NAVAL POSTGRADUATE SCHOOL

COVID-19 OCCUPATIONAL HEALTH ANALYSIS WORK-TASK RISK ASSESSMENT

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Important information/Literature Review:

Respiratory Infection Information:

In general, Respiratory Infections can be transmitted via:

- **Via Droplets and Droplet Nuclei:** People with contagious respiratory infections may produce aerosols (<5um). All human mouth and nose activity such as singing, breathing, talking, laughing, coughing, and sneezing produce particles (bioaerosols) within the inhalable range for humans of <1 to >100 µm. [1] Comparatively, coughing and sneezing produce greater quantities of particles[2,3,4] that travel further due to the velocity of expulsion from the nose or mouth.[5] These are forced respiratory maneuvers that generate high velocity, turbulent airflow release.

- **Via Droplet or Contact:** Agent transmission by large (>5 um) droplets are considered an extension of direct contact because these droplets settle rapidly and travel only short distances from their sources. Direct contact is a common mode of transmission for agents infectious for the mucosa of the upper respiratory tract. For example, contaminated fingers as well as relatively large respiratory droplets generated by coughs or sneezes[5] or water sprays or splashes can deliver infectious agents to the nose and mouth.[6]

Whether Droplet and nuclei or contact transmission; The closer an individual is situated to an aerosol source then the greater the likelihood of large particles being inhaled prior to complete evaporation.[1]

Human responses to bioaerosols range from innocuous effects to serious, even fatal, as seen with SARS-COV-2, depending on the specific and amount of material involved and individual's susceptibility to it.[6] To understand the exposure in the occupational environment is to identify sources, pathways, and receivers. In this case the source is people and the primary Pathway is direct person to person contact. The receivers can either be susceptible (presenting severe outcomes) or non-susceptible (no symptoms or mild to moderate symptoms). Infections spread from person to person may be transmitted in any indoor environment that infectious and susceptible persons share.[6]

SARS-COV-2 Specific:

Incubation Period- 5.1 days, with 99% of individuals exhibiting symptoms within 14 days of exposure.[7] Fewer than 2.5% of infected individuals show symptoms sooner than 2 days after exposure.[7]

Infectivity–Moderately infectious – Asymptomatic patients can transmit infection to contacts[8] However asymptomatic patients shed the virus for a shorter time and were likely to be younger.[9] Asymptotic people were found to be about 50% less infectious than symptomatic persons.[10] Latent infectious period unknown (est. 0-7 days). The major mode of transmission is through the upper respiratory tract.[11] Evidence is mounting that the viral shedding pattern in patients with SARS-CoV-2 is similar to influenza, and is similar between symptomatic and asymptomatic patients,[12] with suspected prolonged shedding of COVID-19 after recovery. Key Differing factor from SARS-COV-1, is **presymptomatic/asymptomatic** transmission. In SARS-COV-1 viral replication occurs primarily in the Lower Respiratory Tract (LRT), while SARS-COV-2 viral replication occurs mostly in the Upper

Respiratory Tract (URT). [13] Viral loads with SARS-CoV-2, which are associated with symptom onset, peak a median of 5 days earlier than viral loads with SARS-CoV-1, which makes symptom-based detection of infection much less effective in the case of SARS CoV-2. The CDC reports that by 10 days after symptom onset, the ability to culture virus, a proxy measure of infectivity, approaches zero.

A smaller number of pathogenic particles are required to infect the lower respiratory tract (LRT) versus the upper respiratory tract (URT), and in comparison, the URT infections are protracted with reduced mortality.[1] We see this in SARS-COV-2, for which viral replication occurs mostly in the URT. [13] It as well presents reduced mortality in comparison SARS-COV-1, which had a case fatality rate of 11% [14] While the mortality rate for SARS-COV-2, age and risk factor dependent, is less than that commonly ascribed to severe community-acquired pneumonia (12–15%) but more than seasonal influenza (~0.1%) by 6–10x.[15]

Mortality- Varies, Older individuals and those with underlying medical conditions are at higher risk of serious illness and death. In a skilled nursing facility in Washington State where a health care provider who was working while symptomatic the mortality from Covid-19 was high; of 57 residents who tested positive, 15 (26%) died.[16]

Age (yrs)	Mortality Rate
≥85	10–27%
65–84	3–11%
55-64	1–3%
20–54	< 1%
≤19	0%

†Severe Outcomes Among Patients with Coronavirus Disease 2019 (COVID-19) — United States, February 12–March 16, 2020. *MMWR Morb Mortal Wkly Rep*. ePub: 18 March 2020.

Mortality rates for reported COVID–19 cases, by age group —United States†

Severity – Many COVID-19 cases are asymptomatic. Most symptomatic cases are mild, but severe disease can be found in any age group. Most symptomatic COVID-19 cases are mild (81%, n=44,000 cases).[17] Impact is severe in susceptible population. Between March 1, 2020, and May 30, 2020. The National overall cumulative hospitalization rate was 82.0 per 100,000 population. Among the 0-4 years, 5-17 years, 18-49 years, 50-64 years, and ≥ 65 years age groups, the highest rate of hospitalization is among adults aged ≥ 65 years (254.7 per 100,000), followed by adults aged 50-64 years (126.2 per 100,000) and adults aged 18-49 years (46.7 per 100,000) https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covidview/index.html. Locally Monterey County has approximately 10% of cases which are severe enough to necessitate hospitalization, as of 08Jun20.

Environmental Stability- SARS-CoV-2 can persist on surfaces for at least 3 days and on the surface of a surgical mask for up to 7 days depending on conditions. If aerosolized intentionally, SARS-CoV-2 is stable for at least several hours. SARS-CoV-2 on surfaces is inactivated rapidly with sunlight.[18] SARS-CoV-2 has an aerosol half-life (required for the activity of a substance taken into the body to lose one half its initial effectiveness) of 2.7 hours (particles <5 μm, tested at 21-23oC and 65% RH).[19]

Decontamination– Soap and water, as well as common alcohol and chlorine-based cleaners, hand sanitizers, and disinfectants are effective at inactivating SARS-CoV-2 on hands and surfaces.[20]

Exposure pathway-

Direct Contact of virus material with mucus membranes, eyes, nose mouth [21]. Exposure does not mean infection. A much higher probability of infection exists in susceptible individuals or large quantity of exposure. SARS-CoV-2 is understood to spread through **close contact** and droplet transmission, with fomite transmission likely and **close-contact** aerosol transmission possible.

Infection- Infection by SARS-CoV-2 may occur in susceptible individuals;

- *Person-to-person, between people who are in close contact with one another[21] (<6 feet, >15min)*
- *Via close contact* **droplet (>5um particle diameter) or aerosol (<5um particle diameter) transmission** through respiratory droplets produced when an infected person coughs or sneezes.*
    - Via inhaled particles as small as aerosol (less than 5 μm in size; capable of staying suspended in the air for a time and easily inhaled into the lungs and distal alveoli) up to droplets (measuring greater than 20 μm in size; quickly pulled to the ground by gravity or, when inhaled, mostly deposited in the nasal cavity),[22]
    - *Contamination of patient rooms with aerosolized SARS-CoV-2 in the human respirable range (0.25-2.5 μm) indicates the potential for airborne transmission.[23]*
- *Via, **fomite transmission** (germs left on surfaces)* direct inoculation of the respiratory epithelium (ie, touching a surface with live virus and then touching one's face).[23] However, this is not considered the primary transmission pathway.

Susceptible Population:

- Higher probability of infection and of severe outcome: Personnel who have weakened immune systems and certain risk factors have a higher probability of contracting the disease [25]. Sever outcomes are expected regardless of age in people with chronic lung or heart disease, severe obesity (>40BMI), diabetes, chronic liver or kidney disease.

*Close Contact is defined by the CDC as within 6 feet of an infected person for at least 15 minutes starting from 48 hours before illness onset until the time the patient is isolated.

However Any duration of exposure should be considered prolonged if the exposure occurred during performance an aerosol-generating procedure or event (singing, coughing, sneezing etc.).

Assessment

NPS Function:

There is a United States Naval Postgraduate School, the primary function of which is to provide advanced instruction and professional and technical education and research opportunities for commissioned officers of the naval service in—(1) their practical and theoretical duties; (2) the science, physics, and systems engineering of current and future naval warfare doctrine, operations, and systems; and (3) the integration of naval operations and systems into joint, combined, and multinational operations. Ref: Title 10 USC § 8541 https://www.law.cornell.edu/uscode/text/10/8541

Purpose: To Preserve the NPS functions and execute mission during the COVID-19 outbreak. NPS will:

- What we need to do: Continue to provide advanced instruction, professional as well as technical education, and research opportunities for commissioned officers of the naval service. **And**,
    - Maintain the Health and Safety of NPS Faculty, Staff, and Students while executing the NPS mission in the most effective and efficient manner while operating in a COVID-19 (or Coronavirus) environment.
- What we cannot do: Conduct our operations in a manner inconsistent with recognized COVID-19 infection control/risk reduction strategies; failing to adhere to such strategies will increase the probability of infection for our staff and students and impair mission/operational readiness.

Location: Naval Postgraduate School (NPS), Monterey. Various locations; Classrooms, Laboratory, Computer laboratories, study areas, passageways, outside walkways, auditoriums, and food/coffee rooms.

Personnel Assigned: Students (on average Active duty mil rank 03-04, mid 20's-late 30's), Faculty, AD (on average , mid 30's-mid 60's), Staff, GS (on average , mid 30's-mid 60's). Population Numbers: Students 1800-2000, Faculty about 600, Staff 380-400.

Process Description: Assigned personnel conducting academic and support activities at NPS. These activities include conducting classes, laboratory work, computer laboratory work, and the access to those locations.

Exposure Assessment:

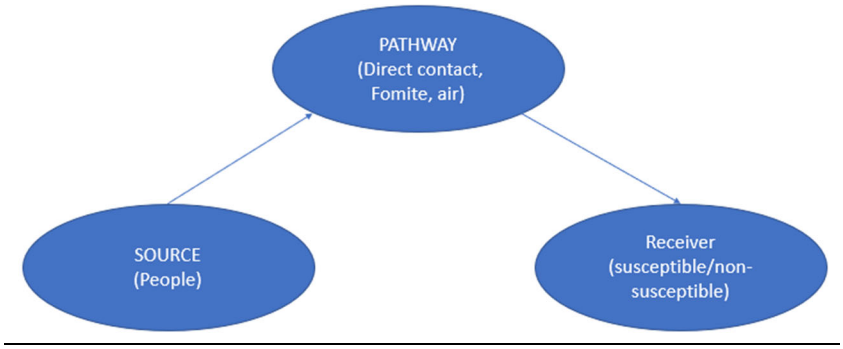
This assessment will focus on controlling the physical contact of viral particles with mucus membranes and inhalation of material which may have viral particles. To this end we will look at the physical properties of these particles and their pathway through the environment.

HAZARD: Biological Hazard. **Biological, Infection from SARS-COV-2, which can produce COVID-19 disease**. There is **contact/exposure** to infected particulate material or contaminated or pathogenic products or materials, which causes infection.

The particles are Aerosols and Droplets containing infectious particles that are <100 µm in diameter are not visible to the naked eye.

- **Infectious aerosols** (<5um diam) are small liquid or solid particles suspended in the air that contain infectious agents.
- **Infectious Droplets** (>5um diam) are larger infectious particles that rapidly fall out of the air, contaminating gloves, the immediate work area, and the mucous membranes of the persons within reach of these materials.

TRANSMISSION, WORK TASK EVALUATIONS:



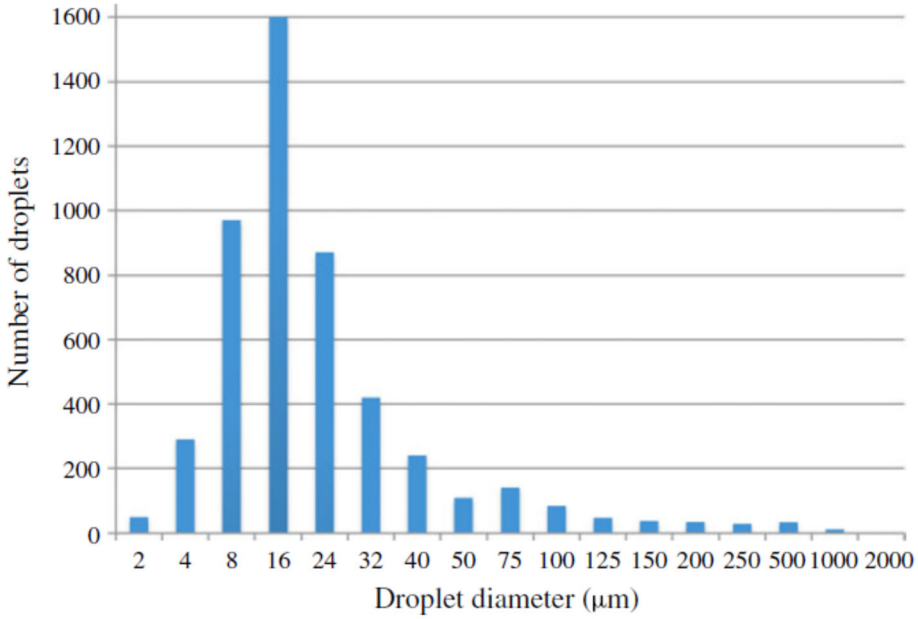
Pathways: SARS-CoV-2 is spread primarily through close contact **Infectious Droplets** transmission,[21] with **fomite** transmission remaining a possible it is not considered the primary transmission pathway, close-contact **aerosol** transmission possible [26] but unconfirmed, aerosol transmission would potentially occur within settings where people who are susceptible are in very close proximity for prolonged time with an infected person.

Particles need to come in physical contact, with mucus membranes in sufficient number to cause infection. Physical contact is through, inertial impaction, Brownian diffusion, gravitational sedimentation, and electrostatic effects.[27] **The smaller the particle, the smaller the quantity of virus within it.**

- <5um diameter particles; diffuse deep into the lung tissue, depositing in the alveoli by several mechanisms including diffusion.[1]
- >5um- ≤100um diameter particles; impact further up the respiratory airways due to greater inertion, depositing in a size-dependent manner from the nasal passages to the larger bronchioles.[1]
- > 10-µm deposit on the nasal epithelium. Viruses cannot initiate infection unless they survive the body's natural defense mechanisms and attach to cells

Source: People. Persons are a primary source of infection for others, with asymptotic and presymptomatic people being 50% less infectious than symptomatic persons[28] and the major mode of transmission is through the upper respiratory tract[21]

Cough particle size varies widely. Experimental studies have been aimed at measuring the size distribution of droplets emitted by various respiratory functions, such as coughing and sneezing, however droplet size distribution for coughs is shown in figure below, which indicates a peak drop size of ~15 µm, the associated settling speed being 6.5 mm/s in ambient air typical of winter indoor conditions.. [29]



Exhaled breath particles (EBPs) were sized < 5 µm, with 80% of them ranged from 0.3 to 1.0 µm.[30]

Sources of Uncertainty: SARS-COV-2 is a new disease, and as such much is still being learned about it.

Risk Characterization

Likelihood: The physical properties of infectious droplet nuclei are like those of other airborne particles of comparable size and density. Under steady-state conditions (no air movement), the expected number of cases, among a given number of susceptible persons, is proportional to the average concentration of infectious droplet nuclei in a room and the probability that susceptible receivers will come into contact with the particles.[6] As well, the concentration of infective particles will be directly proportional to the number of infected persons present and the rate of turbulent respiratory releases (cough or sneeze), increasing the likelihood of exposure. Another factor that will increase the likelihood of exposure is physical distance. Most cases of SARS-COV-2 infection have occurred within close contact situations where personnel are physically close for prolonged periods of time.

Severity: The severity will be determined by the susceptibility (vulnerability) of the receiver. For SARS-COV-2 the at risk vulnerable population are;

- people who are immunosuppressed ,
- People with chronic lung disease or moderate to severe asthma

- People who have serious heart conditions
- People with severe obesity (body mass index [BMI] of 40 or higher)
- People with diabetes
- People with chronic kidney disease undergoing dialysis
- People with liver disease

Assumptions Used:

- Latent Period = 5.2 days
- Infectious Period = 7.2 days
- 50% of infected individuals are symptomatic
- Asymptomatic individuals are equally infectious as symptomatic individuals
    - Current literature indicates lower transmission from asymptomatic people, due to less shedding time and lower forced expulsion, cough or sneeze, of infected material from asymptomatic personnel, however assumption made for a safety margin.
- R0 = Varied by state, between 2 and 3, and determined, the R_0 can also vary by number of susceptible people exposed.
- Controls provide in-parallel reliability.

Methodology[31,32,33]:

A probabilistic matrix was used. Both Navy Risk management and American Industrial Hygiene Association (AIHA) Health risk Rating (HRR) matrixes were utilized, to verify risk. A Monte Carlo simulation was used for the determination of probabilities for the Navy risk matrix. Reliabilities of the probabilities were calculated in parallel since each control functions independently of each other. Probabilities of controls working were based on professional knowledge to include a safety factor, every control was reduced by 5-10% to balance the ongoing knowledge of the infection as well as for variabilities in implementation.

- Avoidance– 80-90% efficiency, (removal of susceptible population, 6ft distancing, removal if symptomatic)
- Engineering Controls – 60-70%. (ventilation systems, physical barriers)
- Admin Controls- 20-30% (Hand and Respiratory hygiene, limit time of exposure)
- PPE 5-10%. (Face coverings- assumption that not everyone will constantly wear)

Evaluation was also focused on susceptible/vulnerable populations.

First, we determined Risk of Tasks, factoring in and assuming vulnerable population was present. Then, we determined the Risk of High and Medium/Moderate risk removing the vulnerable population.

Measure of effectiveness (MOE): Controls reduce the residual risk to "low or minor".

AIHA:

ACTIVITY CATEGORY
High Hazard
II Moderate Hazard
III Low Hazard

Navy Risk Management (quantification added)

RAC = Prob x Severity		
15 above	1	Extremely High
14-10	2	High
9 to 5	3	Medium
4	4	Minor
3 below	5	Low

Results: The Risk matrixes worksheets are included as enclosure (1), summaries below.

Hazard Category	Biological Agent. Material and Particulate Material (PM) from respiratory system containing Infectious agent, SARS-COV-2					
Exposure routes	Via direct contact or inhalation of PM with mucus membranes, Eyes, Nose, Mouth.					
Similar Exposure Groups (SEGs)	HRR (AIHA)	Risk Matrix (USN)*	Controls Advised	Residual risk	Reliability of Controls in‖(modeled)	MOE met
Educators and Attending Class (VULNERABLE POPULATION)	**High Hazard**	**12-High**	Individuals w/ active symptoms*. Physical Distancing. Source Control**, Hand washing, good ventilation	**4.7- Medium to Minor**	98% - Probability	NO
Customer Service (VULNERABLE POPULATION)	**High Hazard**	**12-High**	Individuals w/ active symptoms*. Physical Distancing. Source Control**, Hand washing, physical barriers, or good ventilation	**4.7- Medium to Minor**	97% - Probability	NO
Perf Inspections & Walkthroughs (VULNERABLE POPULATION)	**High Hazard**	**12-High**	Individuals w/ active symptoms*. Physical Distancing. Source Control**, Hand washing, good ventilation	**4.9 Medium to Low**	98% - Probability	NO
Computer Lab or Study Rm (VULNERABLE POPULATION)	**High Hazard**	**9-Medium to High**	Individuals w/ active symptoms*. Physical Distancing. Source Control**, Hand washing, good ventilation	**3.4-Minor**	98% - Probability	YES

Hazard Category	Biological Agent. Material and Particulate Material (PM) from respiratory system containing Infectious agent, SARS-COV-2					
Exposure routes	Via direct contact or inhalation of PM with mucus membranes, Eyes, Nose, Mouth.					
Similar Exposure Groups (SEGs)	HRR (AIHA)	Risk Matrix (USN)*	Controls Advised	Residual risk	Reliability of Controls in‖(modeled)	MOE met
Educators and Attending Labs (VULNERABLE POPULATION)	**Moderate Hazard**	**9-Medium to High**	Individuals w/ active symptoms*. Physical Distancing. Source Control**, Hand washing, good ventilation	**3.2-Minor to Low**	98% - Probability	YES
Workers Single Office (VULNERABLE POPULATION)	**Moderate Hazard**	**6-Medium**	Individuals w/ active symptoms*. Physical Distancing. Source Control**, Hand washing, good ventilation	**1.5-Low**	96%- Probability	YES
Stopping to talk (VULNERABLE POPULATION)	**Moderate Hazard**	**6-Medium**	Individuals w/ active symptoms*. **Reduced contact time Control****, Hand washing, good ventilation	**1.6-Low**	97% - Probability	YES
Walking by Someone (VULNERABLE POPULATION)	**Moderate Hazard**	**3-Low**	Individuals w/ active symptoms*. Much **Reduced contact time Control****, Hand washing, good ventilation	**0-Low**	98% - Probability	YES
High Hazard tasks (NON-VULNERABLE POPULATION)	**High Hazard**	**8-Medium**	**No Vulnerable personnel present**, No Symptomatic personnel present. Physical Distancing. Source Control**, Hand washing, good ventilation	**2.9-Low**	99% - Probability	YES
Moderate hazard tasks (NON-VULNERABLE)	**Moderate**	**6-Medium**	**No Vulnerable personnel present**, No Symptomatic personnel present. Physical Distancing. Source Control**, Hand washing, good ventilation	**1.9-Low**	98% - Probability	YES

* Symptoms can include: Cough, Fever, Muscle Ache, Chills, Loss of smell, Shortness of Breath, sore throat

** Face coverings/masks prevent spread from pre or symptomatic individuals to others, they do not protect you. These coverings do not seal around your face and provide very limited protection. Respirators such as N95's have to be fit-tested, that means they have to seal against your face and this provides the protection against particles along with the N95 material construction, which filters our 95% of particles >0.3um. **If physical distancing can be maintained however an individual who self identifies as being at risk, may request personnel use in their presence**.

Findings:

MOE Met for: Computer Lab or Study Rm, Educators and Attending Labs, Walking by Someone, Workers Single Office, and Stopping to talk for vulnerable populations.

MOE not met for:

1. Educators giving class.
    a. Due to the time they will be potentially around personnel who could be sick but asymptomatic.
2. Customer Service Individuals.
    a. Due to the frequent interaction with different personnel at NPS. Length of time of interaction with different personnel will vary dependent on the type of customer service location.
3. Personnel doing inspections or walkthroughs.
    a. These individuals will have a ranging type of exposure dependent on the number of people they interact with and the times duration of that interaction.

These tasks had a residual risk of Moderate and High-risk.

The risk was calculated again for these High and moderate tasks and we removed the vulnerable population. Since the **severity** was initially determined assuming the presence of susceptible/vulnerable personnel during the assessment. Once the Vulnerable population was taken out, the overall risk fell to **Low**.

All other controls taken to reduce the **probability** of exposure worked well in parallel providing together 97-98% reliability when taken together.

Controls:

- Screen (or self-screen) Individuals w/ active symptoms, do not come to campus.
- Reduced contact time,
- Maintain Physical distancing
- Hand washing,
- Physical barriers
- Low density population at NPS (telework when possible)
- Good ventilation
    - For indoor ventilation situations where windows are not present in the rooms, procedures to validate system are included in enclosure (2)

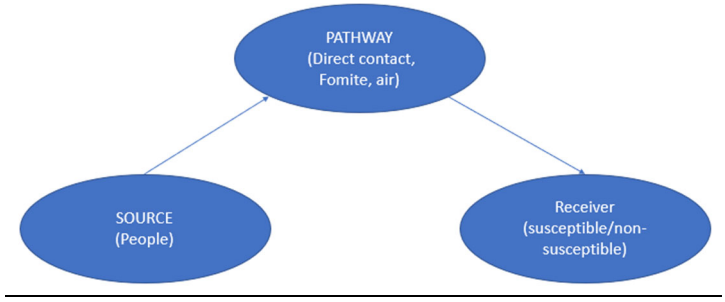
Recommendations:

For those tasks that met the MOE requirements, recommend implementation of controls as presented in the table.

For those tasks which did not meet the MOE in addition to the above controls, remove susceptible/vulnerable population. If this cannot be achieved, then for inspections: maintain exposure times low. For Customer service: automate where possible, lower the density to contacts and use physical barriers when there no technological solution.

Break the triangle from source, via pathway to receiver:

- Control the Source; Utilize face coverings when around other people. Disallow personnel who are showing symptoms to come on campus, as allowed in specific Phase of the NPS Plan.
- Control the receivers; have susceptible/vulnerable populations self-identify and not come to campus to the maximum extent possible.
- Control the environment: indoors, ensure properly working HVAC system by providing 35-50 CFM/person of outside air[22]. Clean high touch surfaces and Wash hands.



Conclusions:

The risk in this disease lies more within the severity of the illness than in the mortality from it. SARS-COV-2, effectively injures the population, increasing hospital stays by those susceptible and taking them away from the workforce. As well, due to its transmissibility between people, it threatens to take down potentially whole shifts of workers, from one potential exposure, incrementing the number of workers which have to be separated from the rest of the workforce further impacting the overall mission.

Since SARS-CoV-2 is spread primarily through close contact **Infectious Droplets** transmission,[21] with **fomite** transmission remaining a possible it is not considered the primary transmission pathway and close-contact **aerosol** transmission possible [26]. Enough particles to cause infection need to come in physical contact, with mucus membranes. However, the number of infectious particles needed to cause disease is unknown and the number of particles to infect a susceptible/vulnerable person is far from being understood. Non-susceptible/nonvulnerable populations likely need a higher dose of particles to become infected.

These findings reflect what was found during the "Course of Actions Safety and Health Risk Assessment", performed by this office 21 April 20, where the root cause was found to be prolonged close contact with infected personnel and infected droplets with mucus membranes (eye, nose, mouth), with the amendment that at-risk personnel have an unknown time or concentration of needed exposure. People with risk factors have a higher probability of developing severe symptoms if infected.

Consequently, to reduce the severity and the likelihood of infection the number susceptible/vulnerable in high to moderate risk tasks should be minimized to the maximum

extent possible that still allows for mission accomplishment. This along with disallowing symptomatic personnel on campus will lower the probability of a severe negative outcome. In the long term for susceptible/vulnerable populations the risk cannot be sustainably lowered to acceptable levels, without a vaccine or readily available pharmaceutical treatment.

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