

Rapid Review Report

Review Title:	What is the evidence on degradation of N95s over time especially past expiry date?
Abbreviated Title:	Degradation of expired N95s
Review ID:	PPE110203 RR
Date/Time:	November 20, 2020 20:00
Version: [to be used for updated reviews]	1
Revision History:	None
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Cite As:	Badea, A; Groot, G; Dalidowicz, M; Miller, L. What evidence is available regarding degradation of N95 respirators/masks? 2020 Nov 20; Document no.: PPE110203 RR. In: COVID-19 Rapid Evidence Reviews [Internet]. SK: SK COVID Evidence Support Team, c2020. 15 p. (CEST rapid review report)

Key Findings

- Laboratory testing of expired masks maintain an acceptable filtration performance with less than 2% failing testing in a study of nearly 4,000 masks from 93 lots
- Another study assessing stockpiled N95 masks in Taiwan found acceptable filtration up to 13 years post storage
- Guidelines indicate that expired N95 respirators should be used before resorting to extended use/reuse

Limitations

- There are no studies examining the efficacy of expired masks against SARS-CoV-2 exposure
- Existing studies examine testing under laboratory conditions

GRADE of Evidence: Select - This field is Select - This field is mandatory

mandatory

For more information about how this rating was determined, visit https://www.essentialevidenceplus.com/product/ebm_loe.cfm?show=grade

Background/Context

The spread of the SARS-CoV-2 pandemic worldwide quickly made evident the gaps and shortages within the supply chain system around the world in providing adequate supplies of PPE to all nations. During these shortages, institutions have had to explore alternative methods of protecting their front-line workers. Many nations have previously stockpiled PPE supplies following previous pandemic events, however, many of these stockpiles are a number of years old with products having passed manufacturer's expiration dates. Existing guidelines largely recommend the use of expired pandemic stock before resorting to extended use/reuse of PPE such as N95 respirators.

Purpose

With many jurisdictions having previously stockpiled reserves of PPE following previous pandemics, the question of whether PPE past manufacturer's expiry dates is safe to use is at the forefront for many jurisdictions facing supply chain shortages for new orders of PPE supplies.

Review Question(s)

- Are N95 respirators past manufacturer's expiry dates safe to use to protect against SARS-CoV-2 exposure?

Method

For each Rapid Review, the initial question is posed by a decision-maker in the health care system seeking the evidence base for a specific policy decision. According to the subject of the question, the Evidence Task Group Intake Committee allocates this question to the appropriate Working Group. Each Working Group comprises a librarian, researcher, 1-2 clinicians, 1-2 subject matter experts, and a group leader. The Working Group and the decision-maker first discuss the question to ensure it was articulated in a clear, searchable manner. The search strategy is developed and executed by a team of medical librarians. The search is conducted in biomedical databases and also includes extensive grey literature searching. Reference lists are also reviewed for articles that may have been missed in the primary search. See Appendix for more details on the search strategies. An Evidence Search Report is thereby created. A Rapid Review of the identified literature is then performed by the researcher using the methods of a systematic review, but without a double review or meta-analysis and in a more rapid fashion. Relevant evidence is summarized in both tabular and narrative form, key findings and limitations articulated, and the quality of the body of evidence evaluated using the GRADE hierarchy. The draft Rapid Review is reviewed and edited by the Working Group clinicians, experts, and leader. Once revisions are complete, the Rapid Review is submitted to the requesting decision-maker and placed in the COVID-19 Repository. For certain topics with rapidly changing evidence, after a period of time an updated evidence search is performed, the review process repeated, and an updated Rapid Review released.

Summary of Evidence

Existing national guidelines such as CADTH¹, INSPQ² and other recommend the use of expired PPE stock before resorting to extended/reuse of PPE such as N95 respirators. These guidelines however, do caution that any respirators that are used beyond the manufacturer's expiry date should be carefully inspected for degradation (especially straps and nosepieces) and seal-checked prior to use. In addition, the CDC specifies that it is important to notify users that masks are expired³, and INSPQ also recommends that expired masks be used by those who are less likely to be exposed or less frequently exposed, and not to use expired masks during surgeries².

A study conducted by NIOSH between 2017 and 2019⁴ assessed nearly 4,000 expired N95 masks in 10 storage facilities across the USA from 93 lots. Their testing found that only 2% of masks failed NIOSH testing for filtration performance, and those masks did not fail any visual inspection tests of outer damage or compromised elastic/nose bridges. The less than 2% of masks that did fail a visual inspection failed due to obvious concerns such as the sticking of nosepiece foam to adjacent ventilators, crushing, band issues or mold.

Several other comparable smaller scale studies assessed the filtration performance of expired N95 masks and found that filtration was maintained even 10-13 years post-storage⁵. Viscusi et al evaluated 21 types of N95 masks following 10 years of storage and noted that while most maintained acceptable filtration performance, degradation rates are likely model specific and cannot be comparably extrapolated⁶.

Conclusions

While there have not been any observational studies assessing the efficacy of expired N95 respirators against SARS-CoV-2 exposure, lab testing has demonstrated that expired masks largely perform to the same standard new masks are tested to in laboratory conditions. Guidelines are currently recommending that institutions use expired pandemic PPE stocks before resorting to recommending the extended use/reuse of PPE, provided that proper visual inspections and fit tests are carried out. In addition, it is recommended that expired masks be used by those individuals at lower risk of being exposed, or those likely to be exposed at a lower frequency, and that individuals provided expired masks be notified of their date and reminded that an inspection and fit test should be carried out prior to use.

Glossary

(Optional, but useful if there are clinical/statistical terms being referenced in the document.)

Table 1: Summary of Literature

Reference	Context	Key Findings
<p>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</p>	<p>CADTH guidance on optimizing N95 during supply shortages</p>	<ul style="list-style-type: none"> - recommend the use of expired masks before resorting to extended use/reuse - first recommendation for additional sources of N95, provided that the components of the mask that affect fit and seal (such as straps and nose bridge) have not degraded
<p>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</p>	<p>Guidance for measures to take before reprocessing</p>	<ul style="list-style-type: none"> - stocks of expired single-use respirators can be used to protect health care personnel provided that 1) masks were safely stored in a place without exposure to the sun, excess humidity or pests; and 2) samples show that they are in good working condition, well fitting (after a fit-check) and without any deterioration (eg elastic bands and nose bridges)
<p>CDC. Inhalation and Exhalation Resistance and Filtration Performance of Stockpiled Air-Purifying Respirators: Overall Performance of Nearly 4,000 Respirators Sampled from Ten Stockpile Facilities. [March 25, 2020] https://www.cdc.gov/niosh/npptl/ppecase/pdfs/PE-CASE-Aggregated-Stockpile-Study-03252020-508.pdf</p>	<p>NIOSH testing of US stockpile expired respirators</p>	<ul style="list-style-type: none"> - 3,971 respirators from 93 lots tested - all stockpiled and control respirators from each model passed the inhalation and exhalation resistance tests - 2% of total respirators tested did not meet NIOSH performance standards for filtration performance - failing units were not associated with any respirator visual inspection concerns (ie no damage to the respirator, straps or metal nose bridge was observed) - <2% of the total respirators visually inspected had visual inspection concerns, which included the respirators' nose foam sticking to adjacent respirators within the box, crushing, mold and damage to straps
<p>CDC. Strategies for Optimizing the Supply of N95 Respirators. [June 28, 2020]. https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirators-strategy/index.html#crisis</p>	<p>Guidelines for optimizing supply</p>	<ul style="list-style-type: none"> - Over time, components such as the straps and nose bridge material may degrade, which can affect the quality of the fit and seal - If used in healthcare delivery, it is particularly important that HCP perform the expected seal check,

		prior to entering a patient care area
<p>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</p>	<p>Review of 21 lab studies to assess the safety of N95 reuse and extended use</p>	<ul style="list-style-type: none"> - devices beyond their labeled shelf life may retain adequate filter performance if stored properly, but aged rubber bands and other elastic parts may not ensure a proper fit - heat and humidity can compromise the filter material - devices should be closely inspected for signs of damage and fit-tested before use
<p>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</p>	<p>Guidance document</p>	<ul style="list-style-type: none"> - review of guidance documents – N95 masks beyond their indicated shelf life may be safe for use as long as they are visually inspected for flaws/degradation and can pass a fit test - Lin et al evaluated filtration performance of 5 expired models and found that without decontamination by gamma irradiation or the use of an autoclave, all expired N95 models maintained acceptable filtration performance and still could be used to collect aerosol effectively, aging of straps and seal materials may affect fit factor and effectiveness - Viscusi et al investigated 21 types of N95 for use during flu pandemics – most N95 filtering facepiece 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 - Zaman et al tested expired Kimberly-Clark duck-bill masks with eroded elastics which were replaced with latex-free tourniquet material and demonstrated a fit factor of at least 95 for all tested conditions - created an assembly line for the retrofitted respirators – able to make up to 500-1,000 retrofitted expired-stock N95 per day. Random samples of each half-day production run have been fit tested with a 100% pass rate

<p>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</p>	<p>Review of evidence/guidance</p>	<ul style="list-style-type: none"> - CDC guidance, NIOSH study - CDC notes that before using expired masks, it is important to inform users that the masks have expired and need to be inspected and seal-checked - recommend not using expired masks during surgical procedures, did not test masks for fluid resistance of flammability - recommends that expired masks be used only by those with lower or less frequent risk of exposure to the virus
<p>Brun D, Curti C, Mekideche T, et al. Stockpiled N95 respirator/surgical mask release beyond manufacturer-designated shelf-life: a French experience. <i>J Hosp Infect.</i> 2020;106(2):258-63. DOI: 10.1016/j.jhin.2020.07.032</p>	<p>Testing of expired masks (France)</p>	<ul style="list-style-type: none"> - 175 batches of FFP2/N95 masks with expiry dates from 2001 to 2018 tested (packaging integrity verification, mask appearance verification, breaking strength test on elastic ties and strength test on nose clip, and face-fit test - 49% compliant, 32% compliant with concerns and 19% non-compliant - non compliant: 1% packaging integrity, 7% visual appearance, breaking of elastic ties 37%, breaking of nose clip 9% and fit problems 16% - concerns for 32% of compliant batches relate to fragility of elastic ties and nose clip
<p>Lin T-H, Tseng C-C, Huang Y-L, et al. Effectiveness of N95 Facepiece Respirators in Filtering Aerosol Following Storage and Sterilization. <i>Aerosol and Air Quality Research.</i> 2020;20(4):833-43. DOI: 10.4209/aaqr.2019.12.0620</p>	<p>Comparison of expired and non-expired N95 from Taiwan stockpile</p>	<ul style="list-style-type: none"> - penetration (P), pressure drop (Δp) and quality factor (q_f) - P and Δp of all expired and non-expired N95FFRs met the US 42 CFR 84 standards - All expired N95FFRs had a higher P and a lower Δp than the non-expired ones of the same model. - all the expired N95FFR models had lower Δp than the non-expired models. Besides, all the expired or non-expired N95FFR models approved the US 42 CFR 84 criteria on exhalation or inhalation resistance - No statistically significant difference in P, Δp or q_f existed between the expired and non-expired N95FFR models

		<ul style="list-style-type: none"> - Most of the expired N95FFR models maintained an acceptable <i>P</i> even 13 years after their manufacture
<p>Rottach DR, Lei Z. Stockpiled N95 Filtering Facepiece Respirator Polyisoprene Strap Performance. <i>J Int Soc Respir Prot.</i> 2017;34(2):69-80.</p>	<p>Lab testing of straps of various ages of N95</p>	<ul style="list-style-type: none"> - elasticity of one brand straps varied based on age – but not linear, some older performed better than some newer - model B that used polyisoprene did not show tension variation with age
<p>Viscusi DJ, Bergman M, Sinkule E, et al. Evaluation of the filtration performance of 21 N95 filtering face piece respirators after prolonged storage. <i>Am J Infect Control.</i> 2009;37(5):381-6. DOI: 10.1016/j.ajic.2008.09.021</p>	<p>Lab testing of respirators in storage</p>	<ul style="list-style-type: none"> - 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% - 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
<p>Moyer ES, Bergman MS. Electrostatic N-95 respirator filter media efficiency degradation resulting from intermittent sodium chloride aerosol exposure. <i>Appl Occup Environ Hyg.</i> 2000;15(8):600-8. DOI: 10.1080/10473220050075608</p>	<p>Open-air storage of N95 and degradation</p>	<ul style="list-style-type: none"> - 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.
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References Included in Summary

1. **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
2. **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>
3. **CDC.** Strategies for Optimizing the Supply of N95 Respirators. [June 28, 2020]. <https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirators-strategy/index.html#crisis>
4. **CDC.** Inhalation and Exhalation Resistance and Filtration Performance of Stockpiled Air-Purifying Respirators: Overall Performance of Nearly 4,000 Respirators Sampled from Ten Stockpile Facilities. [March 25, 2020] <https://www.cdc.gov/niosh/npptl/ppecase/pdfs/PPE-CASE-Aggregated-Stockpile-Study-03252020-508.pdf>
5. **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
6. **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

Appendix: Evidence Search Details

Search Strategies for Main Databases

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 protect* 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-	Expanders - Apply	22,737

	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*))	equivalent subjects Search modes - Boolean/Phrase	
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	88,886

		Search modes - Boolean/Phrase	
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" 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?))))	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	0
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

Sources

- Grey literature was searched
- Refer to the evidence search report for extensive sources



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