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EVIDENCE SEARCH REPORT

RESEARCH QUESTION: What evidence is available regarding degradation of N95 respirators/masks?	**UNIQUE IDENTIFIER:** PPE110203-01 ESR
CONTEXT: Focus is on use past the expiry date	

RESOURCES USED:

- Ovid MEDLINE
- Ovid Embase
- CINAHL
- BC Centre for Disease Control
- CADTH
- Canadian Medical Protective Association
- CDC
- CIDRAP – Center for Infectious Disease Research and Policy
- COVID-19 Best Evidence Front Door
- CEBM (UK)
- ECRI
- Evidence Check (Australia)
- Evidence Synthesis Network
- Google
- Google Scholar
- Health Canada
- IPAC Canada
- medRxiv
- NCCMT (McMaster)
- Public Health Agency of Canada
- Public Health Ontario
- SPOR Evidence Alliance
- TRIP
- US Food & Drug Administration
- Veteran Affairs Database
- WHO COVID-19 Database

LIMITS/EXCLUSIONS/INCLUSIONS: English	**REFERENCE INTERVIEW COMPLETED:** November 2, 2020
DATE: November 10, 2020	
LIBRARIAN: Michelle Dalidowicz & Lukas Miller	**REQUESTOR:** Kevin Seibert
TEAM: PPE	
SEARCH ALERTS CREATED: N	
CITE AS: Dalidowicz, M; Miller, L. What evidence is available regarding degradation of N95 respirators/masks? 2020 Nov 10; Document no.: PPE110203-01 ESR. In: COVID-19 Rapid Evidence Reviews [Internet]. SK: SK COVID Evidence Support Team, c2020. 16 p. (CEST evidence search report)	

LIBRARIAN NOTES/COMMENTS

Hi there,

Overall, there was very little primary research on this topic. We have included some supporting documents and recommendations from major bodies to supplement this lack of direct evidence.

Kind regards,
Michelle & Lukas

SEARCH RESULTS

To obtain the full-text articles or to request offsite access, email library@saskhealthauthority.ca.

SUMMARIES, GUIDELINES & OTHER RESOURCES

REVIEWS & INFORMATION PIECES

3M.

- Why do disposable respirators have a defined shelf life? https://www.3mcanada.ca/3m/en_ca/worker-health-safety-ca/safety-town-square/articles/why-do-disposable-respirators-have-a-defined-shelf-life
- Frequently Asked Questions: 3M Health Care Particulate Respirator and Surgical Masks Storage Conditions and Shelf Life [5 February 2020] https://multimedia.3m.com/mws/media/869238O/3m-health-care-particulate-respirator-and-surgical-masks-storage-conditions-and-shelf-life-faq.pdf

LevittSafety. Why do disposable respirators have a defined shelf life? [18 March 2020]. https://www.levitt-safety.com/blog/can-you-use-an-expired-n95-respirator/

CADTH. Optimization of N95 Respirator Masks During Supply Shortages. [16 October 2020] https://cadth.ca/sites/default/files/covid-19/er0009-optimization-of-n95-respirator-masks-during-supply-shortages.pdf?utm_source=external-website&utm_medium=referral-june22&utm_campaign=esnetwork-site

Evidence Synthesis Network. N95 Mask Shortage and Handling Before Reprocessing. [16 September 2020] https://esnetwork.ca/briefings/n95-mask-shortage-and-handling-before-reprocessing/?highlight=expired

- See Long-term storage of unused masks

McMaster Health Forum. COVID-19 rapid evidence profile #6. What is known about strategies for supporting the use of masks under shortage conditions to prevent COVID-19? [30 April 2020] https://www.mcmasterforum.org/docs/default-source/covidend/rapid-evidence-profiles/covid-19-rep-6_masks.pdf?sfvrsn=21bf57d5_2

GUIDANCE

CDC

- Considerations for Release of Stockpiled N95s Beyond the Manufacturer-Designated Shelf Life [20 July 2020] https://www.cdc.gov/coronavirus/2019-ncov/hcp/release-stockpiled-N95.html
    - "The Gerson 1730 and the Medline/Alpha Protech NON27501 models do not have a manufacturer-designated shelf life. All other models included in the study exceeded their manufacturer-designated shelf life."
    - Refers to these PPE Case reports which includes many units that had expired https://www.cdc.gov/niosh/npptl/ppecase.html
- Operational Considerations for Personal Protective Equipment in the Context of Global Supply Shortages for Coronavirus Disease 2019 (COVID-19) Pandemic: non-US Healthcare Settings [15 September 2020] https://www.cdc.gov/coronavirus/2019-ncov/hcp/non-us-settings/emergency-considerations-ppe.html
- Strategies for Optimizing the Supply of N95 Respirators. https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirators-strategy/index.html [28 June 2020]
    - See recommendations for use of expired N95s

- Recommended Guidance for Extended Use and Limited Reuse of N95 Filtering Facepiece Respirators in Healthcare Settings.[27 March 2020] https://www.cdc.gov/niosh/topics/hcwcontrols/recommendedguidanceextuse.html
    -

California Department of Public Health. Frequently Asked Questions about the Use of Stockpiled N95 Filtering Facepiece Respirators for Protection from COVID-19 Beyond the Manufacturer-Designated Shelf Life. [18 March 2020] https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/FAQ-N95.aspx

ECRI
Safety of Extended Use and Reuse of N95 Respirators. [March 2020] https://ipac-canada.org/photos/custom/Members/pdf/COVID-ECRI-N95-Respirators-updated-2.pdf

Health Canada

- Reprocessing of N95 Respirators for Healthcare Professionals – Notice. [17 April 2020] https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/activities/announcements/covid19-notice-reprocessing-n95-respirators-health-professionals.html
- Health Canada. Important Regulatory Considerations for the Reprocessing of Single Use N95 Respirators during the COVID-19 Response: Notice [10 May 2020] https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/activities/announcements/covid19-notice-reprocessing-n95-respirators.html

Ontario Health Quality. Extended Use and Layering of N95 Respirators and Use of Expired Personal Protective Equipment: Supplemental Information. [15 April 2020] https://www.hqontario.ca/Portals/0/documents/evidence/reports/extended-use-and-layering-of-n95-respirators-and-use-of-expired-ppe.pdf

Pan-American Health Organization. Technical and Regulatory Aspects of the Extended Use, Reuse, and Reprocessing of Respirators during Shortages. [10 June 2020] https://iris.paho.org/handle/10665.2/52431

Quebec. Institut national de santé publique du Québec. COVID-19: Interim Recommendations Concerning the Use of Expired N95 Masks. https://www.inspq.qc.ca/en/publications/2921-use-expired-n95-masks-covid19

World Health Organization. Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages. [6 April 2020]. https://apps.who.int/iris/bitstream/handle/10665/331695/WHO-2019-nCov-IPC_PPE_use-2020.3-eng.pdf

ARTICLES

Note: References are sorted by year (newest to oldest)

1. Bauchner H, Fontanarosa PB, Livingston EH. Conserving Supply of Personal Protective Equipment-A Call for Ideas. JAMA. 2020;323(19):1911. DOI: 10.1001/jama.2020.4770
URL: https://www.ncbi.nlm.nih.gov/pubmed/32196543
DOI: 10.1001/jama.2020.4770

2. Brosseau LM, Rosen J, Harrison R. Selecting Controls for Minimizing SARS-CoV-2 Aerosol Transmission in Workplaces and Conserving Respiratory Protective Equipment Supplies. Ann Work Expo Health. 2020;21:21. DOI: 10.1093/annweh/wxaa083
ABSTRACT: With growing evidence of inhalation of small infectious particles as an important mode of transmission for

SARS-CoV-2, workplace risk assessments should focus on eliminating or minimizing such exposures by applying the hierarchy of controls. We adapt a control banding model for aerosol-transmissible infectious disease pandemic planning to encourage the use of source and pathway controls before receptor controls (personal protective equipment). Built on the recognition that aerosol-transmissible organisms are likely to exhibit a dose-response function, such that higher exposures result from longer contact times or higher air concentrations, this control banding model offers a systematic method for identifying a set of source and pathway controls that could eliminate or reduce the need for receptor controls. We describe several examples for workers at high risk of exposure in essential or return to work categories. The goal of using control banding for such workers is to develop effective infection and disease prevention programs and conserve personal protective equipment.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32820333
DOI: 10.1093/annweh/wxaa083

3. Brun D, Curti C, Mekideche T, et al. Stockpiled N95 respirator/surgical mask release beyond manufacturer-designated shelf-life: a French experience. J Hosp Infect. 2020;106(2):258-63. DOI: 10.1016/j.jhin.2020.07.032
ABSTRACT: BACKGROUND: To reduce the shortage of N95 respirators and surgical masks during the COVID-19 pandemic, stockpiled equipment beyond its expiry date could be released. AIM: Centralized testing of batches of expired surgical masks and N95 for safe distribution to hospital departments saving users time. METHODS: Tests of compliance with health authority directives were developed and carried out on 175 batches of N95 masks and 31 batches of surgical masks from 12(th) March 2020 to 16 April 2020. Five quality-control tests were performed on batch samples to check: packaging integrity, mask appearance, breaking strength of elastic ties and strength of nose clip test, and face-fit. FINDINGS: Forty-nine per cent of FFP2 mask batches were compliant with directives, 32% of batches were compliant but with some concerns and 19% of batches were non-compliant. For surgical masks, 58% of batches were compliant, 39% of batches compliant but with concerns and 3% of batches were non-compliant. CONCLUSION: The main areas of non-compliance were the breaking strength of the elastic ties and the nose clip but these alone were not considered to make the masks unacceptable. Only mask appearance and face-fit results were decisive non-compliance criteria.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32745593
DOI: 10.1016/j.jhin.2020.07.032

4. Gibney B. Stockpiling of Used Personal Protective Equipment Now for Future Decontamination and Reuse in the COVID-19 Pandemic. J Patient Saf. 2020;16(3):e103. DOI: 10.1097/PTS.0000000000000730
URL: https://www.ncbi.nlm.nih.gov/pubmed/32404851
DOI: 10.1097/PTS.0000000000000730

5. Grinshpun SA, Yermakov M, Khodoun M. Autoclave sterilization and ethanol treatment of re-used surgical masks and N95 respirators during COVID-19: impact on their performance and integrity. J Hosp Infect. 2020;105(4):608-14. DOI: 10.1016/j.jhin.2020.06.030
ABSTRACT: BACKGROUND: An exceptionally high demand for surgical masks and N95 filtering facepiece respirators (FFRs) during the COVID-19 pandemic has considerably exceeded their supply. These disposable devices are generally not approved for routine decontamination and re-use as a standard of care, while this practice has widely occurred in hospitals. The US Centers for Disease Control and Prevention allowed it "as a crisis capacity strategy". However, limited testing was conducted on the impact of specific decontamination methods on the performance of N95 FFRs and no data was presented for surgical masks. AIM: We evaluated common surgical masks and N95 respirators with respect to the changes in their performance and integrity resulting from autoclave sterilization and a 70% ethanol treatment; these methods are frequently utilized for re-used filtering facepieces in hospitals. METHODS: The filter collection efficiency and pressure drop were determined for unused masks and N95 FFRs, and for those subjected to the treatments in a variety of ways. The collection efficiency was measured for particles of approximately 0.037-3.2 mum to represent aerosolized single viruses, their agglomerates, bacteria and larger particle carriers. FINDINGS: The initial collection efficiency and the filter breathability may be compromised by sterilization in an autoclave and ethanol treatment. The effect depends on a protective device, particle size, breathing flow rate, type of treatment and other factors. Additionally, physical damages were observed in N95 respirators after autoclaving. CONCLUSION: Strategies advocating decontamination and re-use of filtering facepieces in hospitals should be re-assessed considering the data obtained in this study.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32599011
DOI: 10.1016/j.jhin.2020.06.030

6. Iannone P, Castellini G, Coclite D, et al. The need of health policy perspective to protect Healthcare Workers during COVID-19 pandemic. A GRADE rapid review on the N95 respirators effectiveness. PLoS One. 2020;15(6):e0234025. DOI: 10.1371/journal.pone.0234025
ABSTRACT: Protecting Health Care Workers (HCWs) during routine care of suspected or confirmed COVID-19 patients is of paramount importance to halt the SARS-CoV-2 (Severe Acute Respiratory Syndrome-Coronavirus-2) pandemic. The WHO, ECDC and CDC have issued conflicting guidelines on the use of respiratory filters (N95) by HCWs. We searched PubMed, Embase and The Cochrane Library from the inception to March 21, 2020 to identify randomized controlled trials (RCTs) comparing N95 respirators versus surgical masks for prevention of COVID-19 or any other respiratory infection among HCWs. The grading of recommendations, assessment, development, and evaluation (GRADE) was used to evaluate the quality of evidence. Four RCTs involving 8736 HCWs were included. We did not find any trial specifically on prevention of COVID-19. However, wearing N95 respirators can prevent 73 more (95% CI 46-91) clinical respiratory infections per 1000 HCWs compared to surgical masks (2 RCTs; 2594 patients; low quality of evidence). A protective effect of N95 respirators in laboratory-confirmed bacterial colonization (RR = 0.41; 95%CI 0.28-0.61) was also found. A trend in favour of N95 respirators was observed in preventing laboratory-confirmed respiratory viral infections, laboratory-confirmed respiratory infection, and influenza like illness. We found no direct high quality evidence on whether N95 respirators are better than surgical masks for HCWs protection from SARS-CoV-2. However, low quality evidence suggests that N95 respirators protect HCWs from clinical respiratory infections. This finding should be contemplated to decide the best strategy to support the resilience of healthcare systems facing the potentially catastrophic SARS-CoV-2 pandemic.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32492045
DOI: 10.1371/journal.pone.0234025

7. Laing S, Westervelt E. Canada's National Emergency Stockpile System: time for a new long-term strategy. CMAJ. 2020;192(28):E810-E1. DOI: 10.1503/cmaj.200946
URL: https://www.ncbi.nlm.nih.gov/pubmed/32586836
DOI: 10.1503/cmaj.200946

8. Lin T-H, Tseng C-C, Huang Y-L, et al. Effectiveness of N95 Facepiece Respirators in Filtering Aerosol Following Storage and Sterilization. Aerosol and Air Quality Research. 2020;20(4):833-43. DOI: 10.4209/aaqr.2019.12.0620
ABSTRACT: The use of electret N95 filtering facepiece respirators (N95FFRs) after prolonged storage or treatment can reduce the expense of buying non-expired N95 and thus enable developing and developed countries to optimize their use of limited resources to against airborne particles and diseases, such as coronavirus disease 2019 (COVID-19). The filtration performance of five N95FFR models following long-term storage, removal of charge using isopropanol alcohol (IPA), autoclaving, or treatment with gamma-radiation was assessed using a TSI 8130 automated filter tester. Statistically significant differences were found in the penetration (P), pressure drop (Δp) and quality factor (qf) between non-expired and expired N95 models 3M-8210 and 3M-8511. A statistically significant linear correlation was also obtained between the N95 penetration ratio (PR) and the difference between year of manufacture and time of test (DYM). The PR of N95 was more strongly influenced by eliminating the charge (for extremely out-of-date respirators) on the electret filter than by the DYM. Sterilization by gamma irradiation increased the P into non-expired and expired N95FFR models ($p < 0.05$), reducing their qf. The qf of all N95FFR models, except UVEX-3200, was strongly affected by gamma irradiation, the removal of charge using IPA, autoclaving, and storage in that order. All expired models maintained acceptable filtration performance and still could be used to collect aerosol effectively, even though models 3M-8511 and 3M-1860 had been manufactured up to 13 years previously. As the COVID-19 outbreaks in 2019 and is getting worse in 2020, these data are useful in developing a global stockpiling strategy to maximize the longevity of N95FFRs for public health and healthcare workers. However, the aging of the straps and seal materials (rubbers, plastics) of the N95FFRs may affect their fit factor and effectiveness.
URL: http://dx.doi.org/10.4209/aaqr.2019.12.0620
DOI: 10.4209/aaqr.2019.12.0620

9. Samaranayake LP, Fakhruddin KS, Ngo HC, et al. The effectiveness and efficacy of respiratory protective equipment (RPE) in dentistry and other health care settings: a systematic review. Acta Odontol Scand. 2020;78(8):626-39. DOI: 10.1080/00016357.2020.1810769
ABSTRACT: OBJECTIVE: The global pandemic of coronavirus disease-19, caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), is the latest hazard facing healthcare workers (HCW) including dental care workers (DCW). It is clear that the major mode of SARS-CoV-2 transmission is the airborne route, through inhalation of virus-infested aerosols and droplets. Several respiratory protection equipment (RPE), including masks, face shields/visors, and respirators, are

available to obviate facial and conjunctival contamination by microbes. However, as their barrier value against microbial inhalation has not been evaluated, we systematically reviewed the data on the effectiveness and efficacy of facemasks and respirators, including protective eyewear, with particular emphasis on dental healthcare. MATERIAL AND METHODS: PubMed, MEDLINE, the Cochrane Library, and Embase databases were searched between 01January 1990 and 15 May 2020. RESULTS: Of 310 identified English language records, 21 were included as per eligibility criteria. In clinical terms, wearing layered, face-fitting masks/respirators and protective-eyewear can limit the spread of infection among HCWs. Specifically, combined interventions such as a face mask and a face shield, better resist bioaerosol inhalation than either alone. The prolonged and over-extended use of surgical masks compromise their effectiveness. CONCLUSIONS: In general, RPE is effective as a barrier protection against aerosolized microbes in healthcare settings. But their filtration efficacy is compromised by the (i) inhalant particle size, (ii) airflow dynamics, (iii) mask-fit factor, (iv) period of wear, (v) 'wetness' of the masks, and (vi) their fabrication quality. The macro-data presented here should inform policy formulation on RPE wear amongst HCWs.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32881590
DOI: 10.1080/00016357.2020.1810769

10. Sickbert-Bennett EE, Samet JM, Clapp PW, et al. Filtration Efficiency of Hospital Face Mask Alternatives Available for Use During the COVID-19 Pandemic. JAMA Intern Med. 2020;11:11. DOI: 10.1001/jamainternmed.2020.4221
ABSTRACT: Importance: Procuring respiratory protection for clinicians and other health care workers has become a major challenge of the coronavirus disease 2019 (COVID-19) pandemic and has resulted in nonstandard practices such as the use of expired respirators and various decontamination processes to prolong the useful life of respirators in health care settings. In addition, imported, non-National Institute for Occupational Safety and Health (NIOSH)-approved respirators have been donated or acquired by hospitals as a potential replacement for limited NIOSH-approved N95 respirators. Objective: To assess fitted filtration efficiencies (FFEs) for face mask alternatives used during the COVID-19 pandemic. Design, Setting, and Participants: For this quality-improvement study conducted between April and June 2020, we used the Occupational Safety and Health Administration's Quantitative Fit Testing Protocol for Filtering Facepiece Respirators in a laboratory atmosphere supplemented with sodium chloride particles to assess the FFEs of a variety of respirators worn by a male volunteer and female volunteer. Main Outcomes and Measures: The FFEs of respirators commonly worn by clinicians and other health care workers and available respirator alternatives during the COVID-19 pandemic. Results: Of the 29 different fitted face mask alternatives tested on 1 man and 1 woman, expired N95 respirators with intact elastic straps and respirators subjected to ethylene oxide and hydrogen peroxide sterilization had unchanged FFE (>95%). The performance of N95 respirators in the wrong size had slightly decreased performance (90%-95% FFE). All of the respirators not listed as approved in this evaluation (n = 6) failed to achieve 95% FFE. Neither of the 2 imported respirators authorized for use by the Centers for Disease Control and Prevention that were not NIOSH-approved tested in this study achieved 95% FFE, and the more effective of the 2 functioned at approximately 80% FFE. Surgical and procedural face masks had filtering performance that was lower relative to that of N95 respirators (98.5% overall FFE), with procedural face masks secured with elastic ear loops showing the lowest efficiency (38.1% overall FFE). Conclusions and Relevance: This quality-improvement study evaluating 29 face mask alternatives for use by clinicians interacting with patients during the COVID-19 pandemic found that expired N95 respirators and sterilized, used N95 respirators can be used when new N95 respirators are not available. Other alternatives may provide less effective filtration.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32780113
DOI: 10.1001/jamainternmed.2020.4221

11. Wong BJ, Lu AC, Tarlow BD, et al. N95 Respirator Alternatives and Conservation Strategies. Anesth Analg. 2020;131(4):e202-e4. DOI: 10.1213/ANE.0000000000005134
URL: https://www.ncbi.nlm.nih.gov/pubmed/32701549
DOI: 10.1213/ANE.0000000000005134

12. Yoon KN, Greenawald LA, Rottach DR, et al. A General Framework to Test and Evaluate Filtering Facepiece Respirators Considered for Crisis Capacity Use as a Strategy to Optimize Supply. J Int Soc Respir Prot. 2020;36(1):36-51.
ABSTRACT: During a public health emergency, respirator shortages can have a profound impact on the national response, such as for the current coronavirus disease 2019 (COVID-19) pandemic. Due to a severe shortage of respirators (particularly filtering facepiece respirators [FFRs]), there may be contexts in which understanding the performance of FFRs that are approved for use as part of a crisis capacity strategy is desired. This includes FFRs that are not covered under the National Institute for Occupational Safety and Health (NIOSH) Respirator Approval Program because they have been stored past

their designated shelf life, have been decontaminated, or are approved by international certification bodies other than NIOSH. The purpose of this document is to provide a general framework to assess the performance of FFRs that are only being used as a crisis capacity strategy. The intended audience are those who are responsible for managing large amounts of FFRs. This framework includes a four-step process consisting of: 1) defining the population of FFRs to be sampled; 2) providing sampling strategy options; 3) inspecting and testing the sampled units; and 4) evaluating the results. In addition to the four-step process, we provide an example of how NIOSH recently evaluated the quality of FFRs sampled from ten U.S. stockpiles.
URL: https://www.ncbi.nlm.nih.gov/pubmed/32508389

13. Hines SE, Brown C, Oliver M, et al. Storage and Availability of Elastomeric Respirators in Health Care. Health Secur. 2019;17(5):384-92. DOI: 10.1089/hs.2019.0039
ABSTRACT: Use of reusable respirators, such as elastomeric half-face respirators (EHFRs), may serve as one solution to combating the problem of N95 respirator shortages experienced during infectious disease emergencies. To clarify whether logistical issues like respirator storage and availability are barriers to implementation of healthcare respiratory protection strategies that include EHFRs, this study aimed to evaluate the availability, storage, and respirator and filter replacement practices of EHFRs used in healthcare settings under routine use. Healthcare workers using EHFRs were surveyed about their use practices. To explore whether issues related to storage and availability of EHFRs affected compliance with assigned respirator use, responses were compared between concordant users and EHFR users who were assigned to use EHFRs but currently use different respirators ("discordant users"). Most concordant EHFR users reported that their respirator was always available when needed (63.8%). Almost two-thirds of concordant but only half of discordant users reported storing their EHFRs conveniently in the patient care area (p = <0.001). Among mobile workers, discordant users had higher odds (aOR = 3.2, 95% CI [1.4,7.5]) of reporting that their respirator was not stored in the patient care area, suggesting that storage location has a significant impact on compliance with expected practice, particularly in this group. Storage and access are barriers to optimal elastomeric respirator use in healthcare. Strategies to assure ready availability and storage of respirators will permit EHFR inclusion in pandemic and routine respiratory protection programs.
URL: https://www.ncbi.nlm.nih.gov/pubmed/31593514
DOI: 10.1089/hs.2019.0039

14. Vuma CD, Manganyi J, Wilson K, et al. The Effect on Fit of Multiple Consecutive Donning and Doffing of N95 Filtering Facepiece Respirators. Ann Work Expo Health. 2019;63(8):930-6. DOI: 10.1093/annweh/wxz060
ABSTRACT: BACKGROUND: N95 filtering facepiece respirators (FFRs) are widely used in healthcare to reduce transmission of airborne infectious diseases. These respirators are generally described as single use or limited reuse devices, but cost and operational issues mean that they may be donned and doffed multiple times. There is scant research on the effect of this practice on adequacy of fit. OBJECTIVE: The purpose of this study was to measure the effect on respirator fit of multiple donning and doffing of N95 FFRs. METHODS: This was an experiment in which 16 women and 9 men employed by the National Institute for Occupational Health (NIOH), Johannesburg, donned their same N95 FFR six times. All 25 were trained in the correct wearing of the devices before the experiment. Four models of respirators were used: the six who did not use respirators at work (novice subjects) were issued a 3M 1860 FFR and the others used their currently supplied one. During the experiment subjects donned their respirators under the supervision of the tester. Quantitative fit testing was done in the NIOH Occupational Hygiene laboratory after each donning according to the OSHA-Accepted Fit Test Protocol using the TSI PortaCount Pro+ Model 8038 Respirator Fit Tester. During the test, fit was measured after each of seven exercises and then an overall fit factor was computed. Only individuals who achieved an initial overall fit factor of >/=100 were allowed to continue participation in the study. Median overall fit factors were calculated for the 25 subjects for each donning and changes across them was examined using Wilcoxon rank sum tests. Men and women and frequent and infrequent users were compared across the six tests. Infrequent use was defined as subjects who wore respirators </= once per week, and novice subjects. RESULTS: Two subjects (8%) had an overall fit factor <100 at fit Test 2, 6 (24%) at Test 3, and 8 (32%) at Tests 4, 5, and 6. Thirteen respirator users (52%) achieved >/=100 throughout the fit testing, so 12 had at least one failure at either Tests 2-6. Five of the 12 subjects with at least one failure showed persistent failures on all subsequent donnings. Six subjects out of 12 (50%) who failed a fit test achieved an overall fit factor >100 at a subsequent test. There was a significant difference between the median first and sixth overall fit factors (195 versus 150; P = 0.0271), but not between the second and sixth (161 versus 150; P = 0.3584). Men and women had similar overall fit factors, but infrequent users had larger average overall fit factors than frequent users after all six donnings. CONCLUSION: Forty-eight percent of study subjects failed at least one fit test after re-donning an N95 FFR. The fit test data suggest that donning practices probably accounted for the fit test failures. The 50% of subjects who produced overall fit factors >/=100 after a test of <100 supports

this contention.
URL: https://www.ncbi.nlm.nih.gov/pubmed/31504129
DOI: 10.1093/annweh/wxz060

15. NIOSH Studying Condition of Stockpiled Respirators, Surgical Gowns. Occupational Health & Safety News. 2018:1-2.
URL: https://ohsonline.com/articles/2018/05/29/niosh-studying-condition-of-stockpiled-respirators-surgical-gowns.aspx

16. NIOSH studying PPE storage methods. Healthcare Life Safety Compliance. 2017;20(7):1-4.
URL: https://www.hcpro.com/SAF-329625-174/NIOSH-studying-PPE-storage-methods.html

17. Myojo T, Nagata T, Verbeek J. The Effectiveness of Specific Risk Mitigation Techniques Used in the Production and Handling of Manufactured Nanomaterials: A Systematic Review. J UOEH. 2017;39(3):187-99. DOI: 10.7888/juoeh.39.187
ABSTRACT: Many kinds of manufactured nanomaterials (MNMs) have been developed and used as basic materials of industrial products, and they may pose health risks for workers in not only developed countries but also in developing countries. Few studies have looked at the evidence for effects of controls that mitigate the risk of exposure to MNMs. Therefore, we systematically searched the literature from the year 2000 to 2015. We included studies that compared the use of an exposure control to the situation without such a technique and those that measured the exposure to MNMs as the outcome. In order to evaluate the effectiveness of these controls, we used their "protection factor", defined as the ratio between concentrations without and with the control. We located 1,131 references in PubMed and other lists, and out of these references, 41 studies fulfilled our inclusion criteria. We categorized them as engineering controls such as enclosure, local exhaust ventilation or process automation, and as personal protective equipment (PPE). For enclosure systems we found a protection factor beyond 100. For other engineering controls, the better controls scored 10 to 20, but many cases of local exhaust ventilation had a protection factor of less than 10 and some cases even increased exposure. PPE such as N95 or equivalent filtering respirators had a protection factor of approximately 10 tested with nano-sized aerosols. We conclude that there is low quality evidence that specific engineering controls can reduce exposure to MNMs but that enclosure is considerably more effective. For respiratory protection the evidence is of very low quality due to the lack of field studies. This information can be used to decide about controls when exposure to MNMs exceeds proposed occupational exposure limits or when no toxicological information is available for a MNM.
URL: https://www.ncbi.nlm.nih.gov/pubmed/28904269
DOI: 10.7888/juoeh.39.187

18. Rottach DR, Lei Z. Stockpiled N95 Filtering Facepiece Respirator Polyisoprene Strap Performance. J Int Soc Respir Prot. 2017;34(2):69-80.
ABSTRACT: Long term storage of personal protective equipment (PPE) in stockpiles is increasingly common in preparation for use during public health emergency responses. Confidence in PPE requires an understanding of the impact of time in storage on all aspects of PPE effectiveness, including protection against inward leakage. Disposable N95 filtering facepiece respirators (FFR) typically rely upon inexpensive elastomeric head straps to provide an effective seal between the filter body and the wearer's face. Annual fit testing provides a measure of assurance that a model fresh from the manufacturer will prove effective, but seal quality may degrade during long term storage. This study examines the stability of a s election of polyisoprene elastomer straps taken from various ages of common N95 FFRs. The tension of the straps at a predetermined strain of 150% was found to differ according to age for one respirator model, though whether due to age or due to manufacturing variations could not be determined. The straps from one manufacturer were found to have notable variation in length, indicating that minor variations in strap tensile properties may not result in significant differences in respirator seal quality. Based on our observations, prolonged storage may affect the tensile properties of headstraps for some models of N95.
URL: https://www.ncbi.nlm.nih.gov/pubmed/30364841

19. Baracco G, Eisert S, Eagan A, et al. Comparative Cost of Stockpiling Various Types of Respiratory Protective Devices to Protect the Health Care Workforce During an Influenza Pandemic. Disaster Med Public Health Prep. 2015;9(3):313-8. DOI: 10.1017/dmp.2015.12
ABSTRACT: Specific guidance on the size and composition of respiratory protective device (RPD) stockpiles for use during a pandemic is lacking. We explore the economic aspects of stockpiling various types and combinations of RPDs by adapting a pandemic model that estimates the impact of a severe pandemic on a defined population, the number of potential interactions between patients and health care personnel, and the potential number of health care personnel needed to

fulfill those needs. Our model calculates the number of the different types of RPDs that should be stockpiled and the consequent cost of purchase and storage, prorating this cost over the shelf life of the inventory. Compared with disposable N95 or powered air-purifying respirators, we show that stockpiling reusable elastomeric half-face respirators is the least costly approach. Disposable N95 respirators take up significantly more storage space, which increases relative costs. Reusing or extending the usable period of disposable devices may diminish some of these costs. We conclude that stockpiling a combination of disposable N95 and reusable half-face RPDs is the best approach to preparedness for most health care organizations. We recommend against stockpiling powered air-purifying respirators as they are much more costly than alternative approaches.
URL: https://www.ncbi.nlm.nih.gov/pubmed/25874891
DOI: 10.1017/dmp.2015.12

20. Bergman M, Zhuang Z, Brochu E, et al. Fit Assessment of N95 Filtering-Facepiece Respirators in the U.S. Centers for Disease Control and Prevention Strategic National Stockpile. J Int Soc Respir Prot. 2015;32(2):50-64.
ABSTRACT: National Institute for Occupational Safety and Health (NIOSH)-approved N95 filtering-facepiece respirators (FFR) are currently stockpiled by the U.S. Centers for Disease Control and Prevention (CDC) for emergency deployment to healthcare facilities in the event of a widespread emergency such as an influenza pandemic. This study assessed the fit of N95 FFRs purchased for the CDC Strategic National Stockpile. The study addresses the question of whether the fit achieved by specific respirator sizes relates to facial size categories as defined by two NIOSH fit test panels. Fit test data were analyzed from 229 test subjects who performed a nine-donning fit test on seven N95 FFR models using a quantitative fit test protocol. An initial respirator model selection process was used to determine if the subject could achieve an adequate fit on a particular model; subjects then tested the adequately fitting model for the nine-donning fit test. Only data for models which provided an adequate initial fit (through the model selection process) for a subject were analyzed for this study. For the nine-donning fit test, six of the seven respirator models accommodated the fit of subjects (as indicated by geometric mean fit factor > 100) for not only the intended NIOSH bivariate and PCA panel sizes corresponding to the respirator size, but also for other panel sizes which were tested for each model. The model which showed poor performance may not be accurately represented because only two subjects passed the initial selection criteria to use this model. Findings are supportive of the current selection of facial dimensions for the new NIOSH panels. The various FFR models selected for the CDC Strategic National Stockpile provide a range of sizing options to fit a variety of facial sizes.
URL: https://www.ncbi.nlm.nih.gov/pubmed/26877587

21. Roberge R, Niezgoda G, Benson S. Analysis of forces generated by n95 filtering facepiece respirator tethering devices: a pilot study. J Occup Environ Hyg. 2012;9(8):517-23. DOI: 10.1080/15459624.2012.695962
ABSTRACT: The restorative forces of elasticized tethering devices on N95 filtering facepiece respirators (N95 FFR), that occur in response to the application of a load (applied force) during donning, create the requisite pressure to effectively seal the respirator against the face and prevent excessive inward migration of harmful elements. Many workers don and doff the same N95 FFR multiple times in the course of a single workday, yet little is known regarding the possible degradation of these restorative loads and, by implication, protection with multiple donnings. This laboratory pilot study evaluated the degradation in loads of tethering devices of three models of N95 FFRs subjected to the strain of five wear periods of 15 min interspersed with 15-min periods without wear. Data indicate that there were load degradations at each donning that differed significantly with the FFR model ($p = <0.001$), the greatest of which occurred with the first donning. The N95 FFR model with the lowest restorative loads was able to pass fit testing in a previous study, indicating that lower loads, perhaps coupled with FFR model-specific features, are sufficient to provide an adequate face/FFR interface seal. Tethering devices are importantly related to issues of comfort and protection afforded by N95 FFR and additional research is warranted.
URL: https://www.ncbi.nlm.nih.gov/pubmed/22746194
DOI: 10.1080/15459624.2012.695962

22. Majchrzycka K, Gutarowska B, Brochocka A. Aspects of tests and assessment of filtering materials used for respiratory protection against bioaerosols. Part I: type of active substance, contact time, microorganism species. Int J Occup Saf Ergon. 2010;16(2):263-73. DOI: 10.1080/10803548.2010.11076841
ABSTRACT: This paper presents the results of a study on antimicrobial activity of polymer filter nonwovens produced by needle-punching or melt-blowing with an addition of disinfecting agents. The first part of the paper discusses how the biocidal activity of nonwovens is a function of the active agent added to the nonwovens, the duration of the contact of microorganisms with nonwovens and the type of microorganisms. The types of fibres and disinfecting agents had a

considerable effect on the biocidal activity of nonwovens. The biocidal effect of nonwovens increased with the duration of their contact with microorganisms. Fibre activity differed considerably depending on the species of the microorganism. The microorganisms most sensitive to biocidal activity of the active filter nonwoven were S. aureus, M. flavus and E. coli. There were no biocidal effects on spore-forming bacterium B. subtilis.
URL: https://www.ncbi.nlm.nih.gov/pubmed/20540844
DOI: 10.1080/10803548.2010.11076841

23. Majchrzycka K, Gutarowska B, Brochocka A. Aspects of tests and assessment of filtering materials used for respiratory protection against bioaerosols. Part II: sweat in the environment, microorganisms in the form of a bioaerosol. Int J Occup Saf Ergon. 2010;16(2):275-80. DOI: 10.1080/10803548.2010.11076844
ABSTRACT: The second part of the article presents the results of a study of antimicrobial activity of filter nonwovens with an addition of biocides, as a function of the presence of sweat in the environment and the method of microbe deposition on a nonwoven in the form of a liquid and a bioaerosol. At the same time, the filtration efficiency of nonwovens against microorganisms in the form of a bioaerosol was tested with the dynamic method. The results showed that the addition of sweat on the surface of a nonwoven resulted in an insignificant decrease of biological activity that still remained high. Moreover, an active nonwoven showed biostatic and biocidal activity only when microbes were deposited on the surface in the form of a solution. The nonwoven did not show any biological activity after deposition of microorganisms with the dynamical method in the form of a bioaerosol.
URL: https://www.ncbi.nlm.nih.gov/pubmed/20540845
DOI: 10.1080/10803548.2010.11076844

24. Hashikura M, Kizu J. Stockpile of personal protective equipment in hospital settings: preparedness for influenza pandemics. Am J Infect Control. 2009;37(9):703-7. DOI: 10.1016/j.ajic.2009.05.002
ABSTRACT: BACKGROUND: Personal protective equipment (PPE) is known to be a crucial means of preventing influenza pandemics; however, the amount of PPE that should be stored in hospital settings has been unclear. OBJECTIVES: The purpose of this paper is to propose a PPE calculation system to help hospitals to decide their PPE stockpile. METHODS: We searched influenza guidelines from a number of countries and research papers on protective devices and infectious diseases. The PPE calculation system included factors such as the influenza pandemic period, risk classification by health care workers (HCW) type, and the type and number of PPE for a HCW per day. RESULTS: We concluded that 4 sets of PPE (N95 respirators, double gloves, gowns, and goggles) per day should be prepared for HCWs in a high-risk group. Similarly, 2 sets of appropriate PPE, depending on the risk level, are required for medium- and low-risk groups. In addition, 2 surgical masks are required for every worker and inpatient and 1 for each outpatient. The PPE stockpile should be prepared to cover at least an 8-week pandemic. CONCLUSION: Purchasing a PPE stockpile requires a sizable budget. The PPE calculation system in this paper will hopefully support hospitals in deciding their PPE stockpile.
URL: https://www.ncbi.nlm.nih.gov/pubmed/19748157
DOI: 10.1016/j.ajic.2009.05.002

25. Viscusi DJ, Bergman M, Sinkule E, et al. Evaluation of the filtration performance of 21 N95 filtering face piece respirators after prolonged storage. Am J Infect Control. 2009;37(5):381-6. DOI: 10.1016/j.ajic.2008.09.021
ABSTRACT: BACKGROUND: Organizations are stockpiling respirators to prepare for an influenza pandemic. To understand better the effects of prolonged storage, this investigation evaluated the filtration efficiency of 21 different models of National Institute for Occupational Safety and Health (NIOSH)-certified disposable N95 filtering face piece respirators. These respirators had been stored in their original packaging for a period of at least 6 years in research laboratories and dry warehouse facilities, ranging in temperature between 15 degrees C and 32 degrees C and relative humidity between 20% and 80%. METHODS: Filter penetration was measured using an abbreviated version of the NIOSH respirator certification test incorporating a polydisperse sodium chloride aerosol at 85 L/min. RESULTS: Of the 21 respirator models tested, 19 models had both average penetration results of less than 5%. Mean initial penetration values ranged from 0.39% to 5.83%, whereas mean maximum penetration values ranged from 0.95% to 5.83%. There did not appear to be any correlation between the length of storage and failure to pass the filtration test. CONCLUSION: Results indicate that most N95 filtering face piece respirators stored for up to 10 years at warehouse conditions will likely have expected levels of filtration performance and that the degree of filtration efficiency degradation is likely model specific.
URL: https://www.ncbi.nlm.nih.gov/pubmed/19188003
DOI: 10.1016/j.ajic.2008.09.021

26. NIOSH cites poor fit of many current N95s, urges fit-test change: quantitative tests needed to weed out poor products...National Institute of Occupational Safety and Health. TB Monitor. 2001;8(3):29-40.
URL: https://www.reliasmedia.com/articles/68801-niosh-cites-poor-fit-of-many-current-n95s-urges-fit-test-change

27. Moyer ES, Bergman MS. Electrostatic N-95 respirator filter media efficiency degradation resulting from intermittent sodium chloride aerosol exposure. Appl Occup Environ Hyg. 2000;15(8):600-8. DOI: 10.1080/10473220050075608
ABSTRACT: The effects of intermittently loading small masses of sodium chloride aerosol on the filtration efficiency of N-95 filtering facepiece respirators was investigated. The National Institute for Occupational Safety and Health (NIOSH) certifies that N-95 respirators must provide at least 95 percent filtration efficiency against a sodium chloride aerosol challenge as per the respirator certification (42 CFR 84) test criteria. N-95 respirators are specified for protection against solid and water-based particulates (i.e., non-oil aerosols). New N-95 respirators from three different manufacturers were loaded with 5 +/- 1 mg of sodium chloride aerosol one day a week, over a period of weeks. Aerosol loading and penetration measurements were performed using the TSI 8130 Filter Tester. Respirators were stored uncovered on an office desktop outside the laboratory. To investigate environmental and temporal effects of filters being stored without sodium chloride exposure, control respirators were stored on the desk for various lengths of time before being initiated into weekly testing. For all manufacturers' respirators, the controls showed similar initial penetrations on their day of initiation (day zero) to those of the study samples on day zero. As the controls were tested weekly, they showed similar degradation rates to those of the study samples. Results show that some of the manufacturers' models had penetrations of greater than 5 percent when intermittently exposed to sodium chloride aerosol. It is concluded that intermittent, low-level sodium chloride aerosol loading of N-95 respirators has a degrading effect on filter efficiency. This reduction in filter efficiency was not accompanied by a significant increase in breathing resistance that would signal the user that the filter needs to be replaced. Furthermore, it was noted that the effect of room storage time prior to initial exposure was much less significant.
URL: https://www.ncbi.nlm.nih.gov/pubmed/10957815
DOI: 10.1080/10473220050075608

28. Brosseau LM, Traubel K. An evaluation of respirator maintenance requirements. Am Ind Hyg Assoc J. 1997;58(3):242-6. DOI: 10.1080/15428119791012900
ABSTRACT: A telephone survey was developed as part of a pilot study to evaluate the inspection, cleaning, maintenance, and storage aspects of respirator protection programs (RPP). Regulations and consensus standards such as those published by the Occupational Safety and Health Administration in the Code of Federal Regulations (CFR) or the American National Standards Institute (ANSI) require or recommend that RPP contain elements that ensure that the respirators provide proper protection. A great deal of research has been done to evaluate the effectiveness of new respirators; however, little research has been conducted to evaluate how respirators behave over time in real industrial settings Respirator inspection, cleaning, maintenance, and storage are significant factors in determining how well a respirator continues to perform. The telephone survey was developed by reviewing the requirements and recommendations of CFR 1910.134 and ANSI Z88.2-1980. Approximately 30 companies were selected based on their use of negative air-purifying respirators. Most of the companies represented the hardgoods manufacturing or service industries. Although the majority of companies were meeting requirements, responses indicated that the following improvements in RPP were necessary: (1) inspection of all respirator parts should be carried out before and after each use, (2) replacement parts should be made readily available on site, (3) regular cleaning should be performed, and (4) more hands-on practice with respirators and their maintenance should be incorporated into training sessions.
URL: https://www.ncbi.nlm.nih.gov/pubmed/9075316
DOI: 10.1080/15428119791012900

29. Pasanen AL, Keinanen J, Kalliokoski P, et al. Microbial growth on respirator filters from improper storage. Scand J Work Environ Health. 1993;19(6):421-5. DOI: 10.5271/sjweh.1452
ABSTRACT: Microbiological contamination and particle penetration were studied in two respirator filters with high efficiency. Microbial growth in filter materials during storage under conditions and the passing of microorganisms through the filters were particularly examined. Filters with different fiberglass and cellulose proportions were loaded in environments containing high microbial levels and incubated at a relative humidity of 98%. Particle penetration through loaded and incubated filters and carbon, nitrogen and microbial content were measured. After incubation, considerable particle penetration and the passing of fungal spores were observed for filters composed mainly of cellulose, probably because of humid conditions, which stimulated fungi to grow and extend mycelia and spores through the filter. Microbial activity, microorganism concentrations, and the chemical properties of the filter materials also supported this hypothesis.

Storing used respirators in humid environments may result in heavy microbial contamination of the filters, especially if the filter material is biodegradable by microorganisms.
URL: https://www.ncbi.nlm.nih.gov/pubmed/8153595
DOI: 10.5271/sjweh.1452

SEARCH STRATEGIES

Ovid MEDLINE(R) ALL <1946 to November 09, 2020>

#	Searches	Results
1	((respiratory or N99 or N95 or N 99 or N 95) adj2 mask*).ti,ab,kf.	551
2	((N99 or N95 or "N 99" or "N 95") adj3 respirator*).ti,ab,kf.	570
3	((protect* or filter*) adj2 respirator*).ti,ab,kf.	2263
4	1 or 2 or 3	2935
5	equipment failure/ or equipment failure analysis/	59584
6	(equipment adj2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)).ti,ab,kf.	907
7	(device? adj2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)).ti,ab,kf.	3620
8	("PPE" adj2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)).ti,ab,kf.	44
9	(storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or conserving or supply management or managing suppl*).ti,kf.	116090
10	(improper* adj2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management)).ti,ab,kf.	250
11	(inappropriat* adj2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management)).ti,ab,kf.	132
12	(shelf life? or expired or expiration date? or expiry date? or "best by" or best before or "use before" or lapse date or lapsed or defunct or "void by" or "voided by" or (manufactur* adj1 date?) or (fabricat* adj1 date?)).ti,ab,kf.	27068
13	"wear and tear".ti,ab,kf.	861
14	((quality or effectiveness or safety or performance) adj2 (compromis* or low or poor or bad or unacceptable)).ti,ab,kf.	66023
15	or/5-14	270888
16	Time Factors/	1194323
17	(time factor? or week? or month? or year? or time period? or time scale?).ti,ab,kf. or time.ti.	5627873
18	16 or 17	6392918
19	4 and 15 and 18	26
20	(unuse? adj2 (equipment or PPE or mask? or n95 or "n 95" or filter* respirator? or proctect* respirator?)).ti,ab,kf.	10
21	4 and 15	124
22	19 or 20 or 21	134
23	"Effectiveness of N95 facepiece respirators in filtering aerosol following storage and sterilization".ti.	0
24	"Evaluation of the filtration performance of 21 N95 filtering face piece respirators after prolonged storage".ti.	1

25	"Stockpiled N95 filtering facepiece respirator polyisoprene strap performance".ti.	1
26	"Conserving Supply of Personal Protective Equipment".ti.	1
27	24 or 25 or 26	3
28	27 or 22	136

Search history sorted by search number ascending

Embase <1974 to 2020 November 09>

#	Searches	Results
1	((respiratory or N99 or N95 or N 99 or N 95) adj2 mask*).ti,ab,kw.	662
2	((N99 or N95 or "N 99" or "N 95") adj3 respirator*).ti,ab,kw.	625
3	((protect* or filter*) adj2 respirator*).ti,ab,kw.	2701
4	1 or 2 or 3	3491
5	device failure/	5729
6	(equipment adj2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)).ti,ab,kw.	1447
7	(device? adj2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)).ti,ab,kw.	5131
8	("PPE" adj2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)).ti,ab,kw.	61
9	(storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or conserving or supply management or managing suppl*).ti,kw.	132683
10	(improper* adj2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management)).ti,ab,kw.	339
11	(inappropriat* adj2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management)).ti,ab,kw.	204
12	(shelf life? or expired or expiration date? or expiry date? or "best by" or best before or "use before" or lapse date or lapsed or defunct or "void by" or "voided by" or (manufactur* adj1 date?) or (fabricat* adj1 date?)).ti,ab,kw.	38917
13	"wear and tear".ti,ab,kw.	1180
14	((quality or effectiveness or safety or performance) adj2 (compromis* or low or poor or bad or unacceptable)).ti,ab,kw.	91699
15	or/5-14	273362
16	Time Factors/ or timeliness/	30306
17	(time factor? or week? or month? or year? or time period? or time scale?).ti,ab,kw. or time*.ti.	8078557
18	16 or 17	8093642
19	(unuse? adj2 (equipment or PPE or mask? or n95 or "n 95" or filter* respirator? or proctect* respirator?)).ti,ab,kw.	19
20	4 and 15	80
21	4 and 15 and 18	26
22	19 or 20 or 21	99
23	limit 22 to medline	22
24	22 not 23	77

CINAHL

Tuesday, November 10, 2020 12:21:53 PM

#	Query	Limiters/Expanders	Results
S1	TI (((respiratory OR "N99" OR "N95" OR "N 99" OR "N 95") N2 mask*)) OR MW (((respiratory OR "N99" OR "N95" OR "N 99" OR "N 95") N2 mask*))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	77
S2	TI ((("N99" OR "N95" OR "N 99" OR "N 95") N3 respirator*)) OR MW ((("N99" OR "N95" OR "N 99" OR "N 95") N3 respirator*))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	186
S3	TI (((protect* or filter*) N2 respirator*)) OR MW (((protect* or filter*) N2 respirator*))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	1,922
S4	S1 OR S2 OR S3	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	1,973
S5	(MH "Equipment Failure+")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	21,154
S6	TI ((equipment N2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*))) OR MW ((equipment N2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	11,249
S7	TI ((device? N2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*))) OR MW ((device? N2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	199
S8	TI (("PPE" N2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*))) OR MW (("PPE" N2 (fail* or defect* or abnorm* or fault* or error* or erroneous* or irregular* or weak or weakness* or degrad* or deteriorat* or weaken* or misuse? or mis-use? or inappropriat*)))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	3
S9	TI ((storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or conserving or supply management or managing suppl*)) OR MW ((storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or conserving or supply management or managing suppl*))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	22,737

S10	TI ((improper* N2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management))) OR MW ((improper* N2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management)))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	3
S11	TI ((inappropriat* N2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management))) OR MW ((inappropriat* N2 (storage or stored or storing or stockpil* or stock-pil* or ration* or conservation or supply management)))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	3
S12	TI ((shelf life? or expired or expiration date? or expiry date? or "best by" or best before or "use before" or lapse date or lapsed or defunct or "void by" or "voided by" or (manufactur* N2 date?) or (fabricat* N2 date?))) OR MW ((shelf life? or expired or expiration date? or expiry date? or "best by" or best before or "use before" or lapse date or lapsed or defunct or "void by" or "voided by" or (manufactur* N2 date?) or (fabricat* N2 date?)))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	26,081
S13	TI ("wear and tear") OR MW ("wear and tear")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	27
S14	TI (((quality or effectiveness or safety or performance) N2 (compromis* or low or poor or bad or unacceptable))) OR MW (((quality or effectiveness or safety or performance) N2 (compromis* or low or poor or bad or unacceptable)))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	1,835
S15	S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	71,770
S16	(MH "Time Factors")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	173,609
S17	TI ((time factor? or week? or month? or year? or time period? or time scale?)) OR MW ((time factor? or week? or month? or year? or time period? or time scale?))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	59,032
S18	TI time*	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	88,886
S19	S16 OR S17 OR S18	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	302,913
S20	TI ((unuse? N2 (equipment or PPE or mask? or n95 or "n 95" or filter* respirator? or proctect* respirator?))) OR AB ((unuse? N2 (equipment or PPE or mask? or n95 or "n 95"	Expanders - Apply equivalent subjects Search modes -	0

	or filter* respirator? or proctect* respirator?))) OR MW ((unuse? N2 (equipment or PPE or mask? or n95 or "n 95" or filter* respirator? or proctect* respirator?)))	Boolean/Phrase	
S21	S4 AND S15	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	63
S22	S4 AND S15 AND S19	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	3
S23	S21 OR S22	Limiters - Exclude MEDLINE records Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	63

Search terms for other resources used in various combinations:

- COVID-19 | Coronavirus
- (N95 OR respirator OR filtering face piece)
- shelf life or expiry or expiration or manufacturer’s date or "best by" or best before or "use before"