel applications in adsorption, separation and filtration. Recently, Glass and Advanced Materials Division, BARC developed floating catalyst chemical vapour deposition (FCCVD) technique, for which a patent has been filed, which enables self-assembly of CNTs to form into sheets of wool. Size of the SARS-CoV-2 virus is in the range of 80-160 nm while the average pore-size of CNT-wool is below 100 nm. In comparison, commercial N-95 masks have a pore size of around 300nm. It is envisaged that CNT wool will be very effective in trapping SARS-CoV-2 virus and therefore ideally suited to make face masks. This is demonstrated by the tests conducted against bacterophage P1 virus with a large head of approximately 55–85 nm diameter attached to a characteristic long tail of 200-300nm.

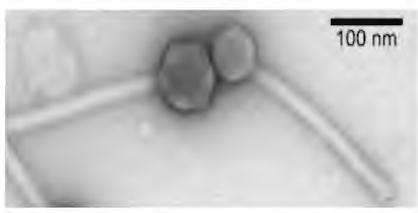
FCCVD technique is scalable for large scale production and the process parameters can be tuned in order to make CNT wool with the CNTs aligned in a preferred direction. An added advantage of this material is that it doesn't lose its functionality when treated with water and alcohol or heat-sterilization. Thus, it has clear advantage over polypropylene based N-95 masks with respect to reusability. A single layered CNT wool filter treated at 121°C under 15 PSI pressure for 15 minutes could retain 87% of the bacterophage P1 virus. A standard four layered N95 mask could retain only 85% when subjected to similar sterilization treatment. Considering all these factors and good air permeability CNT-wool could be a candidate for making reusable masks against viruses and microorganisms.



SEM image of randomly oriented CNT-wool



SEM image of bacterophage P1 virus trapped in CNT wool



TEM image of bacterophage P1 virus

Heat Sterilization of Masks

Tata Memorial Hospital (TMH) in collaboration with Tata Institute of Fundamental Research (TIFR), established a scalable process for sterilising N95 masks for reuse in TMH.

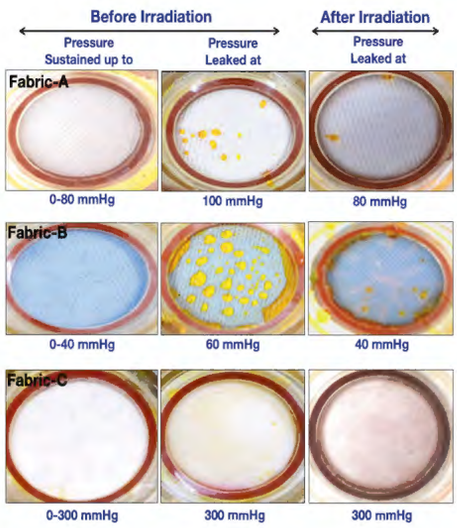
The most appropriate method was found to be Heat Sterilization at 70°C for one hour (Dry Heat Method). Post sterilization efficacy on filtration capacity and fit of masks, have been confirmed for most common N95 masks in use, thereby increasing life of N95 masks at least 5 fold. This is now being shared widely as one of the most cost effective and efficient models for decontamination of N95 masks across the country.

Oven for control sterilisation of masks

The device has been functioning since last week of May 2020. As on 10th June 2020, 872 N95 masks were sterilized at TMH, leading to huge cost savings.

Radiation Sterilization of PPEs

Aprons, a major constituent of PPE, are designed for single-time use. A systematic study on effect of gamma irradiation on physicochemical properties and performance of PPE aprons was carried out to examine the reusability of PPE after radiation sterilization. PPE kits from thirteen suppliers or manufacturers were used in this study. Extensive laboratory scale as well as plant scale experiments were conducted. After radiation treatment, aprons were first evaluated manually for visible color change, deterioration in mechanical properties (by push-pull), or any pungent smell. Later aprons were evaluated for their composition, change in morphology, mechanical properties and barrier properties using established characterization techniques. Most of the aprons were made either of polypropylene or polyethylene or polypropylene blended with polyethylene. All samples which passed manual pull-push test displayed systematic decrease in tensile strength and elongation at break on irradiation. Barrier properties are not apron material specific but depend on the manufacturing and design protocol. No observable change in number and size of voids was observed in aprons after gamma irradiation. The investigation indicated that radiation processing is an effective process for enabling the reuse of PPE aprons. Based on the positive outcomes of these investigations, a Standard Operating Procedure for the radiation sterilisation of used PPE aprons has been prepared and submitted to the Ministry of Health & Family Welfare for approval.



Penetration of synthetic blood through the test fabric at different pressures before and after gamma irradiation.

Metal Nanoparticle Generator for Coating PPEs

Metal nanoparticles (MNPs) are reported to have microcidal property. Coating the PPE fabrics with MNPs may enhance their efficacy. A machine was developed to produce MNPs by rapidly vaporizing the metal wire or foil placed between two electrodes using an intense current discharge from a capacitor bank. Subsequent condensation of the metal vapour produces about 50 mg of copper MNPs of 10 nm size in one discharge shot. The shots can be repeated every six seconds for bulk production required for coating the PPE fabric.

The copper nanopowder is coated on a medical fabric using a scheme which can be fitted in the cloth production line itself.

Quality Assessment of PPE Fabrics

Ability to resist penetration of body fluid and withstand various sterilization processes are the key issues in the choice of a material for making a PPE. Regulatory bodies qualify a material whether it is suited for making a PPE or not, based on penetration test and splash resistance test . RPAD, BARC has developed a test set up following the guidelines of ISO 16603 ASTM F1670 and JIST 8060 and 8122 for carrying out these tests.

Penetration test involves spreading 20 ml synthetic blood (SB) on one side of the fabric to be tested and then subjecting it to an air pressure ranging from 60-300 mm Hg. Quality of the fabric is assessed by how much SB penetrates the fabric and appears and the other side. SB has very similar physical characteristics as human blood.

In a **Splash Resistance Test** an injector splashes 8 ml of SB fluid on to a circular fabric held at a distance of 30 cm. The fabric is then examined for penetration by the fluid.

Synthetic Blood Penetration Resistance Test setup

The penetrated SB was detected at 3 levels; 1) visual detection, 2) visual detection by absorbent paper wiped on to the downstream surface and 3) detection by magnifying lens (for both penetrated droplets and spots created on absorbent paper). The test set ups help in a quick screening and selection of fabric materials for manufacturing of PPEs.

Development of Powered Air Purifying Respirator

A Powered Air Purifying Respirator is an air sealed face mask, which provides comfort to an occupational worker by continuously replacing the exhaled air by fresh and pure air. It is originally intended to protect occupational workers from direct exposure to any air borne contaminants in industrial (pharmaceutical, chemical, nuclear, etc.,) settings. The respirator weighing about 1.6 kg consists of indigenous headgear with air seal, DC blower fan assembly, rechargeable Li-ion battery and HEPA filter. The respirator pumps filtered air at a rate typically in the range of 170 to 190 Liters Per Minutes, which is the quantity of air exhaled by humans under normal conditions.

These respirators can also be operated as positive-pressure masks, essential in radiation environments such as hot-cells, where radioactive material is handled. The respirators can be repurposed to protect medical professionals against various infections and operate in COVID environment, particularly during surgeries.

Materials going into making the face shield, in particular the air seal, should be able to withstand standard disinfection and sterilization protocols such as autoclaving at 80°C, treating with 50ppm chlorine solution or 10 minutes exposure to UV-C light. Overcoming these challenges is essential for the powered respirator to be reusable.

Commercially available full-face snorkel masks are selected to meet these criteria and augmented with additional air ducts, filters and pump with associated electronics mounted in a companion belt pack unit connected to a non-collapsible breathing pipe.

Diagnosis of COVID

COVID-19 Testing at NCBS (in collaboration with inStem)

Widespread testing for SARS-CoV-2 is a critical national need in monitoring and controlling the pandemic. However, both national and state resources are inadequate to meet the rising demand for testing. Testing requires high standards of biosafety and containment. Such facilities do exist, for example, in academic research institutions. At the Bangalore Life Sciences cluster (BLiSC) which includes TIFR's National Centre for Biological Sciences (NCBS), DBT-InStem and CCAMP, cutting-edge facilities are used for fundamental and team driven biological science research, and to foster innovation. In an attempt to bridge the testing gap, NCBS and DBT-inStem have established a COVID-19 testing facility based on RT-qPCR technology. Following its conception, this pop-up diagnostic lab assembled permissions, protocols and student and postdoc volunteers in a record two weeks, and started operations on the 13th of April, 2020. Testing a sample requires a standardized pipeline that starts with sample receipt and transport to the biosafety space, which is monitored through a webcamera. Personnel in stringent PPEs inactivate the virus, followed by RNA extraction and conducting quantitative RT PCR to detect viral and human RNA. Another very important part of the entire process is data entry and reporting to both Karnataka state and ICMR. This requires very diligent data operators. This effort has been sustained by a dedicated team of student volunteers and faculty from both institutions. To date, the testing facility has been running non-stop for over three and a half months, and have received and reported over 30,000 patient samples from across Karnataka.

Development of RT-PCR Based Kit for COVID-19

In response to the present COVID-19 pandemic, Bio Science Group, BARC (BSG) has developed an RT-PCR kit for detecting the SARS-CoV-2 virus. The detection in this kit occurs by the use of oligonucleotides primers and probes specific to two different and highly conserved regions of the viral genome. The kit was assembled and standardized using virus derived synthetic DNA fragments. Subsequently, the kit was evaluated with the use of in vitro transcribed RNA fragments that simulated the virus. After initial validation of the kit at Kasturba Hospital for Infectious Diseases, with COVID-19 positive and negative samples, the kit was being sent to National Institute of Virology (NIV), Pune for further validation and deployment for clinical use. As per report obtained from NIV, Pune, the kit is showing 100% specificity for COVID-19 but the sensitivity limit was 63% (unable to detect samples with low to very low virus counts; acceptable value should be >90%). We are now working to improve the sensitivity and submit it soon for revalidation. This kit costs about Rs 400/- per reaction.

Serological Survey to Assess Prevalence of COVID-19 in Mumbai

Tata Institute of Fundamental Research (TIFR), in a joint venture with Translational Health Science and Technology Institute (THSTI, Faridabad), University of Chicago, Duke University, ATE Chandra Foundation (Mumbai), Kasturba Hospital (Mumbai) and IDFC Institute (Mumbai), under the aegis of the NITI Aayog, has undertaken a serological survey of 10,000 randomly selected asymptomatic residents of Mumbai in the age group above 12 years (both in slum and non-slum areas). The blood samples were tested to check for possible COVID-19 infection / immunity. This study will not only help in understanding the extent to which the population in Mumbai has already been exposed to COVID-19 infection but also enables to predict the future spread of the infection so that the local authorities can formulate appropriate public health policies in the region.

In partnership with BMC, the survey began in F-North (Matunga), M-West (Chembur) and R-North (Dahisar) wards, selected on the basis of the number of COVID cases. F-North is among the wards with the higher case load, M-West closer to the average and R-North represents a ward with a lower case load. The blood samples were tested in Kasturba Molecular Diagnostics lab, Mumbai and THSTI, Faridabad for presence of Immunoglobulin G antibodies.

Teams of members from Ministry of Health and NGOs with the help of local counsellors collected blood samples along with basic demographic information including contact history and comorbidities from the selected households volunteered to participate in the survey.

Preliminary results indicated that the slum areas with antibodies detected in about 57% of the population are closer to herd immunity. Improved estimates of asymptomatic infections, and repeated measurements will help estimate the trajectory of the epidemic and its progress towards herd immunity. The results of this survey will be valuable in determining how future surveillance should be conducted in this and other locations in India. In further phases, the sample size will be increased and the study will be extended to other cities across India. Testing in communities of different densities will also help in determining the risk in other similarly dense areas.

A Novel Method of Pooled Testing for COVID-19

Currently, primary method for COVID-19 detection is the RT-PCR test using nasal swabs. The throughput and capacity for such testing is severely limited. Since COVID-19 can be transmitted from asymptomatic carriers, these testing bottlenecks have left states with the dilemma of either risking a free spread of the virus, or imposing severe lockdown and physical distancing measures with heavy economic costs. There is an urgent need to find economical and scalable ways to test more people. It has been shown that pooling of samples from different individuals is a cost-effective way to test for the presence of virus. Simple pooling involves pooling samples of *N* individuals, and re-testing each individual sample if the pool tests positive. The ICMR recommended pooled sampling using pool sizes of 5 in areas with low prevalence less than 2% or for community screening or surveillance in asymptomatic individuals in areas with prevalence of 2 to 5%.

In combinatorial tapestry pooling, individual samples are mixed into pools in various combinations. Using computerized algorithms. Depending on which pools test positive, it is possible for the algorithm to predict which of the individual sample is positive, without second-round individual testing

The Tata Memorial Hospital, in collaboration with the National Centre for Biological Sciences (NCBS) and the Indian Institute of Technology Bombay (IIT-B) is currently conducting a study to validate the combinatorial tapestry pooling technique. If found to be valid, combinatorial tapestry pooling could replace individual testing especially in screening asymptomatic populations, thereby improving the access to testing while decreasing the costs.

ACTREC-SARS-CoV-2 kit

ACTREC developed a rapid and accurate one-step multiplex TaqMan probe-based real-time RT-PCR assay, alongwith a novel COVID qPCR Analyzer tool with graphic user interphase to analyze the raw qRT-PCR data at a cost of under $3 per reaction and turnaround time of less than 2h. The assay could detect to a limit of 1.5 copies of SARS-CoV-2 transcripts based on experiments performed by spiking total human RNA with in vitro synthesized viral transcripts. The assay was further evaluated by performing 166 validations for the SARS-CoV-2 Nucleocapsid genes and human RNase P as an internal control reference gene with dilutions ranging from 1-100 ng for human RNA on a cohort of 26 clinical samples. 5 of 26 patients were confirmed to be infected with SARS-CoV-2, while 21 tested negative, consistent with the standards. The accuracy of the assay was found to be 100% sensitive and 100% specific based on the 26 clinical samples that need to be further verified using a large number of clinical samples in an unbiased manner to enable in-house SARS-CoV-2 testing across laboratories.

Based on the evaluation performed by National Institute of Virology, (ICMR), this kit is 75% sensitive and 100% specific based on 160 odd samples tested by them. We are working to further improve the sensitivity.

RNA Virus Detector

Several non-invasive Raman spectroscopy-based assays have been reported for rapid and sensitive detection of pathogens. We

developed a novel statistical model for the detection of RNA viruses in saliva, based on an unbiased selection of a set of 65 Raman spectral features that mostly attribute to the RNA moieties, with a prediction accuracy of 91.6% (92.5 % sensitivity and 88.8 % specificity). Furthermore, to minimize variability and automate the downstream analysis of the Raman spectra, we developed a GUI (Graphic User Interface) based analytical tool 'RNA Virus Detector (RVD)'. Overall, this conceptual framework has a potential application in managing the COVID-19 pandemic.

Infectious Pathogen Detector

We developed a computational approach to study the dynamics of variability in infectious pathogens with application to COVID-19 pandemic. The magnitude of the number of variables in NGS datasets presents formidable computational challenges limiting its application in public health laboratories engaged in studying epidemic outbreaks. The Infectious Pathogen Detector (IPD) works on the principle of computational subtraction, followed by quantification and analysis of pathogen traces in the NGS data. It aligns and quantifies heterogenous datasets such as short- and long-read data. The pipeline integrates read quality assessment, pathogen burden normalization and genome coverage calculation. The confident reads are further used for pathogen assembly and pathogen genome variant analysis. Also, IPD quantifies pathogen burden from the samples in the same run. The complete pipeline, including the graphical user interface (GUI), is developed in python. Using IPD, 1275 SARS-CoV-2 sequenced samples were analysed and 717 human transcriptomes along with validation of the detected pathogen using orthologous techniques. We also extend the SARS-CoV-2 genomic analyses integrating mutational dynamics of variability in infectious pathogens. IPD predicts the occurrence and mutational dynamics of variability among infectious pathogens with a potential for direct utility in the COVID-19 pandemic to help automate the NGS based pathogen analysis in responding to public health threats, in an efficacious manner.

Testing of COVID-19 Samples

DAE is participating for testing of COVID-19 samples wherein ACTREC and BARC are acting as 'Hub' and 'Spoke' respectively. In this effort, ACTREC is collecting samples, doing the RNA extraction while RT-PCR analysis is being carried out by BSG, BARC as per ICMR guidelines. The daily analysis report is being submitted to ACTREC for national reporting. Till date we have performed five batches of RT-PCR analysis on 96 clinical samples.

CRISPR-Cas Based COVID-19 Detection

In addition to RT-PCR tests, a quicker and simpler method for CRISPR-Cas-based detection of SARS-CoV-2 has been standardized. The method is relatively faster compared to the standard RT-PCR method. For preliminary testing surrogate viral RNA were generated. Testing with surrogate positive and negative samples showed high level of specificity. The sensitivity and reproducibility of this technique is currently being established in order to develop it into a point of care diagnostic method. As per the initial findings, the technique could detect the positive samples as positive and negatives as negative.

A Rapid Detection Kit for COVID-19

Detection of COVID-19, is generally, a PCR based detection technology which includes real-time quantitative polymerase chain reaction (RT-qPCR) and high-throughput sequencing for COVID-19 diagnosis. The major drawback of this method is its dependence on an expensive qPCR instrument and high cost due to involvement of reverse-transcriptase enzyme and other consumables. On the other hand, few serological methods and kits have been developed where presence of IgM and IgG antibodies are detected in the infected person.

WSCD is attempting to develop a second type kit which can immobilize monoclonal antibodies and specifically detect the particular antigen of SARS-CoV-2 virus (like pregnancy test kit). Thus, it doesn't need a humoral response to produce antibodies. Still, it needs enough antigen in the form of virus, which can easily be collected from nasal swab, or saliva (a more non-invasive method). We believe this type of kit can be useful at a much early stage, as nasal passage and upper respiratory tract are the first tissues to get the infection and further the propagation of the virus. This kit may be able to detect virus carriers who do not show symptoms of the disease.