# Evidence Search Service Results of your search request

## Microbial contamination of powered air purifying respirators (PAPR)

**ID of request:** 27262  
**Date of request:** 27th January, 2021  
**Date of completion:** 27th January, 2021

If you would like to request any articles or any further help, please contact:  Tom Roper at [tom.roper@nhs.net](mailto:tom.roper@nhs.net)

Please acknowledge this work in any resulting paper or presentation as: Evidence search: Microbial contamination of powered air purifying respirators (PAPR). Tom Roper. (27th January, 2021). BRIGHTON, UK: Brighton and Sussex Library and Knowledge Service.

**Sources searched**  
Cochrane Library (0)  
Google Scholar (2)  
MEDLINE/EMBASE (9)  
MedRxiv (0)  
PROSPERO (1)  
TRIP Database (0)

**Date range used** (5 years, 10 years): No restrictions   
**Limits used** (gender, article/study type, etc.): None   
**Search terms and notes** (full search strategy for database searches below):

Relevant natural language and controlled vocabulary terms were selected and combined. Thesaurus terms were adapted for different databases. Final result sets were de-duplicated and reviewed for relevance by the searcher, irrelevant results being discarded.

One paper (Howard, 2020, Am J Infect Control) was prosepctively citation searched in Google Scholar. A search of medRxiv found your preprint, Microbial contamination of powered air purifying respirators (PAPR) used during the COVID-19 pandemic: an in situ microbiological study medRxiv 2020.07.30.20165423; doi: https://doi.org/10.1101/2020.07.30.20165423

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## A. Systematic Reviews

#### Centre for Reviews & Dissemination, University of York

**Use of Powered Air-Purifying Respirator (PAPR) for preventing highly infectious viral diseases - a systematic review of evidence** (2020)

Licina A., Silvers A.

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This is an in-progress systematic review registered with Prospero. It ig probable that it became the narrative review by the same authors included below in the report

## B. Original Research

1. **Are loose-fitting powered air-purifying respirators safe during chest compression? A simulation study**  
   Park S. H. American Journal of Emergency Medicine 2020;:No page numbers.

Background: The application of appropriate personal protective equipment for respiratory protection to health care workers is a cornerstone for providing safe healthcare in emergency departments. We investigated the protective effect and usefulness of loose-fitting powered air-purifying respirators (PAPRs) during chest compression. Method(s): This was a single-center simulation study performed from May 2019 to July 2019 in a tertiary hospital. We measured the concentrations of ambient aerosol and particles inside the loose-fitting PAPR during chest compression, and this ratio was set as the simulated workplace protecting factor (SWPF). According to the National Institute for Occupational Safety and Health regulations, the assigned protection factor (APF) of loose-fitting PAPRs is 25. Thus, the loose-fitting PAPRs were assumed to have a protective effect when the SWPF were >= 250 (APF x 10). We measured the SWPF of PAPR in real time during chest compression and also investigated the problems encountered during its use. Result(s): Ninety-one participants (median age 29 [interquartile range (IQR): 26-32] years; 74% female) completed the simulation. None of the participants failed with SWPF below 250 during three sessions of chest compression. The median (IQR) values of SWPF at three cycles were 17,063 (10,145-26,373), 15,683 (9477-32,394), and 16,960 (7695-27,279). There was no disconnection of equipment or mechanical failures during chest compression. In addition, most participants (83%) replied that they rarely or never experienced difficulty in verbal communication and felt that the loose-fitting PAPR was comfortable. Conclusion(s): The loose-fitting PAPRs provided sufficient respiratory protection without disturbances during chest compression.Copyright © 2020 Elsevier Inc.

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1. **Demystifying theoretical concerns involving respirators with exhalation valves during COVID-19 pandemic**  
   Chang James C. American journal of infection control 2020;48:1564-1565.

1. **Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff**  
   Verbeek J. H. Cochrane Database of Systematic Reviews 2020;2020:CD011621.

Background: In epidemics of highly infectious diseases, such as Ebola, severe acute respiratory syndrome (SARS), or coronavirus (COVID-19), healthcare workers (HCW) are at much greater risk of infection than the general population, due to their contact with patients' contaminated body fluids. Personal protective equipment (PPE) can reduce the risk by covering exposed body parts. It is unclear which type of PPE protects best, what is the best way to put PPE on (i.e. donning) or to remove PPE (i.e. doffing), and how to train HCWs to use PPE as instructed. Objective(s): To evaluate which type of full-body PPE and which method of donning or doffing PPE have the least risk of contamination or infection for HCW, and which training methods increase compliance with PPE protocols. Search Method(s): We searched CENTRAL, MEDLINE, Embase and CINAHL to 20 March 2020. Selection Criteria: We included all controlled studies that evaluated the effect of full-body PPE used by HCW exposed to highly infectious diseases, on the risk of infection, contamination, or noncompliance with protocols. We also included studies that compared the effect of various ways of donning or doffing PPE, and the effects of training on the same outcomes. Data Collection and Analysis: Two review authors independently selected studies, extracted data and assessed the risk of bias in included trials. We conducted random-effects meta-analyses were appropriate. Main Result(s): Earlier versions of this review were published in 2016 and 2019. In this update, we included 24 studies with 2278 participants, of which 14 were randomised controlled trials (RCT), one was a quasi-RCT and nine had a non-randomised design. Eight studies compared types of PPE. Six studies evaluated adapted PPE. Eight studies compared donning and doffing processes and three studies evaluated types of training. Eighteen studies used simulated exposure with fluorescent markers or harmless microbes. In simulation studies, median contamination rates were 25% for the intervention and 67% for the control groups. Evidence for all outcomes is of very low certainty unless otherwise stated because it is based on one or two studies, the indirectness of the evidence in simulation studies and because of risk of bias. Types of PPE. The use of a powered, air-purifying respirator with coverall may protect against the risk of contamination better than a N95 mask and gown (risk ratio (RR) 0.27, 95% confidence interval (CI) 0.17 to 0.43) but was more difficult to don (non-compliance: RR 7.5, 95% CI 1.81 to 31.1). In one RCT (59 participants), people with a long gown had less contamination than those with a coverall, and coveralls were more difficult to doff (low-certainty evidence). Gowns may protect better against contamination than aprons (small patches: mean difference (MD) -10.28, 95% CI -14.77 to -5.79). PPE made of more breathable material may lead to a similar number of spots on the trunk (MD 1.60, 95% CI -0.15 to 3.35) compared to more water-repellent material but may have greater user satisfaction (MD -0.46, 95% CI -0.84 to -0.08, scale of 1 to 5). Modified PPE versus standard PPE. The following modifications to PPE design may lead to less contamination compared to standard PPE: sealed gown and glove combination (RR 0.27, 95% CI 0.09 to 0.78), a better fitting gown around the neck, wrists and hands (RR 0.08, 95% CI 0.01 to 0.55), a better cover of the gown-wrist interface (RR 0.45, 95% CI 0.26 to 0.78, low-certainty evidence), added tabs to grab to facilitate doffing of masks (RR 0.33, 95% CI 0.14 to 0.80) or gloves (RR 0.22, 95% CI 0.15 to 0.31). Donning and doffing. Using Centers for Disease Control and Prevention (CDC) recommendations for doffing may lead to less contamination compared to no guidance (small patches: MD -5.44, 95% CI -7.43 to -3.45). One-step removal of gloves and gown may lead to less bacterial contamination (RR 0.20, 95% CI 0.05 to 0.77) but not to less fluorescent contamination (RR 0.98, 95% CI 0.75 to 1.28) than separate removal. Double-gloving may lead to less viral or bacteria contamination compared to single gloving (RR 0.34, 95% CI 0.17 to 0.66) but not to less fluorescent contamination (RR 0.98, 95% CI 0.75 to 1.28). Additional spoken instruction may lead to fewer errors in doffing (MD -0.9, 95% CI -1.4 to -0.4) and to fewer contamination spots (MD -5, 95% CI -8.08 to -1.92). Extra sanitation of gloves before doffing with quaternary ammonium or bleach may decrease contamination, but not alcohol-based hand rub. Training. The use of additional computer simulation may lead to fewer errors in doffing (MD -1.2, 95% CI -1.6 to -0.7). A video lecture on donning PPE may lead to better skills scores (MD 30.70, 95% CI 20.14 to 41.26) than a traditional lecture. Face-to-face instruction may reduce noncompliance with doffing guidance more (odds ratio 0.45, 95% CI 0.21 to 0.98) than providing folders or videos only. Authors' conclusions: We found low- to very low-certainty evidence that covering more parts of the body leads to better protection but usually comes at the cost of more difficult donning or doffing and less user comfort, and may therefore even lead to more contamination. More breathable types of PPE may lead to similar contamination but may have greater user satisfaction. Modifications to PPE design, such as tabs to grab, may decrease the risk of contamination. For donning and doffing procedures, following CDC doffing guidance, a one-step glove and gown removal, double-gloving, spoken instructions during doffing, and using glove disinfection may reduce contamination and increase compliance. Face-to-face training in PPE use may reduce errors more than folder-based training. We still need RCTs of training with long-term follow-up. We need simulation studies with more participants to find out which combinations of PPE and which doffing procedure protects best. Consensus on simulation of exposure and assessment of outcome is urgently needed. We also need more real-life evidence. Therefore, the use of PPE of HCW exposed to highly infectious diseases should be registered and the HCW should be prospectively followed for their risk of infection.Copyright © 2020 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

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1. **Selection and Use of Respiratory Protection by Healthcare Workers to Protect from Infectious Diseases in Hospital Settings**  
   Chughtai A. A. Annals of work exposures and health 2020;64:368-377.

OBJECTIVES: Infection control policies and guidelines recommend using facemasks and respirators to protect healthcare workers (HCWs) from respiratory infections. Common types of respirators used in healthcare settings are filtering facepiece respirators (FFRs) and powered air-purifying respirators (PAPRs). Aims of this study were to examine the current attitudes and practices of HCWs regarding the selection and use of respiratory protection and determine the acceptability of a novel PAPR. METHOD(S): In-depth interviews were undertaken with 20 HCWs from a large tertiary hospital in Sydney, Australia. Participants were fit tested with a lightweight tight-fitting half-facepiece PAPR (CleanSpace2TM Power Unit, PAF-0034, by CleanSpace Technology) using the TSITM Portacount quantitative fit test method. RESULT(S): Interview results showed that HCWs had a limited role in the selection and use of facemasks and respirators and had been using the devices provided by the hospital. The majority of subjects had no knowledge of hospital policy for the use of facemasks and respirators, had not been trained on the use of respirators, and had not been fit tested previously. Compliance with the use of facemasks and respirators was perceived as being low and facemasks and respirators were typically used only for short periods of time.All 20 participants were successfully fit tested to the CleanSpace2TM PAPR (overall geometric mean fit factor-6768). According to the exit surveys, CleanSpace2TM PAPRs were easy to don (14/20) and doff (15/20) and comfortable to wear (14/20). Most participants believed that PAPRs provide higher protection, comfort and reusability over N95 FFR and can be used during pandemics and other high-risk situations. CONCLUSION(S): HCWs should be aware of infection control policies and training should be provided on the correct use of respiratory protective devices. PAPRs can be used in hospital settings to protect HCWs from certain highly infectious and emerging pathogens, however, HCWs require adequate training on storage, use, and cleaning of PAPRs.Copyright © The Author(s) 2020. Published by Oxford University Press on behalf of the British Occupational Hygiene Society.

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1. **Sterile field contamination from powered air-purifying respirators (PAPRs) versus contamination from surgical masks**  
   Howard R. A. American Journal of Infection Control 2020;48:153-156.

Background: Currently, powered air-purifying respirators (PAPRs) are not recommended for usage in close proximity to sterile fields owing to concerns that exhaled, unfiltered air potentially may cause contamination; however, this has not been confirmed by experimental study. Method(s): After establishing background levels of airborne contamination, our team placed settling plates in a sterile field and collected contamination from participants who were performing particulate-generating actions. Participants performed the actions while wearing various forms of respiratory protection, including: (1) a full facepiece PAPR, (2) a full facepiece PAPR with a shoulder-length hood, (3) a surgical mask, and (4) no facial covering (as a positive control to determine contamination-reduction effectiveness). Specimens were collected at the end of a 10-minute sampling time frame. After incubation at 36.5C for 72 hours, we tabulated colony forming units as a marker of contamination. Result(s): Surgical masks and the 2 PAPR configurations all drastically reduced aerosolized droplet contamination. Surgical masks reduced contamination by 98.48%, and both PAPRs reduced contamination by 100% (compared with the usage of no facial covering). There was no statistical difference between their effectiveness (surgical mask vs both PAPRs, P value =. 588 and no hood PAPR vs hood PAPR, P value >.999). Discussion/Conclusions: Based on these findings, the tested PAPR configurations are effective at reducing aerosolized droplet contamination into a sterile field, and further testing is warranted to assess other PAPR configurations as well as PAPR suitability in an operating room.Copyright © 2019

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1. **Use of Powered Air-Purifying Respirator (PAPR) as part of protective equipment against SARS-CoV-2-a narrative review and critical appraisal of evidence**  
   Licina Ana American journal of infection control 2020;:No page numbers.

1. **Common Behaviors and Faults When Doffing Personal Protective Equipment for Patients With Serious Communicable Diseases**  
   Mumma Joel M. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America 2019;69:S214-S220.

BACKGROUND: The safe removal of personal protective equipment (PPE) can limit transmission of serious communicable diseases, but this process poses challenges to healthcare workers (HCWs)., METHODS: We observed 41 HCWs across 4 Ebola treatment centers in Georgia doffing PPE for simulated patients with serious communicable diseases. Using human factors methodologies, we obtained the details, sequences, and durations of doffing steps; identified the ways each step can fail (failure modes [FMs]); quantified the riskiness of FMs; and characterized the workload of doffing steps., RESULTS: Eight doffing steps were common to all hospitals-removal of boot covers, gloves (outer and inner pairs), the outermost garment, the powered air purifying respirator (PAPR) hood, and the PAPR helmet assembly; repeated hand hygiene (eg, with hand sanitizer); and a final handwashing with soap and water. Across hospitals, we identified 256 FMs during the common doffing steps, 61 of which comprised 19 common FMs. Most of these common FMs were above average in their riskiness at each hospital. At all hospitals, hand hygiene, removal of the outermost garment, and removal of boot covers were above average in their overall riskiness. Measurements of workload revealed that doffing steps were often mentally demanding, and this facet of workload correlated most strongly with the effortfulness of a doffing step., CONCLUSIONS: We systematically identified common points of concern in protocols for doffing high-level PPE. Addressing FMs related to hand hygiene and the removal of the outermost garment, boot covers, and PAPR hood could improve HCW safety when doffing high-level PPE. We identified ways that doffing protocols for high-level personal protective equipment may fail to protect healthcare workers. Hand hygiene, removing the outermost garment, boot covers, and respirator hood harbored the greatest risk and failed in similar ways across different hospitals. Copyright © The Author(s) 2019. Published by Oxford University Press for the Infectious Diseases Society of America. All rights reserved. For permissions, e-mail: journals.permissions@oup.com.

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1. **Adherence to protocols by healthcare workers and self-contamination during doffing of personal protective equipment**  
   Lee M. A. American Journal of Infection Control 2018;46:S11.

Background: Self-contamination during the doffing of personal protective equipment (PPE) has been considered a major risk during medical care for patients with high-consequence emerging infectious diseases (HCEID), such as Ebola virus disease. To prevent selfcontamination, strict adherence to the PPE doffing protocols is critical. We sought to evaluate the adherence of HCWs to doffing protocol and the rate of self-contamination. Method(s): The study was conducted as a part of training of the dedicated response team for HCEID. HCWs donned PPE which consisted of a coverall, an apron, double gloves, a powered air purifying respirator (PAPR), and shoe covers. After donning, trainees conducted various simulated activities including intubation and insertion of central venous catheters. Before doffing the PPE, the surface of PPE was artificially contaminated with fluorescent fluid. Doffing of PPE was monitored by another trainee who verbally instructed each step using a checklist. Performance of each step was recorded by infection preventionists. Self-contamination was evaluated by the visualization of fluorescent fluid on HCWs using a handheld ultraviolet light. Result(s): A total of 75 subjects were evaluated. At least one violation of protocol was observed in 22.7% of subjects. Most common violation occurred during decontamination of shoes (9.3%), followed by doffing coverall (8.0%), doffing shoe covers (6.7%), visual inspection for gross contamination (5.3%), doffing gloves (4.0%), doffing PAPR (2.7%), and hand hygiene (1.3%). Self-contamination was detected in 64.0% of subjects. The neck was most commonly contaminated (45.3%), followed by arms (28.0%), hands (26.7%), and the head (20.0%). No specific type of violation was shown to be significantly associated with self-contamination. However, all subjects who missed decontamination of gloves or those who failed to properly doff gloves or PAPR were contaminated. Conclusion(s): Violation of doffing protocol was common during an intensive training session. Self-contamination was also common during PPE doffing.

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1. **Human Factors Risk Analyses of a Doffing Protocol for Ebola-Level Personal Protective Equipment: Mapping Errors to Contamination**  
   Mumma Joel M. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America 2018;66:950-958.

Background: Doffing protocols for personal protective equipment (PPE) are critical for keeping healthcare workers (HCWs) safe during care of patients with Ebola virus disease. We assessed the relationship between errors and self-contamination during doffing., Methods: Eleven HCWs experienced with doffing Ebola-level PPE participated in simulations in which HCWs donned PPE marked with surrogate viruses (phi6 and MS2), completed a clinical task, and were assessed for contamination after doffing. Simulations were video recorded, and a failure modes and effects analysis and fault tree analyses were performed to identify errors during doffing, quantify their risk (risk index), and predict contamination data., Results: Fifty-one types of errors were identified, many having the potential to spread contamination. Hand hygiene and removing the powered air purifying respirator (PAPR) hood had the highest total risk indexes (111 and 70, respectively) and number of types of errors (9 and 13, respectively). phi6 was detected on 10% of scrubs and the fault tree predicted a 10.4% contamination rate, likely occurring when the PAPR hood inadvertently contacted scrubs during removal. MS2 was detected on 10% of hands, 20% of scrubs, and 70% of inner gloves and the predicted rates were 7.3%, 19.4%, 73.4%, respectively. Fault trees for MS2 and phi6 contamination suggested similar pathways., Conclusions: Ebola-level PPE can both protect and put HCWs at risk for self-contamination throughout the doffing process, even among experienced HCWs doffing with a trained observer. Human factors methodologies can identify error-prone steps, delineate the relationship between errors and self-contamination, and suggest remediation strategies.

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1. **Risk of self-contamination during doffing of personal protective equipment**  
   Chughtai A. A. American Journal of Infection Control 2018;46:1329-1334.

Background: The aim of this study was to describe the risk of self-contamination associated with doffing of personal protective equipment (PPE) and to compare self-contamination with various PPE protocols. Method(s): We tested 10 different PPE donning and doffing protocols, recommended by various health organizations for Ebola. Ten participants were recruited for this study and randomly assigned to use 3 different PPE protocols. After donning of PPE, fluorescent lotion and spray were applied on the external surface of the PPE to simulate contamination, and ultraviolet light was used to count fluorescent patches on the skin. Result(s): After testing 30 PPE sequences, large fluorescent patches were recorded after using "WHO coverall and 95" and "North Carolina coverall and N95" sequences, and small patches were recorded after using "CDC coverall and N95" and "Health Canada gown and N95" sequences. Commonly reported problems with PPE use were breathing difficulty, suffocation, heat stress, and fogging-up glasses. Most participants rated PPE high (18/30) or medium (11/30) for ease of donning/doffing and comfort. PPE sequences with powered air-purifying respirators (PAPRs) and assisted doffing were generally associated with fewer problems and were rated the highest. Conclusion(s): This study confirmed the risk of self-contamination associated with the doffing of PPE. PAPR-containing protocols and assisted doffing should be preferred whenever possible during the outbreak of highly infectious pathogens.Copyright © 2018 Association for Professionals in Infection Control and Epidemiology, Inc.

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1. **Contamination: A comparison of 2 personal protective systems**  
   Zamora J. E. CMAJ 2006;175:249-254.

Background: The purpose of this study was to examine the difference in self-contamination rates and levels of contact and droplet protection associated with enhanced respiratory and contact precautions (E-RCP) and a personal protective system that included a full body suit, personal protective equipment and a powered air-purifying respirator (PAPR). Method(s): In this prospective, randomized, controlled crossover study, 50 participants donned and removed E-RCP and PAPR in random order. Surrogate contamination consisted of fluorescein solution and ultraviolet (UV) light-detectable paste, which was applied after each ensemble was donned. A blinded evaluator inspected participants for contamination using a UV lamp after removal of each ensemble. Areas of contamination were counted and measured in square centimetres. Donning and removal violations were recorded. The primary end point was the presence of any contamination on the skin or base clothing layer. Result(s): Participants wearing E-RCP were more likely to experience skin and base-clothing contamination; their contamination episodes measuring >= 1 cm2 were more frequent, and they had larger total areas of contamination (all p < 0.0001). The anterior neck, forearms, wrists and hands were the likeliest zones for contamination. Participants donning PAPR committed more donning procedure violations (p = 0.0034). Donning and removing the PAPR system took longer than donning and removing E-RCP garments (p < 0.0001). Interpretation(s): Participants wearing E-RCP were more likely to experience contamination of their skin and base clothing layer. Those wearing PAPR required significantly more time to don and remove the ensemble and violated donning procedures more frequently. © 2006 CMA Media Inc.

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**Word documents**  
Select Edit from the menu, the Find and type in your term in the search box which is presented. The search function will locate the first use of the term in the document. By pressing 'next' you will jump to further references.

## C. Search History

|  | **Source** | **Criteria** | **Results** |
| --- | --- | --- | --- |
| 1. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | \*Respiratory Protective Devices/ | 1556 |
| 2. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | (powered adj3 air-purifying).ti,ab. | 156 |
| 3. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | 1 and 2 | 52 |
| 4. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | air-purifying respirator\*.ti,ab. | 234 |
| 5. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | (PAPR or PAPRs).ti,ab. | 227 |
| 6. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | 3 or 4 or 5 | 385 |
| 7. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | Equipment Contamination/ or Infection Control/ | 35946 |
| 8. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | "Containment of Biohazards"/ | 1756 |
| 9. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | Contaminat\*.ti. | 41687 |
| 10. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | 7 or 8 or 9 | 76745 |
| 11. | Ovid MEDLINE(R) ALL <1946 to January 26, 2021> | 6 and 10 | 31 |
| 1. | Embase <1974 to 2021 Week 03> | \*gas-mask/ | 851 |
| 2. | Embase <1974 to 2021 Week 03> | (powered adj3 air-purifying).ti,ab. | 158 |
| 3. | Embase <1974 to 2021 Week 03> | 1 and 2 | 17 |
| 4. | Embase <1974 to 2021 Week 03> | air-purifying respirator\*.ti,ab. | 252 |
| 5. | Embase <1974 to 2021 Week 03> | (PAPR or PAPRs).ti,ab. | 271 |
| 6. | Embase <1974 to 2021 Week 03> | 3 or 4 or 5 | 440 |
| 7. | Embase <1974 to 2021 Week 03> | \*medical device contamination/ or \*infection control/ | 28351 |
| 8. | Embase <1974 to 2021 Week 03> | \*biosafety/ | 1174 |
| 9. | Embase <1974 to 2021 Week 03> | Contaminat\*.ti. | 47637 |
| 10. | Embase <1974 to 2021 Week 03> | 7 or 8 or 9 | 76698 |
| 11. | Embase <1974 to 2021 Week 03> | 6 and 10 | 19 |

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