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Knowledge from filter material studies using radioactive labelled nano-particles with potential applications in pandemics control

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Abstract
When Covid-19 reached US it ignored the hierarchy of pandemic control, misinformed population on virus propagation needed protection by using masks and other complementary protection measures facilitating the human disaster. The population mindset was to dismiss science, the virus and hope to dodge the pandemic with a fabric over the mouth and a free vaccine that will result in more than 600,000 deaths, and over 40 Million infected. In fact, masks are filters, and have a limited protection factor, known when used in medical practice. The masks were mainly designed and measured for stopping solid particulates, but when used against aerosolized watery droplets loaded with bio-agents nano-fluidic effects are responsible for anomalous, nonlinear and unpredictable complex behaviour. Using an aerodynamic test bench, and various sizes of radioactive nano-powders, we performed measurements on the retention factor dependence for various filter materials of airflow magnitude, temperature, airflow regime, and filter's load. The results showed that a retention function of particle magnitude, measured for particulates, vary with temperature and when filter is used for aerosolized loaded watery droplets, an "atomization" effect happens transforming larger aerosols in finer ones, due to micro-nano-fluidic and aerodynamic instabilities. The measurements showed that pulsed and reciprocating airflow regimes trigger loaded filters to release some of previously retained particles, making the masks offer a reduced protection factor, and imposing special rules of safe usage. It was not told to public that ifs a contagious person uses correctly a mask, without any lateral leakage, through the mask passes nano-sized, airborne aerosols, containing virioli that float in air for weeks, driven by air currents, and special complementary measures to sterilize or remove the air have to be taken for safety.

Keywords: Nano-particles; Radioactive labelling, COVID-19; Corona viruses; Nano-fluidics; Micro-fluidics; Masks; Filters; Pandemic; Radioactive tracers; PPE; aerosol; Protection factor.

Introduction

By 2019 mostly in unknown circumstances SARS-CoV-2 appeared, and starting from Nov. in China, and exploded in rest of the countries during 2020. Some countries as China, New Zeeland enforced the masks, cell phone tracking, and shout down important sectors of economy, others like Sweden simply ignored, while most of the other countries oscillating in between. In the US lack of appropriate education mixed into political stunts and alternate reality excelled and the results were disastrous, putting "America first", and with only 4% or world's population US delivered about ¼ of world's death and infections. In spite US health organizations know in the finest detail the respiratory viruses aerosolized transmission and has developed advanced Hazardous Material handling procedures and equipment, the communication of appropriate protective knowledge to population was a failure. Fig. 1 shows a similitude between the map of political division, where in red are the republican leaning populations, and covid-19 infection map where dark red and brown are used to show the highest infection levels, using a similar chromatic with virus' ideogram, where orange are the spikes, and dark red is the core. On the right side is presented the "Hierarchy of Pandemic Controls", and their effectiveness. From all these the most accessible measures, are the use of PPE and administrative measures, that are compatible with the level of education and understanding of population, which proved exceptionally unprepared to pass this "ecologic exam". This were reduced to simple, sloppy instructions as "wear a mask", and "keep social distancing", proven insufficient by nature, but without any detailed information on how to obtain a better protection, than might have translated in minimal economical losses and deaths. On the left lower side, it is briefly showed the "RADAR" of control levers used by China, USA and a recommended one based on existent science.

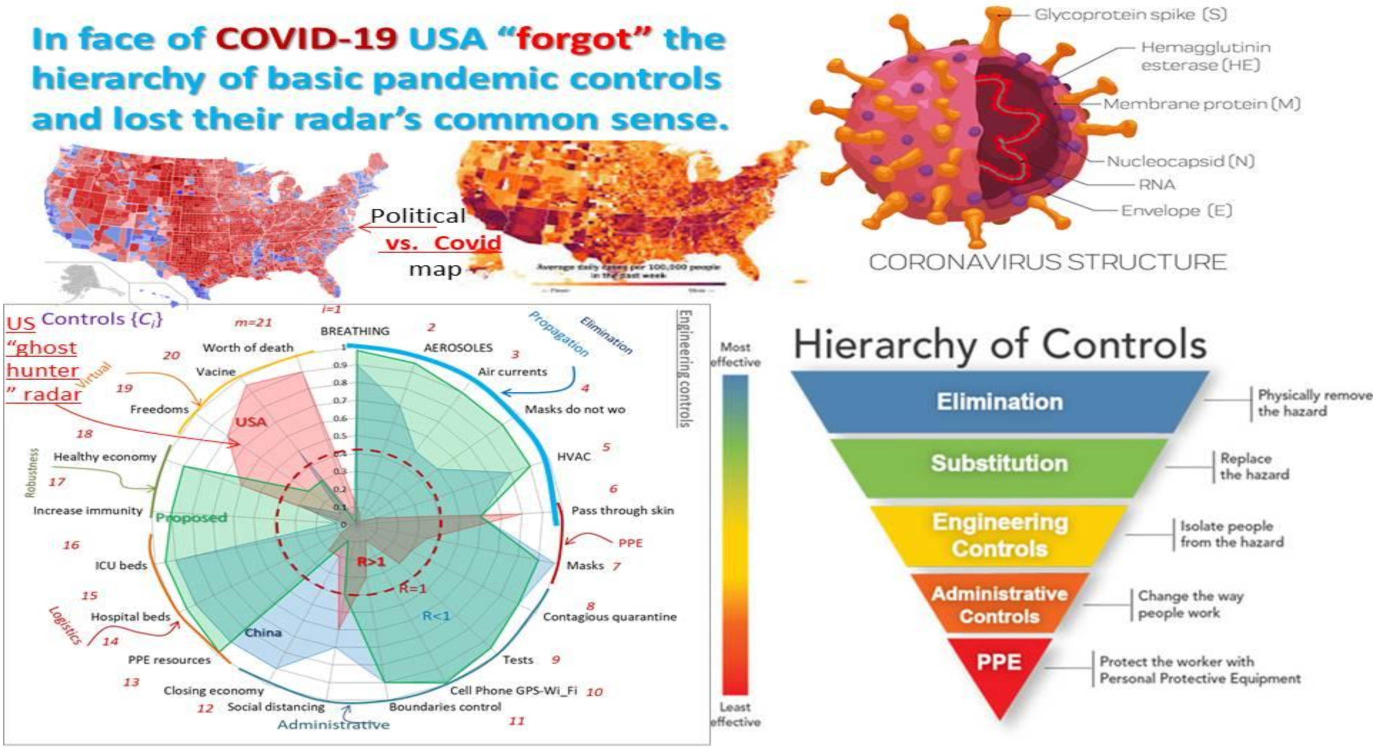

Fig. 1: Synthesis of COVID-19 pandemic in the USA and the comparative use of pandemic controls.

The "Radar" of control levers, [1] recommended is shown with green, uses complete protection, and the only use of protective equipment with controls set as on green curve, may stop pandemic in 3 weeks, and terminate it in 6 weeks, but with the help of medicine and real time contamination tracking, may terminate any pandemic in less than 1 month, without shutting down economy and without social distancing, briefly being like Sweden without causalities, but requires an educated, intelligent community, with a national investment in protective equipment of about $200 per capita. The blue curve, showed the Chinese approach, where the cost was paid upfront of about $2000 per capita, indirectly by the losses due to economic shutdown, and less than 5,000 death and 100,000 infected at a population of 1.4 Billion. Their radar of control level setup is very little different from the recommended one, being at about 75% in competence level, versus 85% of the recommended one, that is not perfect but doable if the right information have been delivered on time. The USA "radar" of controls, looks like a "ghost hunting" setup, in an alternate reality, having almost all the levers set under the red-dashed circle, set on 40%, where the pandemic multiplication rate is 1. The competence level of US authorities being calculated at under 15%, while most of the controls pushed at maximum are counter-variant, being mainly distractions and having an adverse effect on the rest of controls, sometimes driving to negative synergy. These affected mainly, the usage of masks and administrative measures, as avoiding people agglomerations. The concept of a "healthy economy", was flawed because that can NOT be achieved with sick people, and altering the restrictions for the sake of business was a grave mistake. The use of infection color code, with associated gradual restrictions, is another fundamental mistake, because it acts as a PID loop, maintaining and average level of infections and deaths that tacitly is considered acceptable by the elected leaders.

Masks and Protection Factor

Face masks re the less efficient pandemic control lever, being part of PPE, but are easily accessible, and cheap, except for USA where there was a chronic shortage and surrogates were used with weak results. In fact a mask offers two their protection, one called mutual protection, by reducing the spit range and another called individual protection, [2] when it is acting as a filter, as Fig. 2 shows.

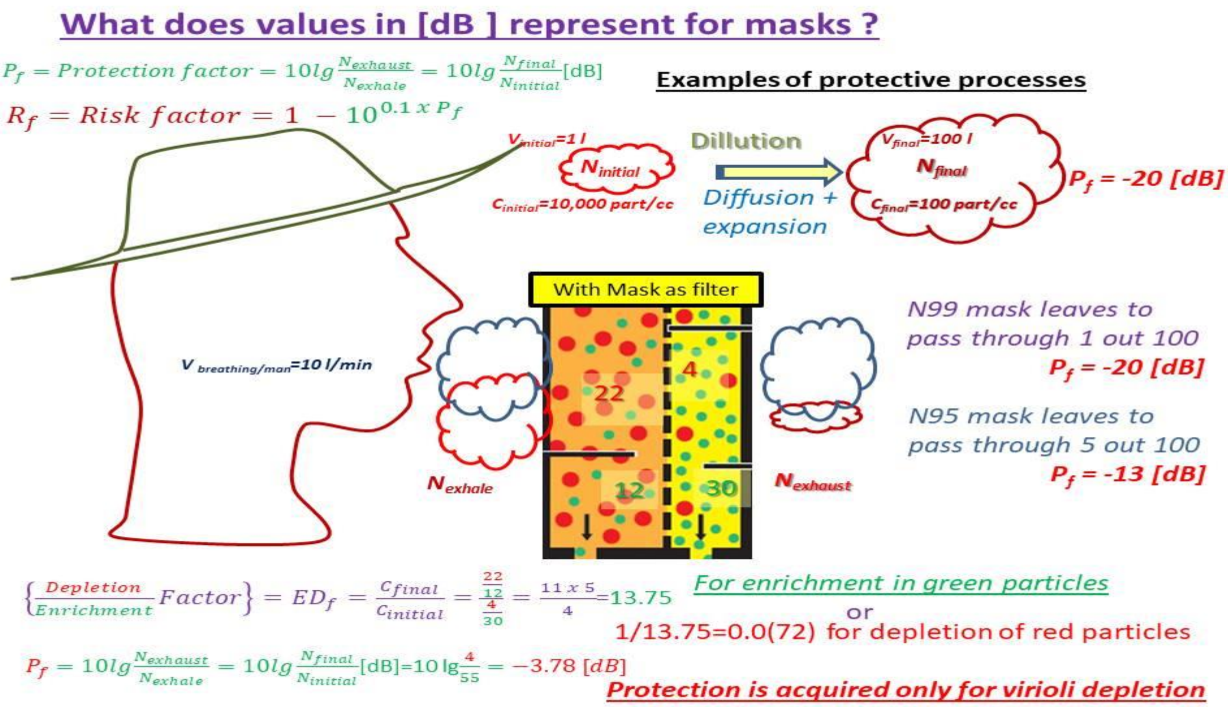

Fig. 2: Mask protection factor calculated in dB as an alternative from depletion factor.

In the fig. 2 is a calculation example of depletion vs. enrichment, and how it may be interpreted in logarithmic scale. If we use natural ln, the result will be in Neper [Np], but the most preferred is decimal logarithm (lg) where the result is in Bell [B], and its submultiple decibel [dB], because a mask is a protective shield, and using dB scale it will be similar to electro-magnetic shields developed for directed energy protection. The formula is: ***{value in [dB]= 10 lg (final value/initial value)}.*** A negative value that can be a concentration or number of particles (virioli), etc. means the attenuation of the incident element, potential threat, while a positive number means amplification. Fig. 2 gives a detailed calculation. On a positive note, a dilution, also adds to protection, performing a similar work as a mask, that in fact is a filter.

Filter details

As one can se in Fig. 3 masks use filters to provide the individual protection, that is not absolute, because no matter how well they are done, there is impossible to filter everything no matter how small the suspensions may be [3].

Fig. 3: Details on filter manufacturing and several most popular types of face masks.

In the upper side of Fig. 3 there is given a sequence of materials that enter in the mask composition for a unidirectional mask, say a N95 with exhalation valve. As a general rule, the first layer touching the skin has to be friendly and soft, and have compatibility with skin. The exterior layer have to protect the mask against rain, while the middle fabrics have to do the filtering, and behave well in liquid effluent mixtures in air. Among the masks N95 and N100 are praised to be the best possible, while surgical masks are lower protection, and equivalent to an N90 down to N80, being designed for reciprocating airflow. The masks in lower –right are rubber made and are used as technologic respirators in polluted airspaces.

Transmission through face mask and air leakage consequences

As one may see in Fig.3 the common use surgical masks as N95 dust masks and N100 have not been designed to fit tight on face, and in spite that respiration have to be performed 100% through the mask is common knowledge in the military since WWI, making the difference between life and death, that was not explained clear enough during the actual pandemic, being a factor that aided pandemic.

Exhalation through an untighten facemask.

Fig. 4 shows in detail what happens when the air exhalation is done partially (60%) through the mask and the rest bypassing the mask all around, for a person having a High Contagiousness Level.

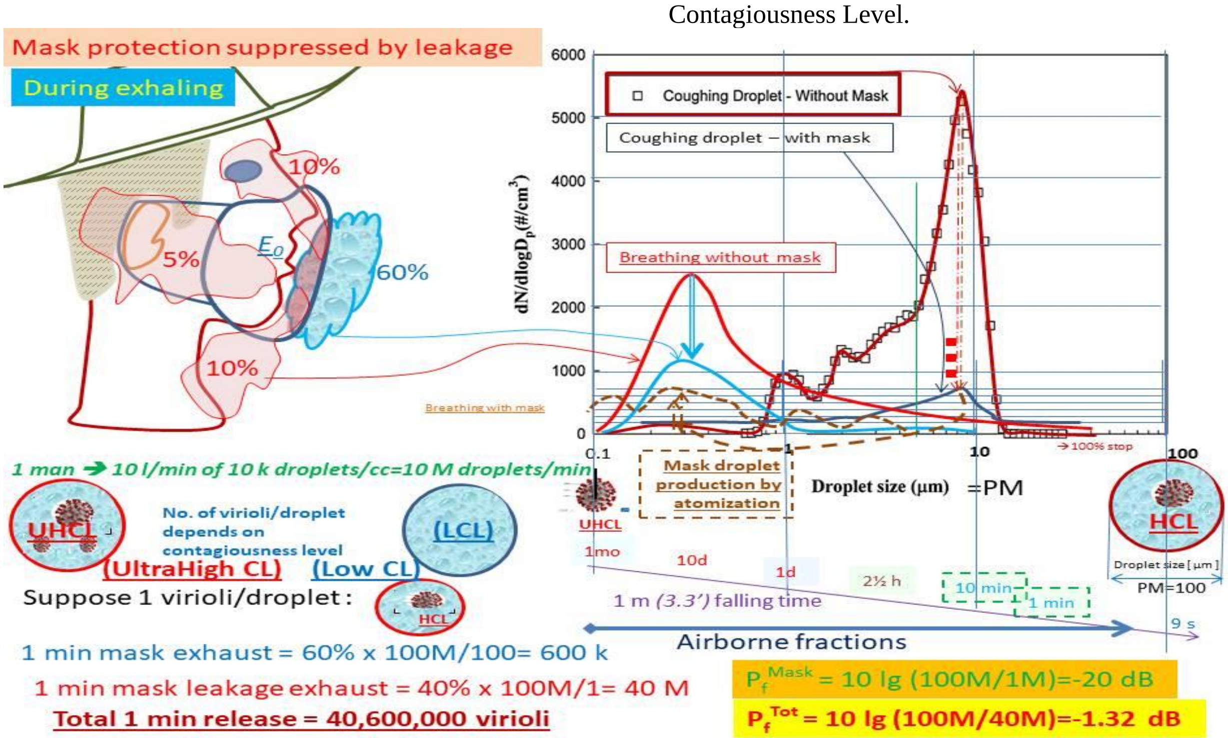

Fig. 4: Exhalation through a leaking facemask.

On the right side it is shown the exhalation airborne watery droplets distribution as function of their size, PM (Particle Magnitude) for two aerodynamic regimes of respiratory system: Coughing and Breathing normal. Number of virioli inside droplets is variable and is given by the contagiousness level, where is considered that at High (HCL) there is 1 virioli per droplet. When coughing [4] the PM size distribution is shown by the brown line with circles in measurement points, exhibiting maximum at larger sizes, of 10 µm and above, having a floating time in air of about 10 minas one may see under the abscesses on the 1 m falling time as function of PM chart, inside dashed-green rectangle. On the same chart one may see that 100 nm (0.1 µm) virioli remains airborne about 1 month, but how long a virioli is alive and ready to infect a person depends on many environmental factors, as air quality and UV light content. Pollution with chemicals and energetic radiation damages virioli incapacitating it.

Breathing through a filter when coughing, using an N95 mask, results in dimming by more than 100 times of the large particles, while small particles under 500 nm pass through. More it was observed an increase in small, sub-micron particles that is due to a micro fluidic effect inside mask's fabric, generically called atomization. This sims to be a more hazardous effect, because when a virioli was inside a 10 µm droplet may fall on ground in about 10 min, while transferred inside a 500 nm droplet it may remain floating in air more than 1 week, because, meanwhile, as function of relative humidity of air, droplet may evaporate increasing its floatability (a kind of buoyancy) up to 1 month, increasing its chances of being inhaled. This effect is shown by the brown-dashed curve, adding to the blue curve, representing the mask larger particles attenuation effect.

Knowing that initial total concentration of droplets is 10,000 droplets/cm^3, we calculated on the lower left side the number of droplets exhaled by the person, knowing that a man exhales about 10 l/min. We have learned that an N100 mask that offers a protection factor Pf= -20 dB, when it has 40% leakage around, as shown, its total Pf=-1.32 dB, which it is practically nothing.

Inhalation through an untighten facemask.

Fig. 5 shows the reciprocating air flow, through the same N100 mask, which due to negative pressure underneath is reducing its leakage by 10% because it becomes tighter on the face.

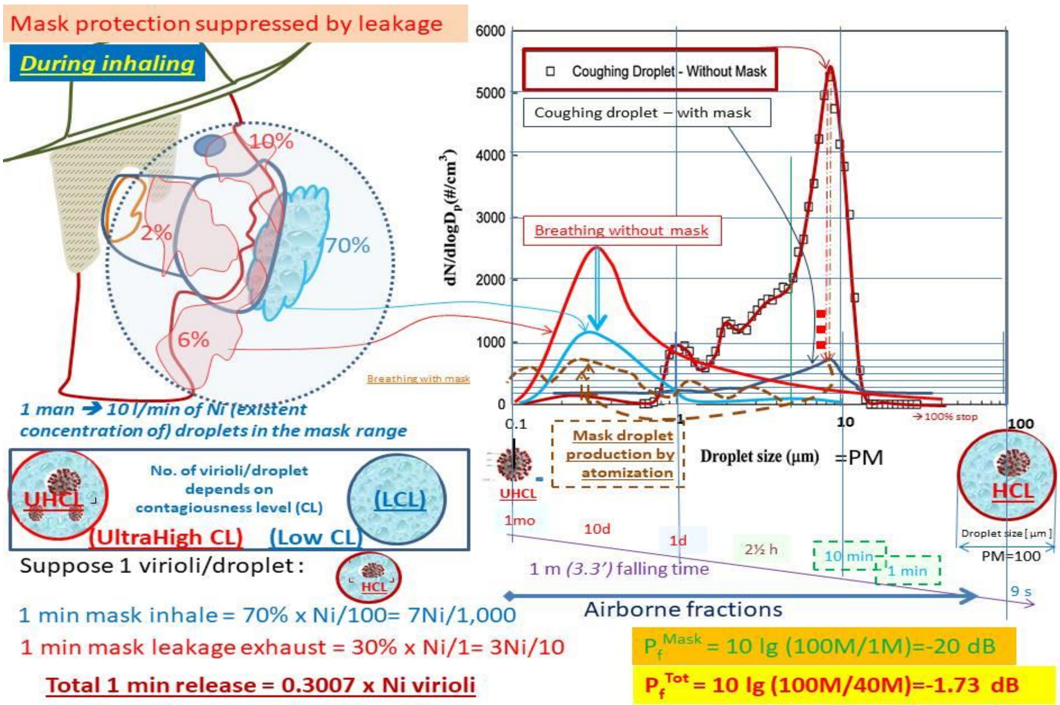

Fig. 5: Inhaling through a leaking N100 mask calculations.

Breathing normally without mask [5] is represented by the red curve, with a maximum at about 600 nm, and after being filtered through the mask the maximum moves down at about 250 nm, as blue curve shows. Atomization process occurs but is smaller in contribution because of milder aerodynamic conditions and smaller concentration of larger airborne particles with PM > 1 µm. The hazard is increased, because the filtration is not so effective as for the case of larger particles, and atomization occurrence is delayed by the need of accumulation of fluid effluents inside a nano-fluidic effect.

As it is seen in Fig. 5 lower-left side, from the basic calculations the results on the right side shows that the protection factor fails from Pf=-20 dB in the case of no leakage down to Pf=-1.73 dB with the leakage shown around the face, also canceling the individual protection factor of the mask.

Transmission from exhalation through an untighten facemask to inhalation.

It is believed that if 2 men wear tight N100 masks the protection factor between them might be higher than P_f^{tot} =-40 dB, but that is not the case when one looks at PM distribution, after exhalation, and observes that first mask was 99% effective in stopping the exhaled particles, but released smaller particles that passed through, in the area where filter's retention power was minimal, and as a consequence will not be retained by the inhaling through filter, as shown in Fig.6

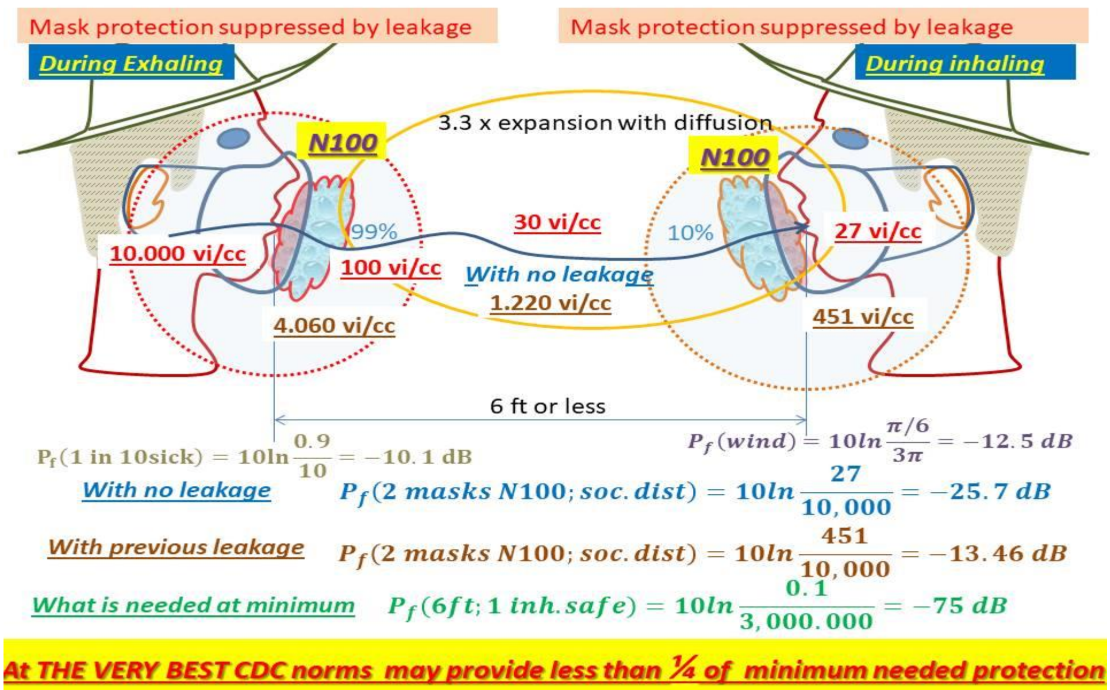

Fig. 6: Virioli transmission from man to man wearing N100 masks.

In the figure the two man were placed at a social distancing recommended value of 6 ft. (about 2 m)and the expansion and diffusion of virioli effect, [6] shown in Fig. 2 as a potential protective effect was considered in virioli concentration numbers. The case in blue, with NO leakage and the case in brown with previous leakage was considered. It is observed that with No leakage the total protection is of -25.7 dB instead of -44 dB as one may have expected, while with mask and the previous leakage figures it is of -13.5 dB. One may ask then, why the statistically seen infection rate is not as high as figures show, and that is because in this calculation we do not considered the probability of having a pair of exhale sick and inhale healthy that in the case of 1 in 10 infected people that acts as a protective factor of -10.1 dB. Then there is the probability of having wind, or air current blow from the contagious person towards the healthy person that will be infected, which delivers another -12.5 dB in protection factor. In other words, in this condition wearing sloppy the mask one may get -40 dB in protection factor, that may curve down the R (virus reproduction rate), while at only – 26 dB without a mask virus is thriving. In other words at about 500 exposures one may get sick. With mask one needs about 10,000 exposures to random people in order to get infected, and at this number pandemic is shrinking. The color code acts that feedbacks loop, and by removing restrictions it increases the number of random exposures in order to give chances to virus to be transmitted, and by default a certain number of death and infections is unconsciously accepted as good. It is not proven that US politicians are thinking so far.

The figure also shows how much protection factor one needs to acquire in order to remain healthy during 1 inhaling of virioli exposure during a bad encounter, and that is of about – 75 dB, and that is much higher than the maximum -50 dB one may obtain in exceptional conditions when both are wearing correctly the best accessible facemasks in US market [7].

Filter material measurements using radioactive nano-powder tracers.

The protection power is finally given by the retention curve of the filtering material.

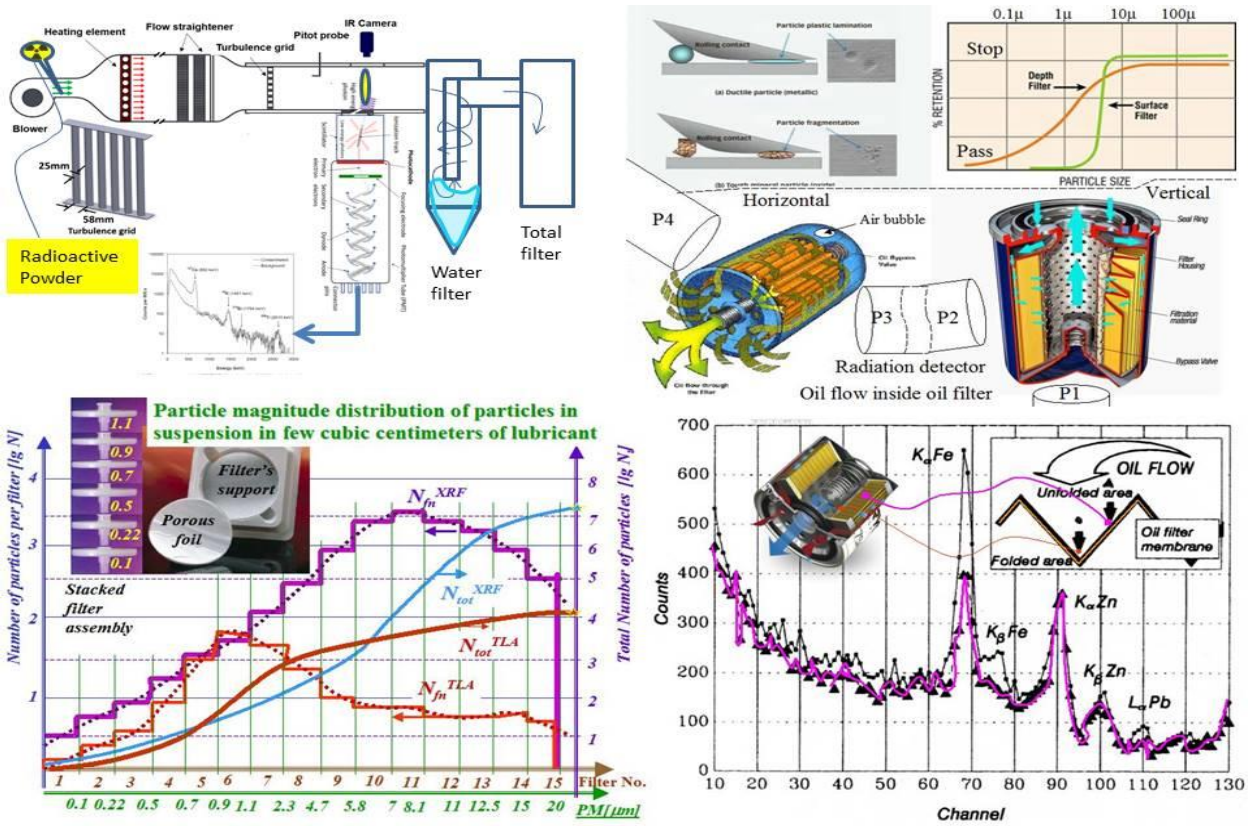

Fig. 7: Synthesis of retention power measurements using nuclear technologies.

Aerodynamic tunnel test-bench and test protocol

The tests presented in Fig. 7 were part of a 1980s special research program, aiming to clarify the properties of various filtering materials for a large range of applications, in nuclear technology and defense, industrial, bio-medical with emphasis of the retention curve and its variation with various parameters. In order to accomplish this ambitious governmental task, we built a test bench, being mainly an aerodynamic tunnel, as seen in Fig. 7 upper right made of a HEPA filtered fan using a water nebulizer to simulate various humidity climates, and a heater to vary the temperature. For lower temperatures, winter cold nights with temperatures down to -10 F (-25 C) was used, using heaters or windows of opportunity to make for intermediary temperatures. Inside the heated flow was introduced the radioactive labeled nano-powder nebulized in air or water that was homogenized for the central laminar flow. To measure the dimensional particle distribution, that was important for radioactive particles suspended in liquid droplets we used a laser and a set of 2 to 4 fast photomultipliers. We collected via the Pitot tube the flow in one position in the aerodynamic tube and pass this in front of laser beam and read the magnitude of reflected light pulse by pulse. A He-Ne with λ= 632.8 nm, and Nd:YAG with λ= 1,064 nm and λ= 534 nm after frequency doubling. We were interested in an Ar-F (Argon-fluoride) lased with λ=193 nm, but were under research, unstable and not really reliable, therefore the 1 m long He-Ne 20 mW remained for current use. After some electronic processing the signal was applied to a MCA (Multi Channel Analyzer) which was building 4 histograms of particle magnitude, of 256 channels, 2 before and 2 after the filter. The radioactive powders were used to see how the retention power varies with the load of the filter. A generic curve for the retention power is given in the upper-left side. Radiation spectrum was measured at the beginning of a test, from time to time and at the end of a test together with calibration samples. During the test, a set of rate-meters and MCA used in MCS (Multi-Channel sampling) measure the radioactivity variation due to accumulation on filter. In order to save radioactive powder, we used non-labeled nano-powder to load the filter, and then apply the radioactivity measurement that took less than ½ hour, per tested point. Samples of filter material were also weighted and optical microscope images as well as autoradiography images were taken and processed. The entire test protocol followed QA (Quality Assurance) guidelines. Radioactive particles that escaped through the filter were collected inside a water filter, and then analyzed by XR and radioactivity in order to detect the non-radioactive load content leaked or escaped by the filter.

A total filter containing oil was used with the intention to collect the rest of the particles, that escapes the total filter with water, in order to prevent the laboratory contamination with radioactive nano-powders, but it failed to work as intended and we had to move the test-bench outside in open air, in order to prevent operators from inhaling the radioactive nano-powders. By default was measured the dynamic pressure drop all along the test, as being an easy indicator for the moment when a filter is used-off.

After measurement, and data processing, for each material tested a complete report was prepared, starting with material description, fabrication, storage, etc. and the retention curve and its variation in various test regimes.

In the lower-left chart is shown the dimensional distribution or the of a suspension of particle inside an engine lubricant, that was filtered with the surface cellulose acetate membrane filters produced at Tandem Linear accelerator with various pore dimensions. The experiment showed the particle distribution dimensions produced inside a thermal engine, in the Thin Layer Activation, selected surface and in the entire engine, measured by sequential lubricant filtration and measured using gamma radioactivity 847, 1247 keV, and 122; 136 keV for 56Fe activated with 13 MeV deuterons, and XRF (X Ray Fluorescence) for 6.4 keV (λ=0.19373 nm).N_{tot} is the integral curve, while N_{fn} histogram represents the amount retained during sequential filtration and normalized.

Retention curve dependence on operating regime

The study went in deeper detail showing how the material bent is influencing the particle local retention, measuring the difference in retention on a lubricant oil filtering paper, as shown in the lower-right chart. It is seen that iron (^{56}Fe) particulates with a maximum at about 7 µm deposited twice as much in the bent, being more sensitive to micro-flow than Tin (^{65}Zn) that were larger, of about 12 µm and less dense (7.27 g/cm^3) than iron (7.87 g/cm^3) while lead (^{82}Pb) particles of about 6 µm density histogram maximum and a density of 11.35 g/cm^3 followed the larger and faster tangential median micro-flow being less prone to turn into perpendicular flow.

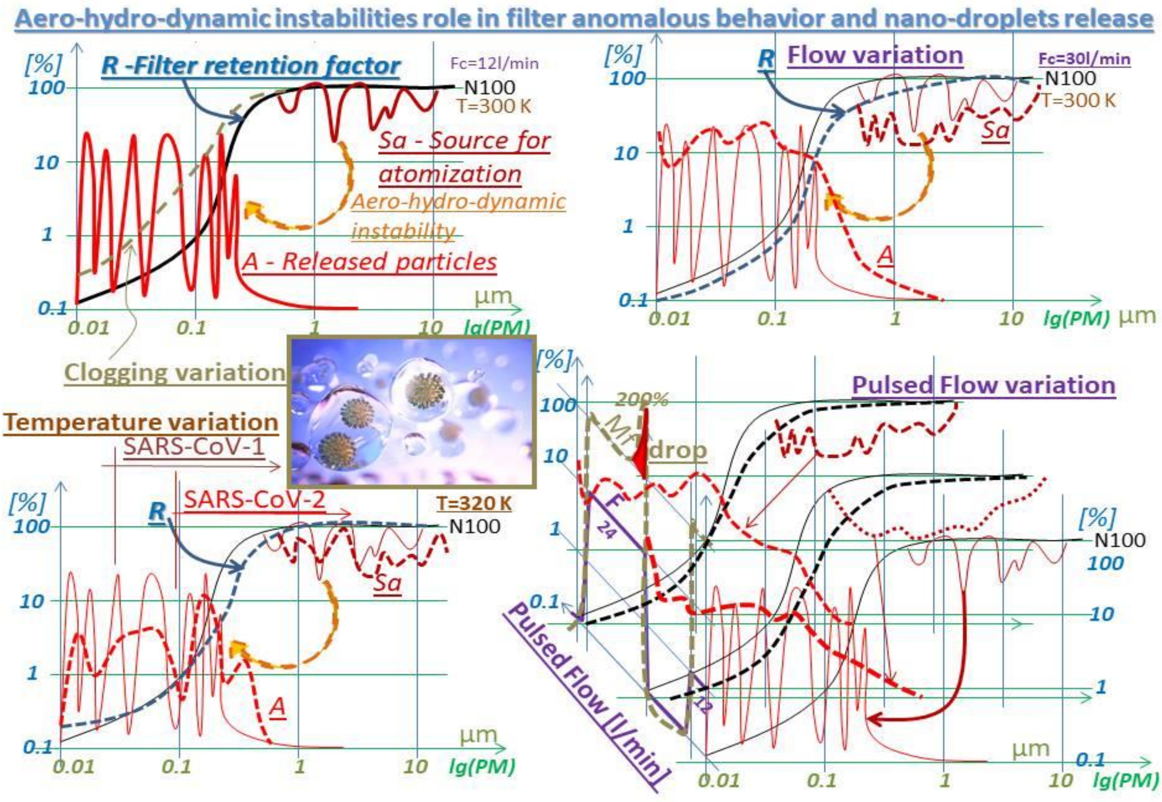

Fig. 8: Details on generic volume filter behavior and retention power.

As it was mentioned before, during the few year operation time many filter materials were characterized, in as many reports impossible and useless to reproduce here in the smallest detail, but in Fig. 8 is presented a synthesis of the most significant aspects with regards to nano-micro flow, and its applications in the actual protection face masks. The numeric value in most of the cases is irrelevant, because it varies with many parameters, we need to be aware of, and when interested to perform the right measurements in order to obtain a quantitative accurate evaluation for the specific application envisioned. In the picture in center it is shown how virioli travel inside a watery droplet that may also contain samples from everything was contained on respiratory tracts and released as function of momentary aerodynamic conditions and contagiousness level [8,9].

In the upper left side of Fig. 8 is given the filter retention factor, for a material similar to N100, at about 300 K, and an equivalent airflow of 12 l/min, for about 10 cm^2 filtering area. Than the filter is loaded by 4 mg/cm^2 equivalent to 8 h exposure in a dust medium polluted urban atmosphere and we measured the retaining curve of the clogged filter, and learned that the filtration power increased, as the curve shows, but the dynamic pressure drop on filter varied from about 150 Pa to about 300 Pa, that almost doubled.

For this load, the retention curve is the dashed one that improved. Applying 10 times that load, the retention curve does not improve significantly but the dynamic pressure drop grows more than 10 times, rendering it unbreathable. One has to understand that the maximum vacuum a lung may produce is about 20 kPa, and a 3 kPa pressure drop translates in oxygen depletion. The increase of filtration power from an N95 to an N100 produces an increase of pressure drop by 30% in average.

Under this chart it is shown what happens with the retention curve when rising the temperature from 27 C to near 50 C, [9, 10] when air become unbreathable. The retention curve deteriorates, and filters nears an fictitious N80 to N85 while the pressure drop does not vary too much; for some materials it may increase a little bit but for most of materials has a tendency of unrestricted expansion and pressure is reducing a little bit, by 5 to 10%.

On the right upper side is shown the variation of the retention curve with flow-rate where pressure drop was implicitly measured between the two pitot tubes, placed at about same flow fiber inside the tube. It is observed that the new retention function is decreased with increasing the flow rate. For doubling it, the pressure drop basically doubles from about 200 Pa to about 450 Pa, while retention curve deteriorates with about 7-10%, mainly in the small particulate region.

The chart in the lower-right side, in a axonometric 3D projection shows what happens in a pulsed airflow, with flow variations. In our case we started with 12 l/min, for a period of time, than stopped for 1 min and start again for 2 min doubling the airflow, and measuring in real time the retention on filters with laser reflection on particles and with radioactivity with the spectral analyzer in MCS mode. The measurement was repeated for each sample nano-powder, about 10+ times. Ignoring all the process detail, a very important finding for the volume filters was that almost any time after the break when the new flow started the filters released an amount of previously retained particles creating what in the chart it is called a ***“DROP”***, which amplitude is proportional with the filter clogging, and the difference of pressure drop corresponding to the previous and current airflows. When running with watery droplets, humidity, temperature and accumulation time were important parameters that sets the size and duration of the “DROP”. The dynamic pressure drop, was varying from about 500 Pa, down in about 5 seconds to 400Pa, and then rising back at previous 440 Pa level, and growing with clogging. The drop has a particle distribution that is different from that for continuous operation, and varies from something cuasi-random to asymptotically to the continuous flow specific dimensional distribution. We did not succeeded to make good correlations for this effect, using mainly laser reflection data that showed some repetitively, as frequency Eigen-modes being present inside the filter’s nano-structure, or some aerodynamic instability, resident in ultrasound domain. As we believed that inside there is sound and vibration two Brüel & Kjær piezo-capacitive ultrasound microphones have been installed, with sound processing electronics, being recorder on a modifies Ampex VR-3000 modified video-tape recorder able to record up to 10 channels of 200 kHz ultrasound, for further processing. The work was time consuming with iffy results, without a reliable calibration due to wind inside the tube, but some ultrasound frequencies were recorded with amplitudes few percent over background level, we attributed to internal aerodynamic instabilities and whistle like vibrations, without becoming clear if the sound was produced due to fiber or aerodynamic vibration.

Leaving aside this complex manifestation inside, what we may learn is that when we use a face mask inside a bio-contaminated environment, even if it protected us well, when leave it aside and reuse after a pause, it become dangerous because it will release a “drop” from the previously retained germs. The humidity conditions may aggravate this effect, because liquid droplets may also evaporate, becoming smaller and harder to be retained, therefore they will escape triggered by any pressure pulse.

Atomization effect and its dependence of operation regime

What is called **“atomization effect**”, shown on all the charts that was omitted from previous simple explanation of the general trend in volume filters is in fact an anomalous occurrence of smaller droplets after a time of inception.

In Fig. 9 is shown a microscope image inside a N95 fiber structure in order to show the magnitude relations between the covid-19 virioli, filter inter-spaces and the virus traveling inside a watery droplet of 600 nm PM. The cube represents a nano-crystal of salt that may be useful as a passive, body compatible chemical agent which may be used to damage and immobilize the virioli inside in a process that uses the watery droplet content. When the droplet is touching a filter fiber, impregnated with salt grains, it dissolves the salt, creating a liquid nano-swamp where salt is dissolved releasing the Cl-, OH- and Na+, H+ H3O+ that react with the virioli damaging its spikes and even the protein shell, incapacitating it. When water evaporates, salt is recrystallizing trapping and sealing inside the damaged virioli. This is an improvement to N100 filter that may be added as a separate layer, because sinking a filter in a saline solution without knowing exactly what

materials are used and what is their interface tension with water may not be always successful.
As an internal mechanism, a watery droplet reaching filter's internal fibers, may adhere on them, drifting around them, if fiber is hydrophilic, or may form a droplet in a very narrow contact with the fiber moving and leaping inside if fiber is hydrophobic. In these condition massive large liquid droplets accumulation may reduce the airflow pores cross section resulting in increase in pressure drop on filter up to the limit of blocking any flow through the filter structure. In partial contact, aerodynamic oscillations and instabilities may break the watery droplet into smaller size droplets that may be carried along by the air currents that form the nano-flow.

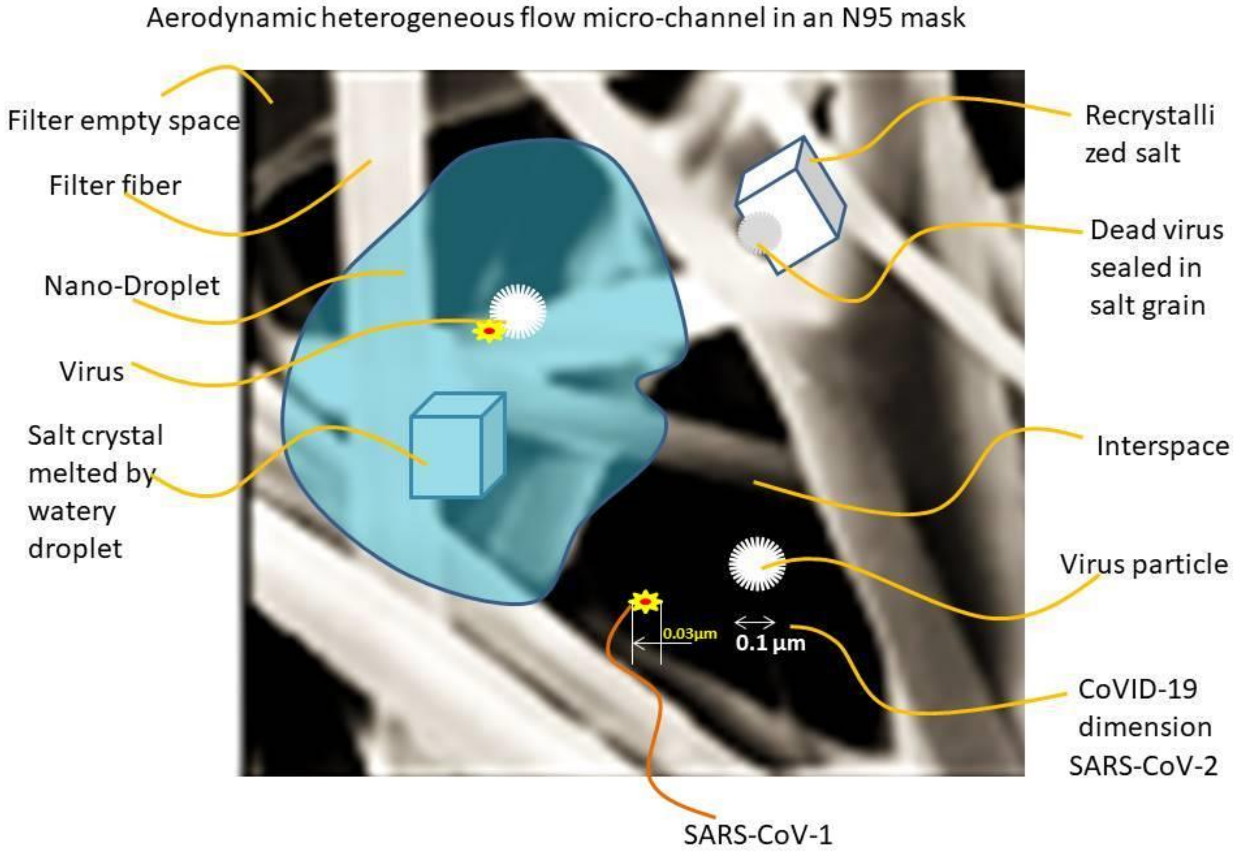

Fig. 9: Microscope view inside a N95 filter, fiber structure.

In Fig. 8 there are presented in each chart with red and brown lines. In fact when starting with a new filter sample, the retention curve is measured, both on laser reflection and radioactive particles. After a while, depending on material parameters, an anomalous small particle excess after filter is observed with peaks at various PMs, as the red curve in the upper-left chart shows. The brown curve is more a speculation, because was not directly measured, as we had no idea what happened inside the filter during the process "nucleation" time but a minimum on a brown curve was obtained by feeding the structure with that particle magnitude and obtaining a total supplementary emission in low particle magnitude domain. We are not sure if that curve was right, even when feeding with a smaller or higher particle magnitude the anomalous emission decreased in amplitude, but this is what have been observed and that is the first approximation for the process inside. It appeared with clogging, most of the time and we omitted to take an early PM distribution for this emission by atomization.
When modifying the temperature as in lower-left chart, the size trends to increase, distribution and peak broadens, may be due to increased evaporation effect inside filter structure.
Increasing the flowrate the distribution of anomalous small particles become even more continuous, and extends inside micron domain, for some filter materials, indicating that a nano-hydro-flow takes place inside with random atomization at the end of micro-fluidic channel, as seen in upper-right chart.
In pulsed flow as shown in lower-right chart the distribution of anomalous released particles is quasi-continuous, being mainly based on laser reflection on droplets after the filter, while the area from where they were released is mainly a supposition having not enough time to feed and measure. In fact if we suppose coalescence among the droplets this is coming from anything that was previously feed, and filter is acting as an intermediate reservoir, releasing what accumulated at a later time after its rules.
When measuring the radioactivity and feeding with submicron particles the radioactivity level was slightly increasing at a rate much lower than the radioactive particle feeding rate, and sometime even got negative, that puzzled us when first occurred, making us suspect a feeding or detector malfunction.

Lesson learned applicable in pandemic control.

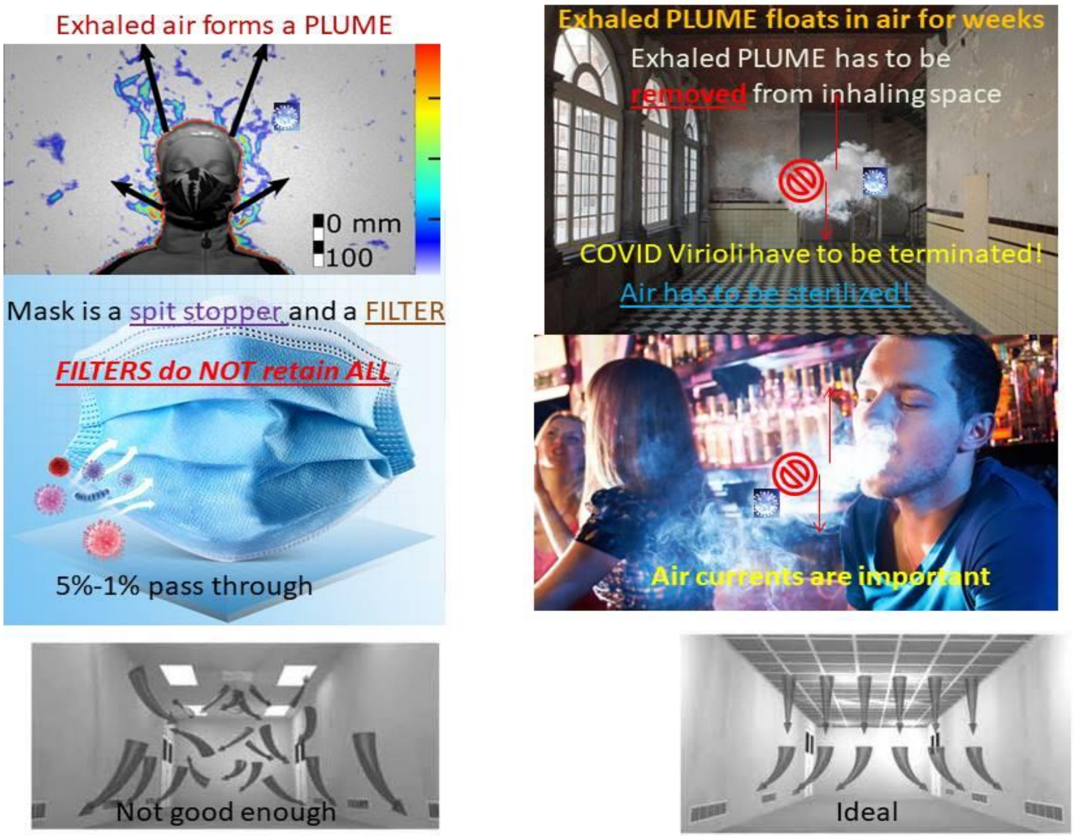

Fig. 10: Closed spaces issues with respect to bio-contamination with virioli.

It is sad to acknowledge that this knowledge on filter behavior we obtained in 1980s is known to world research organizations and CDC, DHS at least since 1990s was not appropriately communicated to public in order to set in place appropriate control levers and reduce the losses of lives and quality of lives. This is known, because during 1990s we collaborated with Prof. Emeritus Thomas Cahill, from UC Davis, who during 1980s developed air quality protocol "IMPROVE" in California, where aerosol pollution propagation outdoors and indoors is well known, and we learned from his team.

Fig. 10 shows that a person using a mask or not have to breathe the same air volume, and even a mask is used a plume around its head remains as shown in upper-left picture, comprising mainly fine aerosol particulates that float in air for weeks carried by the air currents. As upper-right picture shows even long after the person disappears from that area the plume remains, "waiting" for the next person to inhale it.

If the plume is bio-contaminated, the building has to deal with it killing all germs; otherwise the building becomes a hazardous area. HVAC systems may be engineered to sterilize the air using UVc and bio-sterile filters, while by the right placement of the air ducts, the airflow inside the building may be reconfigured to take away any plume from the potential breathing zones [11].

It was not clear stated that surgical masks are worse than unidirectional filters due to reciprocating flow, that makes what have been accumulated in one direction flow to be in part released when flow changes direction as a "drop", making the real protection factor to be much smaller. For example an N100, tight set on face, that is praised to deliver a P_f=-20 dB in reality it delivers -12 to -15 dB and worsens after few hours of wearing reaching even -10 dB. It was not said that what passes through or escapes from mask remains in air like smoke, and social distancing rules do not work in closed spaces, even in open spaces, when air currents flow from contagious persons towards healthy persons in the area, carrying the plume around their heads. It is recommended to have directional filters with valves to avoid airflow reciprocating movement and "drops" on both directions.

A simple measures most of US buildings might have applied if told, was to extend the HVAC return ducts near the floor, to make the air currents similar to those used inside clean rooms [12] as shown in the lower side of Fig. 10.

The efficiency of actual protection system against Influenza and other airborne viruses

It is well known that for filters retaining smaller than 100 nm particles is very difficult, and their retention coefficient is under 5% for this PM range. But even in these conditions masks are a very effective instrument to because of their mutual protection.

Fig.11 in the upper left side shows that an N95 filter Pf is reduced down to -5 dB from -13, but if a building has clean room like air currents, it by default provides -10 dB protection factor no matter virus magnitude. As it is shown on upper-right side a HVAC loses HEPA filter protection, but UVc sterilization and antiseptic filter collaborate and assures -35 dB in protection factor instead of -50 dB. It is also recommended to use personal filtering systems that to collect inhaling air from above the head, and to sterilize and release the exhaled air near the floor, to be directly sucked into return duct.

It is also recommended that buildings with high occupation factor to use exhaled air drain systems.

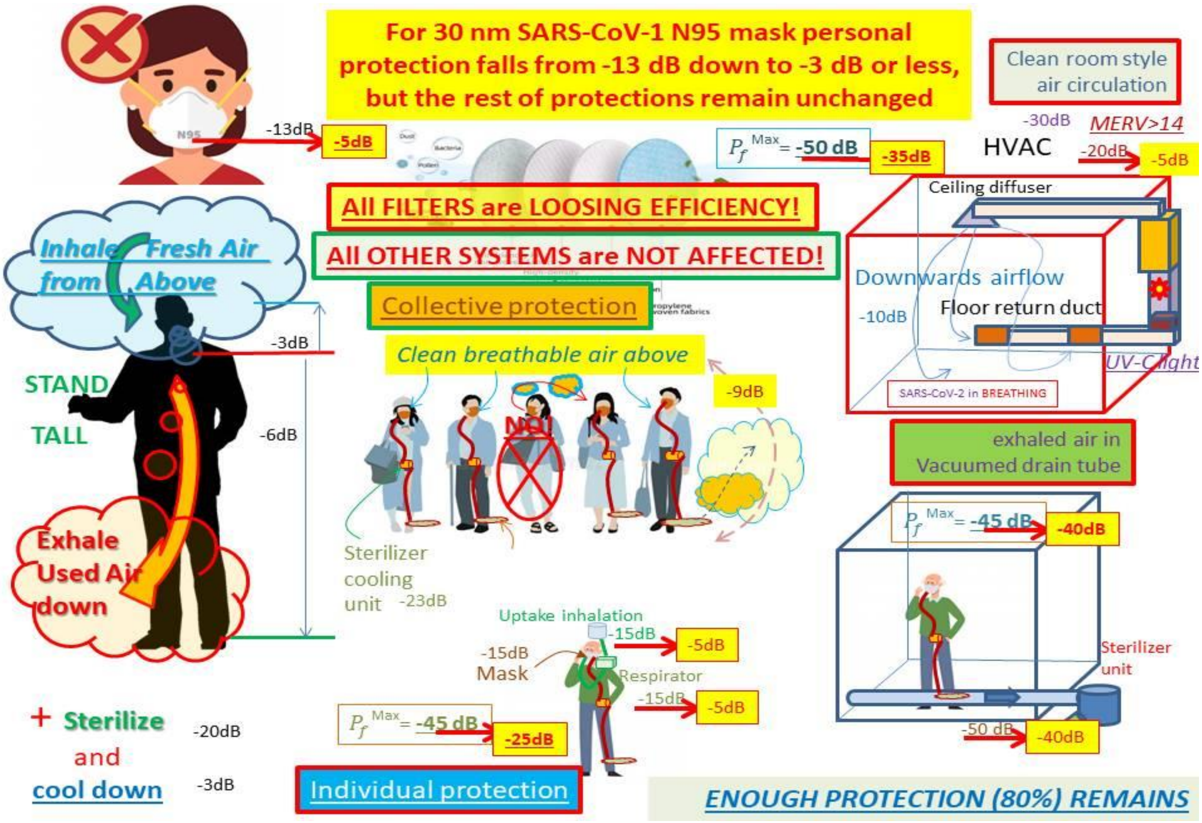

Fig. 11: The effectiveness of engineered protection system against smaller virioli.

Fig. 11 shows a set of protection system and their protection factor for COVID-19 and their Protection factor for Influenza inside the yellow rectangle with red borders. It is seen that the recommended [2,7] engineered protective system, able to set the control levers as shown in Fig. 1 green radar image is able to stop and terminate any airborne propagating pandemic, no matter how contagious it is.

Conclusions

Filters are an efficient instrument for mutual protection, but they alone with "social distancing", cannot offer the necessary protection to terminate a pandemic.

If correctly set on face a N100 filter pair may provide up to -25 dB protection factor.

Wearing facemasks or not a person breathe same amount of air, and what passes through filters is a plume formed of small aerosolized watery droplets that remain in a closed space for weeks, and building ventilation system have to remove and sterilize it, using UVc and sterilization bio-filters.

A face mask filter used in reciprocating air currents exhibits a much smaller protection factor after few hours of usage because filter "drops", and it also releases an abnormal small particulates plume by a process called " atomization", that is the result of filter loading with liquid effluents and micro-fluidic effects combined with aerodynamic instabilities and filter structure mechanical resonances.

It is recommended that face masks to be disposable after each period of continuous wearing, because when reused they will release as a "drop" the previously retained particulates and virioli, and an appropriate sterilization is required before re-wearing.

Folding, pressing vibrating worsens the retention power, and it is not recommended.

Using appropriate protective systems may stop any pandemic in less than 1 mo. and terminate it in about 6 weeks without shutting down economy or applying social distancing, but requires a smart, appropriately educated and ethical population.

Understanding aerodynamics and micro-nano-fluidic effects inside the filter is an important step in building better respiratory system and in improving their safe usage.

References

1. Spigarelli C., "How to Apply the Hierarchy of Controls in a Pandemic", https://www.assp.org/news-and-articles/2020/03/31/how-to-apply-the-hierarchy-of-controls-in-a-pandemic, NIOSH, Mar 31, 2020).
2. Popa-Simil V. et. Al., "Method and device for holistic protection and virus transmission suppression", US Patent Appl. 17/018,177, Sept. 11, 2020.
3. He T.C., Z.S., da Costa L.T., Yu J, Kinzler K.W., Vogelstein B., A simplified system for generating recombinant adenoviruses. Proc Natl Acad Sci U S A, 1998. 95(5): 2509-14.
4. Yang S., Lee G.W., Cheng M.C., Wu C.C.,Yu K.P. The Size and Concentration of Droplets Generated by Coughing in Human Subjects. J Aerosol Med., 2007, 20(4): 484-94.
5. Papineni R.S., R.F.S., The size distribution of droplets in the exhaled breath of healthy human subjects. J Aerosol Med., 1997.10(2): 105-16.
6. Zhou Kang, Calculation of Evaporation Rate of a Droplets Cluster and Conceptual Design of a Structure

Utilizing Water Droplets for Evaporation. Hydrology Current Research, 2014. 5(3): p12.

7. Popa-Simil V. et. al. "Method and device to allow antiseptic proximity seating". US Patent appl. 16/876,337, 2020.
8. Holterman H.J., Kinetics and evaporation of water drops in air. CIP-DATA ROYAL LIBRARY, DEN HAAG, NL, 2003. Report -12: p. 67.
9. Grosshans H., Evaporation of a droplet. Project Report, 2012. MVK160 Heat and Mass Transport (2012, Lund, Sweden).
10. Leung N.H.L., Chu D.K.W., Shiu E.Y.C., Chan K.-H., Mc Devitt J.J., Hau B.J.P., Yen H.-L., Li Y., Ip D.K.M., Peiris J.S.M., Seto W.-H., Leung G.M., Milton D.K., Cowling B.J. Respiratory virus shedding in exhaled breath and efficacy of face masks. Nat. Med. 26, 676–680 (2020).
11. Popa-Simil I.L., Popa-Simil L., Nano-Science Based Developments to Combat Covid-19 Pandemic. Advanced Nano-Bio-Materials and Devices, 2020. 4(1): 541-560.
12. IEST, ISO 14644-1FEDERAL STANDARD 209E. Institute of Environmental Sciences & Technology (IEST), 2010.