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Statement of support

This report is the result of an extensive collaborative effort and reflects shared agreement of the terminology between WHO and the esteemed four public health agencies:

- Africa Centres for Disease Control and Prevention;
- Chinese Center for Disease Control and Prevention;
- European Centre for Disease Prevention and Control;
- United States Centers for Disease Control and Prevention;

This agreement underlines our collective commitment to moving forward together in implementing these statements.

Contents

Abbreviations

Abbreviations	Description
Africa CDC	Africa Centres for Disease Control and Prevention
CDC	Centers for Disease Control and Prevention, United States of America
COVID-19	Coronavirus Disease 2019
IPC	Infection Prevention and Control
IRP	Infectious Respiratory Particle
MERS	Middle East respiratory syndrome
PHEIC	Public Health Emergency of International Concern
PHSM	Public Health and Social Measures
PPE	Personal Protective Equipment
SARS-CoV-1	Severe Acute Respiratory Syndrome Coronavirus 1
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
TB	Tuberculosis
TCG	Technical Consultation Group
TTAT	Through the air transmission
WG	Working Group

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Technical Consultation Group

The Technical Consultation Group on TTAT (November 2021 to present) included representatives from invited public health agencies (Africa Centres for Disease Control and Prevention, Chinese Center for Disease Control and Prevention, European Centre for Disease Prevention and Control, and the United States Centers for Disease Control and Prevention) and others who were engaged in their personal capacity as experts in areas relevant to the consultation topic, as listed below.

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Other WHO technical departments

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Executive summary

Terminology used to describe the transmission of pathogens through the air varies across scientific disciplines, organizations and the general public. While this has been the case for decades, during the coronavirus disease (COVID-19) pandemic, the terms 'airborne', 'airborne transmission' and 'aerosol transmission' were used in different ways by stakeholders in different scientific disciplines, which may have contributed to misleading information and confusion about how pathogens are transmitted in human populations.

This global technical consultation report brings together viewpoints from experts spanning a range of disciplines with the key objective of seeking consensus regarding the terminology used to describe the transmission of pathogens through the air that can potentially cause infection in humans.

This consultation aimed to identify terminology that could be understood and accepted by different technical disciplines. The agreed process was to develop a consensus document that could be endorsed by global agencies and entities. Despite the complex discussions and challenges, significant progress was made during the consultation process, particularly the consensus on a set of descriptors to describe how pathogens are transmitted through the air and the related modes of transmission. WHO recognizes the important areas where consensus was not achieved and will continue to address these areas in follow-up consultations.

The scope of what type of pathogens were covered in this consultation and the resulting descriptors used in this document are as follows:

- Pathogens, contained within a particle (known as 'infectious particles'), that travel through the air, when these infectious particles are carried by expired airflow (they are known as 'infectious respiratory particles' or IRPs), and which enter the human respiratory tract (or are deposited on the mucosa of the mouth, nose or eye of another person) and;
- Pathogens from any source (including human, animal, environment), that cause predominantly respiratory infections (e.g., Tuberculosis [TB], influenza, severe acute respiratory syndrome [SARS], Middle East respiratory syndrome [MERS]), but as well as those causing infections involving the respiratory and other organ systems (e.g. COVID-19, measles).

The following descriptors and stages have been defined by this extensively discussed consultation to characterize the transmission of pathogens through the air (under typical circumstances):

- Individuals infected with a pathogen, during the infectious stage of the disease (the source), can generate particles containing the pathogen, along with water and respiratory secretions. Such particles are herein described as potentially 'infectious particles'.
- These potentially infectious particles are carried by expired airflow, exit the infectious person's mouth/nose through breathing, talking, singing, spitting, coughing or sneezing and enter the surrounding air. From this point, these particles are known as 'infectious respiratory particles' or IRPs.
- IRPs exist in a wide range of sizes (from sub-microns to millimetres in diameter). The emitted IRPs are exhaled as a puff cloud (travelling first independently from air currents and then dispersed and diluted further by background air movement in the room).
- IRPs exist on a continuous spectrum of sizes, and no single cut off points should be applied to distinguish smaller from larger particles, this allows to move away from the dichotomy of previous terms known as 'aerosols' (generally smaller particles) and 'droplets' (generally larger particles).
- Many environmental factors influence the way IRPs travel through air, such as ambient air temperature, velocity, humidity, sunlight (ultraviolet radiation), airflow distribution within a space, and many other factors, and whether they retain viability and infectivity upon reaching other individuals.

The descriptor 'through the air' can be used in a general way to characterize an infectious disease where the main mode of transmission involves the pathogen travelling through or being suspended in the air. This has similarity with other public health descriptors of infectious diseases, such as 'waterborne' and 'bloodborne', that refer to the main medium through which a specific disease is transmitted, and as commonly understood by the scientific, clinical, public health communities and the general public.

The descriptor 'transmission through the air' can be used to describe the mode of transmission of IRPs through the air.

Under the umbrella of the 'through the air', two descriptors can be used:

- '**Airborne transmission/inhalation':** Occurs when IRPs expelled into the air as described above and enter, through inhalation, the respiratory tract of another person and may potentially cause infection. This form of transmission can occur when the IRPs have travelled either short or long distances from the infectious person. The portal of entry of an IRP with respiratory tract tissue during airborne transmission can theoretically occur at any point along the human respiratory tract, but preferred sites of entry may be pathogen specific. It should be noted that the distance travelled depends on multiple factors including particle size, mode of expulsion and environmental conditions (such as airflow, humidity, temperature, setting, ventilation).
- '**Direct deposition'**: Occurs when IRPs expelled into the air following a short-range semi-ballistic trajectory, then directly deposited on the exposed facial mucosal surfaces (mouth, nose or eyes) of another person, thus, enter the human respiratory tract via these portals and potentially cause infection.

Pathogens that can be transmitted to another human via contact transmission (direct contact) and not via transmission through the air (e.g. via hands) or indirectly via touching secondary objects (fomites e.g. tabletops), or that enter the human body via routes (e.g. open wounds, sharps or needle-stick injuries) or pathogens with an environmental reservoir with a predilection for lungs (e.g., Legionella and melioidosis) are not covered by the included descriptors but are referenced for completeness.

This consultation is the first phase of the global scientific debate led by WHO. From which the next steps will require further technical and multidisciplinary research and exploration of the wider implications of the updated descriptors before any update on infection prevention and control or other mitigation measures guidance is issued by WHO.

CHAPTER 1
Introduction

Understanding the modes of transmission for any pathogen is essential for developing and adapting effective and appropriate public health, clinical, infection prevention and control measures to prevent infections and mitigate the spread of that pathogen.

Key public health and social measures include implementing multiple approaches, such as:

- case finding;
- separation and/or isolation;
- contact tracing and supported quarantine;
- robust testing;
- physical distancing;
- hand hygiene, mask-wearing;
- delivery of prompt and appropriate treatments;
- environmental cleaning and disinfection;
- ensuring adequate ventilation;
- infection prevention and control measures in health care settings;
- clinical case management.

All these measures are influenced by an understanding of how, where and when transmission of a pathogen occurs and are implemented in a variety of different settings, including for health care workers and other occupations in health care settings, usually using a 'hierarchy of controls' approach.

The way pathogens are transmitted is complex and depends on many factors and may be classified in different ways. The modes of transmission follow classic epidemiological principles and refer to how an infectious agent, which can be pathogenic, can be transferred to another person, object, the environment, water, food, insect or animal. In this sense, transmission could simply be classified through the various media the infectious pathogens use to move between the source and susceptible recipient e.g. bloodborne, waterborne, vector-borne, airborne and through the air (*1–3*). How to measure and quantify the predominant mode of transmission for different pathogens that are transmitted through the air remains challenging, particularly for newly emerging pathogens.

One current major issue contributing to this challenge is that the terminology used to describe the transmission of pathogens through the air varies significantly across scientific dis-

ciplines, organizations and the general public (*4*). While this issue has been known for many years (*4–20*), it was brought to the forefront during the COVID-19 pandemic when intensive global communications were needed. During the pandemic, the terms 'airborne', 'airborne transmission', 'droplets' and 'aerosols' were used in different ways, by different stakeholders, which contributed to confusion in communicating how this pathogen was transmitted in human populations via air (*21*). Hence, a lack of consensus on what exactly is meant by 'airborne', 'airborne transmission' has highlighted the need for better alignment of these terms across disciplines, agencies and pathogens.

In 2020, the WHO COVID-19 leadership team consulted with other major public health agencies and agreed on the need to reassess the use of terminology relating to transmission of pathogens through the air. As a starting point, and in order to ascertain whether significant and unresolved variation in the definitions existed between different scientific disciplines, the WHO Health Emergencies Programme, together with the Science Division's Rapid Review Group, conducted a scoping literature review of the existing definitions of airborne transmission of pathogens in 2021. This review (manuscript under preparation) found considerable variation in the scope of the term 'airborne transmission', including differences in particle size limits, duration in the air, distance travelled, method of dispersal and other properties.

In November 2021, WHO began the process of convening a global technical consultation with the aim to resolve inconsistencies in terminology and seek agreement regarding descriptors and terminology relating to the transmission of pathogens through the air. This consultation report summarizes the areas of consensus reached from the expert discussions on the proposed terminology and descriptors to be used.

CHAPTER 2
Objectives, aim and scope

The key objectives of this global technical consultation process were:

- to bring together global experts of various disciplines including (but not limited to) experts in epidemiology, microbiology, clinical management, infection prevention and control, bioengineering, physics, air pollution, aerosol science, aerobiology, public health and social measures, and social science; and
- to share knowledge and seek a consensus regarding generic terminology and descriptors used to describe the transmission of pathogens through the air that can potentially cause infection in humans.

The aim of the consultation was to:

- identify a language for these terms that can be understood, accepted and eventually implemented by all disciplines and experts globally.

The scope of pathogens covered in this consultation and the resulting descriptors contained in this document are as follows:

- Pathogens, contained within a particle (known as 'infectious particles'), that travel through the air and these infectious particles are carried by expired airflow (now known as 'infectious respiratory particles' or IRPs), which enter the human respiratory tract (or are deposited on the mucosa of the mouth, nose or eye of another person);
- Pathogens from any source (including human, animal, environment), that cause predominantly respiratory (e.g., TB, influenza, SARS, MERS) but also those pathogens causing infections involving the respiratory and other organ systems (e.g. COVID-19, measles).

To note:

- Pathogens that are transmitted to another human via contact transmission (direct contact), not via transmission through the air (e.g. via hands) or indirectly via touching secondary objects (fomites e.g. tabletops), or that enter the human body via routes (e.g. via the skin or open wounds, via sharps or needle-stick injuries) or pathogens with an environmental reservoir with a predilection for lungs (e.g., Legionella

and melioidosis) are not covered by the included descriptors but are referenced for completeness;

- For simplicity, the descriptors, figures, tables and other text included in this document usually refer to humans only (e.g. 'person/individual' rather than the more generic term 'source', which could be used to refer to environmentally derived pathogens) and focus on transmission from, and to, the respiratory tract of humans, rather than other ports of entry (e.g. via skin or open wounds);
- Detailed descriptions of all possible transmission factors, for every known pathogen, in all possible settings, were not included in this consultation.

CHAPTER 3
Methods and processes

Details of the governance structure and formation of the Technical Consultation Group (TCG) can be found in Annex 1. This global technical consultation used a staged approach (see Annex 2), with two complementary methods (see Annex 3). This was a multi-agency, multidisciplinary initiative, including 41 technical experts and the WHO Secretariat (see Annex 4) selected to provide expert evidence and to contribute to open discussions via virtual meetings and submit written comments following each draft of the resulting document(s). The members of the full TCG were included based on their technical expertise, and to ensure appropriate gender and geographical balance. Invitations to join the TCG of experts were approved and issued by the WHO Chief Scientist. All consulted experts were assessed for conflicts of interest and asked to sign confidentiality agreements, per normal WHO procedures. None of the experts reported any conflict considered relevant. Given the high likelihood of substantive disagreement among the diverse selected experts, all were encouraged to provide full, frank but respectful contributions to the consultation discussions via their verbal contributions and written feedback, but to aim for overall descriptors that multiple agencies could co-endorse and adopt.

This technical consultation process was not that of a formally constituted WHO TCG, and thus, formal recommendations were not an expected output of the process. As such, comprehensive systematic evidence reviews pertaining to every known pathogen were not undertaken. Instead, the process aimed to be a starting point for what is anticipated to be difficult and complicated discussions on a topic with enormous complexity, which would form the basis for common language across disciplines. However, it would likely require further work in order to operationalize and implement within pathogen-, discipline- and setting-specific contexts.

Comments provided during virtual meetings and via written feedback covered an extremely wide range of areas relating to the topic. This included mechanisms, modes, settings, pathogen specific characteristics, epidemiological factors, source control, host and many other factors relating to the transmission of IRPs.

An informal approach, with unstructured discussion, was used for this consultation, as this can enable better articulation of views and opinions rather than using more structured approaches (such as the Delphi method, surveys or formal voting). The possibility of having strongly dissenting views recorded was offered to members of the TCG. The term 'consensus' has been used in this document to convey a process whereby these group decision-making methods were employed in the consultation to achieve the resulting document.

CHAPTER 4
Outcomes

The lengthy consultation process confirmed how extremely complex and sensitive it is to address the objective laid out in this global technical consultation. As anticipated, it was challenging to achieve consensus on all aspects of this topic where experts had mutually exclusive and diametrically opposed positions regarding the supporting science, some of which still remain, and are summarized in Annex 5.

Despite these hurdles, progress was made to reach a consensus of the overarching terminology of 'transmission through the air' with sub-categories of 'airborne transmission" and 'direct deposition'. Importantly, it was agreed by the TCG that Figure 1 is a schematic depiction of current understanding on how pathogens are transmitted through the air, although not all organisms employ all the routes shown. There remains some disagreement regarding some of the chosen labels and terminology to describe the schematic (see Annex 5 for discussion points). To articulate the schematic depiction of Figure 1 in words, the following descriptors are proposed to be used to characterize the transmission of pathogens through the air, under usual circumstances.

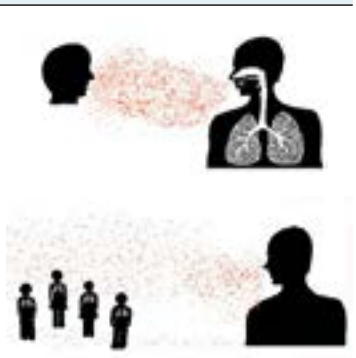
Figure 1. Potential modes of transmission of infectious respiratory particles

Source: Developed by A. Manna and L. Bourouiba, adapted from (*8, 12, 22, 23*).

3.1 Modes of transmission

The mode of transmission (Table 1) includes the formation, release, transport and biophysical/biochemical changes to IRPs that occur when they move away from an infectious individual and travel towards another individual. In addition, IRPs may directly deposit on the mouth, nose or eye of another individual, and can potentially infect the individual.

Table 1. Features of infectious respiratory particles and descriptors for modes of transmission[§]

Mode of transmission	Typical distance from the source	Route of transfer to another human	Respiratory tract entry mechanism	Respiratory tract entry portal	Schematic depiction
THROUGH THE AIR					
Airborne transmission/ inhalation	Any distance	Through the air (suspended in air or moving via air flows)	Inhalation	Anywhere along the respiratory tract	
Direct deposition	Short	Through the air (semi-ballistic trajectory)	Deposition on the mucosa	Mouth, nose or eyes*	
CONTACT[#]					
Direct contact	*Short*	*Not through the air*	*Direct transfer (via touch[¤], usually with hands)*	*Mouth, nose or eyes**	
Indirect contact	*Any distance*	*Not through the air, although IRPs may reach an intermediate object through the air*	*Indirect transfer (via touching an intermediate object)*	*Mouth, nose or eyes**	

* Note that the mucosa of the eyes is not part of the human respiratory tract but are a portal of entry into the respiratory system.

[#] Note that this mode of transmission to another human does not involve a 'through the air' route but is included here for completeness. Depictions above assume the human(s) on the left is/are the infectious person(s) and the human on the right is the recipient of the IRP.

[¤]Note that 'touch' is not through the air transmission but included for completeness and it does not include sharp injuries like needle prick.

[§]Source of figures: A. Manna and L. Bourouiba. Based on (*8*, *12*, *23*).

During the infectious stage of the disease, an infected person can generate particles containing the pathogen, along with water and respiratory secretions. Such particles are here described as 'infectious respiratory particles' or IRPs (*24–36*). These IRPs are then carried by expired airflow, exit the infectious person's mouth and/or nose when they breathe, talk, sing, spit, cough or sneeze and are released into the surrounding air. The IRPs exist in a wide range of sizes (from sub-microns to millimetres in diameter) (*22*, *25*, *32*, *37–55*) and travel in the air in a turbulent puff cloud (exhaled mixture of gases from the lungs and respiratory particles) (*8*, *23*). The IRPs are carried by the puff cloud and remain concentrated until the cloud reduces sufficiently in momentum to enable IRP dispersal by the background air movement.

There are many factors that can influence the particle distribution, spread and subsequent effect on an individual of exhaled IRPs (depicted in Figure 1):

- **Host**: Immune status of the host, including prior infection, vaccination, status of an individual's innate, cellular and humoral immunity;
- **Pathogen characteristics**: The ability of the pathogen to remain infective after suspension in the air and the dose-infection relationship for the pathogen after it deposits on a surface in the host's respiratory tract;
- **Particle size**: IRPs are formed with a continuous spectrum of aerodynamic sizes, and no single cut off points should be applied to distinguish smaller from larger particles, this allows to move away from the dichotomy of what have previously been known as 'aerosols' (generally smaller particles) and 'droplets' (generally larger particles) (*8*, *12*, *56*, *57*). Nonetheless, there are usually more numerous smaller, compared to larger, particles;
- **Speed of expulsion**: The speed of expulsion can vary depending on the force of expiration and other factors relating to the surrounding conditions (*8*, *12*, *14*, *23*, *55*, *58–67*). Because of dilution, the concentration of IRPs is higher closer to the source (where the IRPs exit the infectious person's respiratory tract) and become less concentrated as they disperse randomly further away from the source;
- **Influence of gravity**: Under the influence of gravity, after being expelled, larger IRPs rapidly fall, eventually reaching the ground or another surface, usually within 1-2 metres of where they were emitted from the infectious person's respiratory tract (*13*, *68*, *69*);
- **Mode of expulsion**: Activities resulting in more forceful expiration (i.e., larger total momentum), such as sneezing, coughing, loud singing and shouting, are known to propel IRPs further than 1-2 metres (*8*, *12*, *23*);
- **Evaporation**: Following emission from the mouth and/or nose, IRPs of all sizes undergo evaporation of some of their water content. IRPs decrease in size and weight at various rates in a common environment. Evaporation rate has an impact on how long particles remain in the air and how far they may be transferred before settling on a surface. The smaller the particle, the longer it is likely to remain in the air, and the further it is likely to travel;
- **Environmental conditions**: In addition to the above factors for transmission, the ambient air temperature, sunlight, humidity, airflow and size, occupancy and use of the space where IRPs are expelled impact the infectivity, duration, speed of transmission and distance travelled of IRPs (*23–25*, *29*, *33*, *48*, *54*, *55*, *62*, *66*, *70–87*);
- **Concentration of IRPs**: With increasing distance from the source, dilution with ambient air increases and concentrations of IRPs decrease. Concentrations are also affected by ambient airflows from ventilation systems. Concentrations can increase over time if ventilation is inadequate (*88–90*).

After IRPs are emitted from an infectious person, they progressively diminish in infectivity over a time frame specific to the pathogen, either due to decrease in an organism's infectivity with time or more dispersion and dilution leading to lower concentrations of particles in the air at any given position. The modes in which IRPs then travel to, enter, and can potentially infect another individual can broadly be described as occurring in the following three ways (depicted in Figure 1 and Table 1):

1. **i) Airborne transmission/inhalation:** Occurs when IRPs expelled into the air (as described above) and enter, through inhalation, the respiratory tract of another person. This form of transmission can occur when the IRPs have travelled either short or long distances from the infectious person (*28*, *37*, *41*, *43*, *53*, *63*, *84*, *91–96*). The portal of entry of an IRP with respiratory tract tissue during airborne transmission can theoretically occur at any point along the human respiratory tract, but preferred sites of entry may be pathogen specific. It should be noted that the distance travelled may depend on multiple factors including particle size, mode of expulsion and environmental conditions (such as airflow, humidity, temperature, setting, ventilation, etc.).
2. **ii) Direct deposition:** Occurs when IRPs are expelled into the air following a short-range semi-ballistic trajectory, then are directly deposited on the exposed facial mucosal surfaces (mouth, nose or eyes) of another person, thus, entering the human respiratory tract via these portals and potentially causing infection (*38*, *41*, *42*, *47*, *48*, *52–54*, *58*, *62*, *67*, *72*, *76*, *84*, *95*, *97–106*).
3. **iii) Contact transmission (added for completeness):** Contaminated surfaces are created when IRPs expelled into the air settle on a surface, or when an infected person transfers infectious respiratory secretions by firstly touching their own mouth, nose or eyes and then touching a surface or shaking hands (*25*, *34*, *42*, *48*, *54*, *58*, *72*, *84*, *97*, *98*, *107*, *108*). Infectious pathogens on the contaminated surfaces are then transferred to another person who touches that contaminated surface and then their own mouth, nose or eyes. This is commonly known as *indirect contact transmission*. In addition, *direct contact transmission* can occur when an infectious person directly transfers infectious pathogens from their own respiratory tract, not via IRPs, to another person by being in direct contact with that person (e.g. via a handshake), who then directly transfers the IRPs into their own mouth, nose or eyes. This form of transmission does not directly involve the transmission of pathogens to humans through the air, so is not considered part of the 'through the air' descriptors covered by this document, but is included here for completeness (see also Figure 1, Table 1).

3.2 The term 'through the air transmission'

The descriptor 'through the air' can be used in an overarching way to characterize an infectious disease where transmission involves the pathogen travelling through or being suspended in the air. This has similarity with other public health descriptors of infectious diseases, such as 'waterborne' and 'bloodborne', which refer to the main medium through which a specific disease is transmitted and is commonly understood by the general public. However, the medium alone does not address the factors of time and distance over which the air remains infectious, and those modifiers will be necessary for the phrase to be useful for public health implementation, which needs to be part of future research.

The phrase 'transmission through the air' can be used to describe the transmission of IRPs through the air, via either airborne transmission/inhalation or direct deposition modes (or

other labels matching equivalent descriptions) as outlined above. This can therefore include the transmission of IRPs on a spectrum of sizes, over both short and long distances. See Figure 1 and Table 1 for schematic descriptions of these modes of transmission (and other related transmission modes for completeness).

3.3 Exposure and its relationship to infection

Exposure of pathogens through the air is a physical phenomenon in which pathogens released from the respiratory tract of an infectious person end up in the respiratory tract of another.

Exposure does not guarantee successful infection of the susceptible host, as infection is an event that can only occur after the expelled IRPs enter the respiratory tract, come into contact with the respiratory tissues, followed by multiplication of the infectious pathogens within a susceptible person – thus, the full chain of events and conditions that comprises transmission. There are a multitude of complex factors that influence whether a susceptible person becomes infected, including biological characteristics of the pathogen and the particles it is contained within, immune responses in the susceptible host, concentration of microbes in the IRP, duration of exposure and environmental factors. This document does not provide detailed information on these complex factors that can ultimately result in infection.

3.4 Some factors affecting 'through the air' transmission of IRPs and infection risk

As mentioned, many factors can affect the viability, infectivity and virulence, and concentration of expelled IRPs and contribute to the risk of infection and disease in another person.

Numerous mitigation measures can reduce the risk of pathogens that transmit through the air; distancing, masking, adequate ventilation/dilution and airflow pattern within indoor spaces should be considered to help mitigate the risk of airborne transmission of IRPs. This is because the transmission of IRPs is more likely to occur indoors than outdoors because the opportunity for dilution of IRPs in the surrounding air is almost always greater outdoors. An example of recent initiatives aiming to estimate the risk of airborne transmission indoors is the 'Indoor Airborne Risk Assessment' in the context of SARS-CoV-2 (*109*). This risk assessment tool uses detailed relevant components, including:

- the emission rate (number/volume of IRPs exhaled by an infectious person in a given time) (*41*, *52*, *75*, *77*, *87*);
- the removal rate (total number/volume of IRPs removed from the air in a given time by ventilation or deposition or inactivation) (*42*, *60*, *63*, *77*, *84*, *110*, *111*);
- Exposure (difference/balance between the emission rate and the removal rate and the exposure time) (*35*, *44*, *81*, *110*, *112–115*, *48*, *50*, *54*, *60*, *63*, *65*, *71*, *76*);
- the administered dose (dose of IRPs which are actually retained and to which another person is exposed) (*25*, *41*, *48*, *50*, *59*, *62–65*, *71–75*, *77*, *80*, *81*, *83*, *111–113*, *116–119*);
- the resulting probability and risk of infection (taking into account the administered dose, the exposed person's susceptibility to infection, severity of the resulting disease, the pathogen specific transmissibility characteristics, and other risk and host factors) (*41*, *108*, *120–125*).

Detailed descriptions of the interplay between these complex factors for specific pathogens, in specific settings, are not within the scope of this document.

It is important to note that different pathogens will have different predominant, or mixed, modes of transmission, including through the air transmission, which require detailed discussions with relevant expert groups to determine appropriate mitigation strategies. In addition to mode of transmission, these discussions will include the epidemiologic and virologic characteristics of the pathogens, the degree or severity of illness caused, the impact and burden on health care systems, and other factors, thus transmission pathways alone are not sufficient to indicate which mitigation strategies are chosen. The development of evidence-based guidance, transmission prevention and mitigation measures will need to be tailored differently for different pathogens via different routes and in different settings. In addition, pathogens vary in their virulence, treatability, frequency and potential impact on different hosts in different settings. Hence, pathogen- and setting-specific guidance regarding mitigation measures, including infection, prevention and control (IPC) guidance, is needed, but is not within the scope of this document.

3.5 Immediate practical implications

The updated terminology no longer includes a cut off of particle size, but rather a continuum of particle sizes of IRPs. These will have practical implications for various technical disciplines. For example, in IPC, the goal is to prevent and/control microbial transmission. Control includes both limiting the spread of infection and limiting the morbidity and mortality resulting from infection. To prevent or limit the spread of infection, exposure must be addressed, prioritizing interventions according to the severity of the resulting diseases. This means that for the same transmission mode, different prevention and control measures may be selected, depending on factors relating to the infectious agent, source, environment and host. There must be a clear understanding that when describing transmission of pathogens, this must work backwards from factors affecting infection risk, not just forwards from source generation and infectious particle characteristics, such as their concentrations, size and aerobiological properties.

There is NO suggestion from this consultative process that to mitigate the risk of short-range airborne transmission full 'airborne precautions'[1] (as they are currently known) should be used in all settings, for all pathogens, and by persons with any infection and disease risk levels where this mode of transmission is known or suspected (*126*). But conversely, some situations will require 'airborne precautions'. This would clearly be inappropriate within a risk-based infection prevention approach where the balance of risks, including disease incidence, severity, individual and population immunity and many other factors, need to be considered, inclusive of legal, logistic, operational and financial consequences that have global implications regarding equity and access.

Additionally, the new term of 'direct deposition' is akin to the existing 'droplet transmission' mode, but without any specific particle size designation. While further understanding of this form of transmission is elucidated, for pathogens suspected or known to transmit via this mode, the existing 'droplet precautions' should continue to be used to prevent direct deposition of respiratory particles, but personnel may still be vulnerable to infection via airborne transmission/inhalation if the pathogen can also transmit via this mode. Similarly, for transmission via 'contact' mode, existing precautions known as 'contact precautions' should continue to be used.

[1] Such as patient placement in an airborne infection isolation room, appropriate personal protective equipment (PPE) use by health care workers (including a respirator), limited transport and movement of patients, and asking the patient to wear a mask when appropriate.

Most importantly, while discussions during the consultation were based on the available best science, it was agreed it was important to balance scientific insights with availability, access, affordability and other practical realities to minimize health inequity and avoid potential consequences such as the ability to access PPE.

The implementation of the terminology on transmission through the air and all other modes of transmission will require further empirical multidisciplinary research and an evidence-based review process. Terminology of the modes of transmission may have ramifications on current measures and recommendations in health care settings, as well as in others including, but not limited to, educational settings, transport and workplaces. Many diverse disciplines will need to be bought together to consider the implications for specific pathogens, for nonspecific infection control measures, such as good hygiene practices, and when the modes of transmission are not known at the time.

3.6 Key research gaps and next steps

Physical science studies have emphasized the importance of understanding the movement of particles through the air in order to design potential interventions to lower the risk of infection. However, studies that measure infection and the impact of mitigation interventions for specific pathogens are challenging as the ability to design and conduct clinical trials, or other study types, is highly affected by the enormous heterogeneity of factors regarding the pathogens themselves (and their characteristics), the settings where pathogens are transmitted, and the individuals who eventually become infected by them. Well-designed research studies are needed to inform mitigation strategies.

Guidance for infection prevention depends on a wide range of factors that need to be considered by health care experts and scientists particularly in emergent situations. However, there remains a clear and urgent need for the design and conduct of further inter–disciplinary research to build robust evidence regarding transmission mechanisms and infection prevention measures and strategies. Future research should include animal models, human challenge experiments, as well as other observational and interventional study designs.

An important next step is to consider how the definitions described here will be applied to wider evidence base and risk assessment processes, to inform wider IPC and clinical research, epidemiology evidence base and future IPC measures as well as for engineering, physics research and aerosol science. Behavioural research is important for implementing acceptance, adoption and action of IPC and public health measures.

CHAPTER 5
Conclusions

This global technical consultation process was a concerted effort of many influential and experienced experts. Despite the challenges faced to arrive at some degree of consensus on such sensitive issues and terminology, progress was made. WHO recognizes the concerns and the non-agreed aspects raised and will continue to address these in future work.

Reaching consensus on the term 'infectious respiratory particles', moving away from a strict dichotomy of particle sizes, and accepting that smaller IRPs can be transmitted at both short- and long-range depending on several influencing factors, are all major achievements. Consideration for the use of the phrase 'transmission through the air' as an umbrella term to describe the transmission of IRPs through the air via either airborne transmission or direct deposition modes simplifies a highly complex issue but will require specific socialization and training to be understood by health care workers and the general public.

Such a shift in the use of this terminology in this way is not without its consequences. Hence, the descriptors included in this document should be seen as a starting point for further evidence review, urgent and detailed discussions and, multidisciplinary research with associated funding to address pathogen-, discipline- and/or setting-specific implementation of the suggested changes.

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Annexes

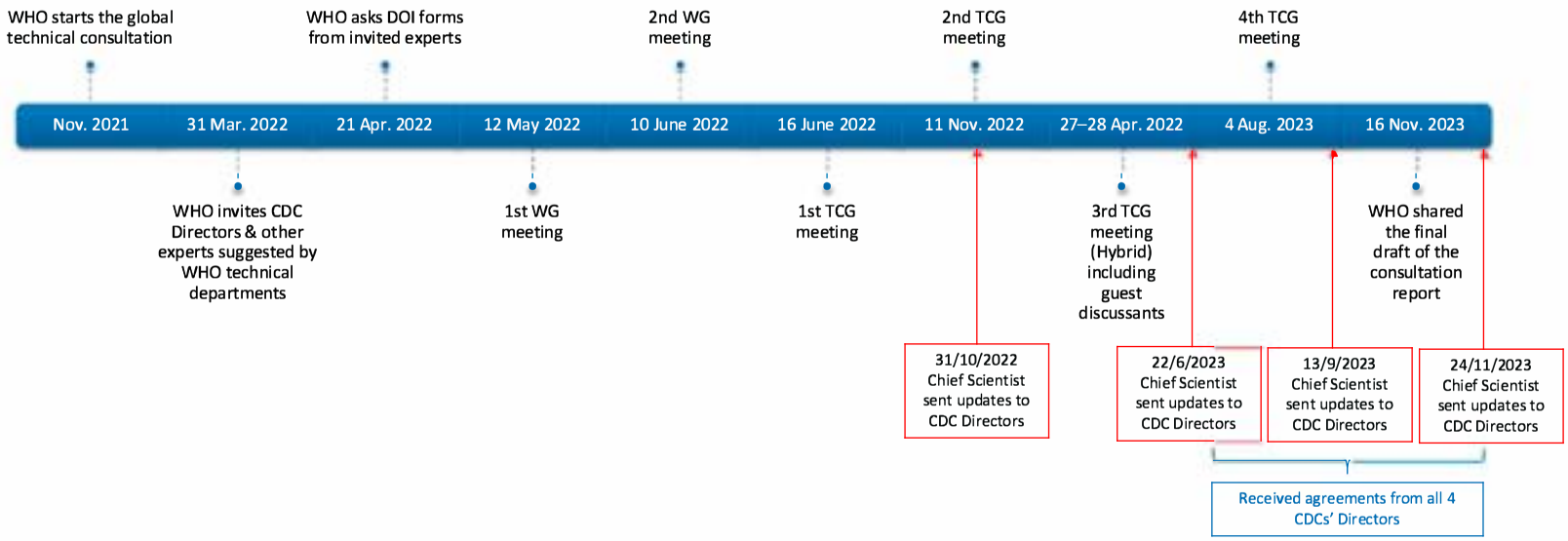
Annex 1. Governance structure

Dr Soumya Swaminathan, the WHO Chief Scientist, was the Convening Lead for this technical consultation until her departure from WHO in December 2022, after which, this role was assumed by the acting Chief Scientist, Dr John Reeder, then from 8 May 2023, by the new incoming Chief Scientist, Dr Jeremy Farrar. The Chief Scientist was supported by a WHO Secretariat who operationalized the project.

A project Working Group (WG) was convened, consisting of 10 representatives from key agencies including the United States CDC, Africa Centres for Disease Control and Prevention, European Centre for Disease Prevention and Control, China CDC, and selected highly cited experts on this topic from academic institutions. Representatives from the key agencies listed above were nominated by the agencies themselves, at the request of the WHO Chief Scientist. The criteria for selecting experts who were highly cited was based on the most cited authors in a scoping literature review of the existing definitions of airborne transmission of pathogens in 2021 (see Introduction), but also with consideration for geographical and gender balance within the WG. This core group was considered a starting point for identifying other relevant global experts who were currently active in this area due to the COVID-19 pandemic.

The WHO Secretariat proposed a WG Chair (Gagandeep Kang) and Co-Chair (Yuguo Li) who were selected from the WG members, with confirmation of election by the WG. The remit of the WG was to drive the consultation process, ensure the required diversity of viewpoints were included (e.g. by suggesting names for the full global TCG), and to assist the Convening Lead in reaching consensus to produce the final document. The list of members, their affiliations and areas of expertise, who were involved in each part of the consultation process are included in Annex 4.

Annex 2. **Steps in the technical consultation process**



WG = Working Group
TCG = Technical Consultation Group
DOI = Declaration of Interest

Annex 3. Two processes undertaken for the consultation process

Stage 1**:** Based on the results of the scoping literature review of the existing definitions of airborne transmission (see Introduction section), and an initial internal consultation, the WHO Secretariat developed a Concept Note and a discussion document with a matrix of the:

- list of key questions (or domains) that needed consensus (i.e., where major disagreement existed);
- major differing viewpoints within each of those questions; and
- list of the potential (different) actionable ways to resolve those questions.

The WG members were selected by the WHO Secretariat (using the criteria outlined in the Governance section in Annex 1) and were sent the Concept Note with an email inviting participation. Two WG meetings were held virtually on 12 May 2022 and 10 June 2022 to collect considered inputs into the first discussion document and suggested members for the wider, full TCG (see **Stage 2** below). In attendance at these meetings were ten members of the WG, the WHO Chief Scientist, and the WHO Secretariat (see Annex 4).

Stage 2**:** The WHO Secretariat convened the full TCG, as follows:

- The full TCG consisted of the WG Chair, Co-Chair, the WG members plus additional key, selected stakeholders/agencies, with wide multidisciplinary representation (see Annex 4);
- Input was sought from this group via informal, but structured, targeted ways e.g., by inviting detailed written comments on the discussion documents, and at three virtual meetings to verbally exchange views and debate unresolved issues;
- TCG members were encouraged to share and discuss draft documents with their relevant constituencies and collect, collate and provide written feedback to the WHO Secretariat.
- The first virtual meeting of the full TCG took place on 17 June 2022 and was followed by an opportunity to provide written feedback on a first draft document;
- This, and all subsequent, drafts were prepared by the WHO Secretariat and approved by the TCG Chair and Co-Chair prior to distribution for feedback;
- A total of 41 technical experts were consulted (see Annex 4). Thirty-one experts provided written feedback and a further eight individuals provided verbal-only input via their contributions at the virtual meetings. Four experts were invited to contribute and accepted but did not provide either verbal or written input;
- Following these consultations, the WHO Secretariat, with assistance from the WG Chair and Co-Chair, revised the draft document and circulated it to the full TCG on 23 October 2022, with a deadline for feedback of 7 November 2022. The feedback provided by the TCG to that point in time was shared with members of the group on 27 October 2022;
- A second virtual meeting of the TCG was held on 11 November 2022 at which remaining unresolved issues were discussed and dissenting views were noted;
- A revised version of the document was circulated to the TCG on 19 December 2022. TCG members were asked to seek and return further consolidated feedback from their respective constituencies by 31 January 2023;
- In response to this version of the document, 523 individual comments were received by the WHO Secretariat. This large amount of detailed input was collated and sum-

marized during February-March 2023. A revised version was drafted and made ready for circulation in mid-April 2023;

- At the request of the WHO Director-General, a hybrid third TCG meeting (in Geneva and online) was held over two days on 27-28 April 2023. All TCG members and the relevant WHO technical leads were invited to attend, along with several additional commentators who had previously expressed views on the topic. 34 TCG members, 31 WHO staff and 23 additional commentators were able to attend at least some parts of this hybrid meeting;
- A revised version was drafted in response to these inputs and was sent to the TCG members for inputs on 16 June 2023, with a request for inputs by 7 July 2023;
- A final, virtual, fourth meeting of the TCG was convened on 4th August 2023 where any remaining input was received and discussed;
- The revised version was shared on 8th September and the final version on 16th November 2023;
- Discussions with the relevant agencies regarding endorsement and publication was then undertaken and the final document was published in April 2024.

As with the development of many other WHO normative products, the decision-making process used for this consultation was to aim for consensus among the contributing experts. As per the WHO Quality Assurance Handbook for normative product development (In publication), the process of reaching consensus in group decision-making always involves discussion and compromise to arrive at a decision that is acceptable to all parties and is a process whereby the consent of all group members is pursued. When consensus is said to have been reached, it generally means that every group member finds the proposed resolution acceptable – or at least lends it support, even if less than wholeheartedly.

Annex 4. Details, affiliations, expertise and roles of participants

No	Name	Sex	Organization	Area of expertise/discipline	Country	Region*	Role
1	Yewande Alimi	Female	Africa CDC	Infection prevention and control	Ethiopia	AFR	WG
2	Yaseen Arabi	Male	College of Medicine, King Saud Bin Abdulaziz University for Health Sciences, Riyadh	Intensive care	Saudi Arabia	EMR	TCG
3	Lisa Askie	Female	World Health Organization	Epidemiology, evidenced-based medicine	Switzerland	Headquarters	Secretariat
4	Abdullah Assiri	Male	Ministry of Health	Infectious diseases	Saudi Arabia	EMR	WG
5	Julie Bennett	Female	Department of Public Health, University of Otago	Epidemiology, infectious diseases, indoor air quality	New Zealand	WPR	TCG
6	Gautam Bhan	Male	Indian Institute for Human Settlements, Bengaluru	Urban poverty, housing	India	SEAR	TCG
7	Arnab Bhattacharya	Male	Tata Institute of Fundamental Research, Mumbai	Engineering, physics	India	SEAR	TCG
8	Gabriel Birgand	Male	Nantes University Hospital; Regional center for IPC, Pays de la Loire region	Infection prevention and control	France	EUR	TCG
9	Lydia Bourouiba	Female	Massachusetts Institute of Technology, Cambridge	Fluid physics, Infectious disease transmission, and Engineering Science	USA	AMR	TCG
10	Giorgio Buonanno	Male	University of Cassino and Southern Lazio	Environmental engineering, Aerosols science, indoor air quality	Italy	EUR	TCG
11	Cheryl Cohen	Female	Centre for Respiratory Disease and Meningitis, National Institute for Communicable Diseases	Epidemiology, influenza, respiratory disease	South Africa	AFR	TCG
12	Benjamin Cowling	Male	School of Public Health, The University of Hong Kong	Infectious disease epidemiology	Hong Kong SAR, China	WPR	TCG
13	Jeremy Farrar	Male	World Health Organization	Infectious disease and tropical medicine, clinical science	Switzerland	Headquarters	**Convening Lead (May 2023-present)**
14	John Grove	Male	World Health Organization	Public health	Switzerland	Headquarters	Secretariat (Nov 2021–Sep 2022)
15	Ana Lorena Guerrero Torres	Female	World Health Organization	Public health and Infectious disease, clinical science	Switzerland	EUR	Secretariat
16	David SC Hui	Male	Stanley Ho Centre for Emerging Infectious Diseases, The Chinese University of Hong Kong	Respiratory medicine	Hong Kong SAR, China	WPR	TCG
17	**Gagandeep Kang**	Female	Christian Medical College, The Wellcome Trust Research Laboratory, Division of Gastrointestinal Sciences, Vellore	Microbiology	India	SEAR	**WG Chair**
18	Michael Klompas	Male	Harvard Medical School, Boston	Infectious diseases	USA	AMR	TCG
19	Nancy Leung	Female	School of Public Health, The University of Hong Kong	Epidemiology, respiratory infections and vaccinations, community–based studies	Hong Kong SAR, China	WPR	TCG

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No	Name	Sex	Organization	Area of expertise/discipline	Country	Region*	Role
20	**Yuguo Li**	Male	Department of Mechanical Engineering, The University of Hong Kong	Building environment, environmental engineering	Hong Kong SAR, China	WPR	**WG Co-Chair**
21	Li Liu	Male	Tsinghua University, Beijing	Aerosol transport, airborne transmission	China	WPR	TCG
22	Taronna Maines	Female	United States CDC	Microbiology, immunology, influenza	USA	AMR	WG
23	Linsey Marr	Female	Virginia Tech	Environmental engineering, aerosol science, airborne transmission	USA	AMR	TCG
24	Donald Milton	Male	Institute for Applied Environmental Health, University of Maryland School of Public Health	Environmental and occupational medicine, aerobiology	USA	AMR	TCG
25	Lidia Morawska	Female	Queensland University of Technology, Faculty of Science, School of Earth & Atmospheric Sciences	Physics, engineering, and indoor air quality	Australia	WPR	WG
26	Shiva Nagendra	Male	Indian Institute of Technology, Madras	Air quality monitoring, environmental engineering	India	SEAR	TCG
27	Edward Nardell	Male	Harvard Medical School, Boston	Pulmonary medicine, tuberculosis	USA	AMR	WG
28	Isabel Ochoa	Female	Ministry of Health, Peru	Building design and engineering approaches to airborne infection control	Peru	AMR	TCG
29	Jon Otter	Male	Healthcare Associated Infections, Antimicrobial Resistance , Imperial College, London	Healthcare Associated Infections, Antimicrobial Resistance, clinical science	United Kingdom	EUR	TCG
30	Malik Peiris	Male	School of Public Health, The University of Hong Kong	Clinical and public health virology	Hong Kong SAR, China	WPR	TCG
31	Diamantis Plachouras	Male	European Centre for Disease Prevention and Control	Infection prevention and control	Sweden	EUR	WG
32	Kevin Poggenpoel	Male	South Africa Federation of Healthcare Engineering	Hospital engineering	South Africa	AFR	TCG
33	Thidar Pyone	Female	World Health Organization	Public health, health systems and policy, medicine	Switzerland	Headquarters	Secretariat
34	Hua Qian	Male	Southeast University, Nanjing	Building ventilation, engineering control of infectious disease	China	WPR	TCG
35	John Reeder	Male	World Health Organization	Infectious diseases, clinical research, microbiology	Switzerland	Headquarters	**Convening Lead (Dec 2022–Apr 2023)**
36	Jacqui Reilly	Female	Glasgow Caledonian University	Infection prevention and control	United Kingdom	EUR	TCG
37	Chad Roy	Male	National Primate Center, Tulane University	Infectious disease aerobiology	USA	AMR	TCG
38	Fatima Serhan	Female	World Health Organization	Virology	Switzerland	Headquarters	Secretariat

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No	Name	Sex	Organization	Area of expertise/discipline	Country	Region*	Role
39	**Soumya Swaminathan**	Female	World Health Organization	Epidemiology, tuberculosis	Switzerland	Headquarters	**Convening Lead (Nov 2021–Nov 2022)**
40	Shin-ichi Tanabe	Male	Department of Architecture, Waseda University	Architecture, human environmental engineering	Japan	WPR	TCG
41	Julian W. Tang	Male	Clinical Microbiology, University Hospitals of Leicester NHS Trust & Respiratory Sciences, University of Leicester	Infectious diseases, microbiology, virology, aerobiology, infection control	United Kingdom	EUR	TCG
42	Raymond Tellier	Male	McGill University, Montreal	Medical microbiology, infectious diseases, virology	Canada	AMR	TCG
43	Kwok Wai Tham	Male	National University of Singapore, Singapore	Airborne transmission and infection control, indoor air quality	Singapore	WPR	TCG
44	Maria van Kerkhove	Female	World Health Organization	Infectious disease epidemiology	Switzerland	Headquarters	Secretariat
45	Richard Webby	Male	St Jude Children's Research Hospital, Memphis	Infectious diseases, virology	USA	AMR	WG
46	Dongqun Xu	Female	National Institute of Environmental Health, China CDC	Occupational and environmental health, Aerosol transmission	China	WPR	WG
47	U Yanagi	Male	Kogakuin University	Microbial pollution in building environment	Japan	WPR	TCG
48	Hui-Ling Yen	Female	School of Public Health, The University of Hong Kong	Epidemiology, influenza, and virology	Hong Kong SAR, China	WPR	TCG
49	Kwok-Yung Yuen	Male	Department of Microbiology, The University of Hong Kong	Internal medicine, infectious diseases	Hong Kong SAR, China	WPR	TCG
50	Walter Zingg	Male	Zurich University Hospital	Infection prevention and control	Switzerland	EUR	TCG

*Regions were assigned by using WHO geographical regions
AFR: African Region
AMR: Region of the Americas
CDC: Center for Disease Control and prevention
EMR: Eastern Mediterranean Region
EUR: European Region
SAR China: Special Administrative Region of the Peoples' Republic of China
SEAR: South-East Asian Region
TCG: Technical Consultation Group
WG: Working Group
WPR: Western Pacific Region

Annex 5. Summary of discussions

Areas of overall general agreement

The discussions of the global TCG, and engagement with others in the group's jurisdictions during the consultation, have resulted in alignment on the following issues:

- IRPs exist on a continuum spectrum of sizes, and no definitive cut off points should be applied to distinguish smaller from larger particles. Recognition of the continuum spectrum of sizes allows to move away from the dichotomy of previous and commonly known terms, such as 'aerosols' (generally smaller particles) and 'droplets' (generally larger particles);
- There was a consensus about how IRPs are expelled within a turbulent puff cloud that moves through the air following emission from the human respiratory tract of an infected person. The trajectory of IRPs is influenced by many factors including the force and volume of exhalation as well as including several environmental conditions, such as ambient air temperature, humidity, airflow magnitude and velocity and distribution within a space. These factors coupled with the pathogen's viability and infectivity in the IRPs contribute to the transmission probability;
- There was agreement on the importance of adequate ventilation and airflow patterns within indoor spaces to help mitigate the risk of transmission of IRPs;
- It was agreed that different pathogens can have different predominant, or mixes of, modes of transmission. In addition, pathogens vary in their frequency, virulence, treatability, and potential impact on hosts and society. This means that transmission prevention and mitigation measures need to be tailored differently for different pathogens and settings. Hence, pathogen- and setting-specific guidance regarding mitigation measures, including IPC guidance, is needed. There was recognition that lumping mitigation measures for all transmission modes, for all pathogens, into one basket, and trying to apply a "one size fits all" approach would be incorrect or impractical;
- Despite a need to tailor mitigation measures to account for different transmission scenarios as described above, most, but not all, agreed that using the more general and broader term of 'transmission through the air' to refer to the overall concept of pathogens being transmitted through the air, and to cover the airborne transmission/inhalation and direct deposition modes of transmission of IRPs outlined in this document, was a useful descriptor, particularly when trying to explain these complex concepts to the general public.

Areas of non-consensus and concern regarding consequences

It is recognized that several revisions of existing terminology that have been put forth as a result of this global technical consultation (and summarized above) could have major ramifications for the use of those terms in other disciplines.

If, as is recognized herewith, smaller IRPs are capable of being transmitted at both short- and long-range, then to effectively counteract this risk, full (what is now known as) 'airborne

precautions', which involves substantive IPC measures, such as use of respirators, with or without specialized hospital rooms etc., may need to be applied to all those at risk of the disease, if a precautionary principle is to be applied or applied selectively depending on the frequency, morbidity, and treatment options for different pathogens (which may vary widely between and within countries). This would have legal, logistic, operational and financial consequences that have global implications with regards to equity and access.

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