ANNEX A: Literature search

Search question:

Exposure to non-exhaust particulate matter from road transport and associated health effects

Terms used:

Concept 1: Non-exhaust emissions	Concept 2: health effects
tyre debris / degradation / wear brake debris / degradation / wear clutch debris / degradation / wear road dust non exhaust / nonexhaust / non-exhaust	pulmonary cardiovascular alveolar bronchoalveolar respiratory oxidative stress mortality toxic mutagen carcinogen low birth weight

Limits applied:

Age group	Language	Publication type	Time limit
	English		

No time limit was applied, the search was completed in August 2019.

Summary of resources searched and results:

Source	No. of results*
Cochrane Library	0
Embase	45
Global Health	4
PubMed	66
Scopus	14

TOTAL = 129

Search strings

PubMed

((((((heavy metal*[tiab]) OR ((tire[tiab] OR tyre[tiab] OR tires[tiab] OR tyres[tiab] OR brake*[tiab] OR clutch*[tiab] OR road[tiab]) AND (wear[tiab] OR degrad*[tiab] OR dust[tiab]))) OR (non-exhaust[tiab] OR "non exhaust"[tiab] OR nonexhaust[tiab]))) AND ((((("Particulate Matter/adverse effects"[Mesh] OR "Particulate Matter/analysis"[Mesh])) OR ("Air Pollutants/adverse effects"[Mesh] OR "Air Pollutants/analysis"[Mesh])) OR ("Vehicle Emissions/adverse effects"[Mesh] OR "Vehicle Emissions/analysis"[Mesh]))))) AND

(pulmonary[tiab] OR cardiovascular[tiab] OR alveolar[tiab] OR bronchoalveolar[tiab] OR respiratory[tiab] OR oxidative stress[tiab] OR mortality[tiab] OR toxic*[tiab] OR mutagen*[tiab] OR carcinogen*[tiab] OR low birth weight[tiab]) Filters: **English**

EMBASE

Database: Embase <1996 to 2019 Week 31>
Search Strategy:
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1 non exhaust.m_titl. (26)
2 particulate matter/ (35184)
3 (Health risk$ or health effect$ or hospital or morbidity or lung$ or pulmonary or cardiovascular or alveolar or bronchoalveolar or respiratory or oxidative stress or mortality or toxic$ or mutagen$ or carcinogen$ or low birth weight).ti,ab. (4438583)
4 (non-exhaust or non exhaust or nonexhaust or ((tire or tyre or tires or tyres or brake$ or clutch$ or road) and (wear or degrad$ or dust))).ti,ab. (2310)
5 2 or 4 (36763)
6 3 and 5 (14062)
7 3 and 4 (632)
8 limit 7 to english language (603)

SCOPUS

TITLE-ABS ("tyre debris" OR "brake debris" OR "clutch debris" OR "tyre degrad*" OR "brake degrad*" OR "clutch degrad*" OR "tyre wear" OR "brake wear" OR "clutch wear" OR "road dust" OR "non
exhaust" OR nonexhaust AND pulmonary OR cardiovascular OR alveolar OR bronchoalveolar OR respiratory OR "oxidative
stress" OR mortality OR toxic OR mutagen OR carcinogen OR "low birth
weight") AND (LIMIT-TO (LANGUAGE , "English"))

Search results

After the first screening (by PHE Librarian), the following papers were found relevant to the topic:

Results are ordered chronologically, most recent first.

1. Cabanova, K., Hrabovska, K., Matejkova, P., et al. 2019. **Settled iron-based road dust and its characteristics and possible association with detection in human tissues**. *Environ Sci Pollut Res Int* 26(3) 2950-2959.
2. Gerlofs-Nijland, M. E., Bokkers, B. G. H., Sachse, H., et al. 2019. **Inhalation toxicity profiles of particulate matter: a comparison between brake wear with other sources of emission**. *Inhalation Toxicology* 31(3) 89-98.
3. Rich, D. Q., Zhang, W., Lin, S., et al. 2019. **Triggering of cardiovascular hospital admissions by source specific fine particle concentrations in urban centers of New York State**. *Environment International* 387-394.
4. Barosova, H., Chortarea, S., Peikertova, P., et al. 2018. **Biological response of an in vitro human 3D lung cell model exposed to brake wear debris varies based on brake pad formulation**. *Archives of Toxicology* 92(7) 2339-2351.
5. Bernstein, D. M., Toth, B., Rogers, R. A., et al. 2018. **Evaluation of the dose-response and fate**

in the lung and pleura of chrysotile-containing brake dust compared to chrysotile or crocidolite asbestos in a 28-day quantitative inhalation toxicology study. *Toxicology and Applied Pharmacology* 351 74-92.
6. Golan, R., Chandresh, L., Greenwald, R., et al. 2018. **Acute pulmonary and inflammatory response in young adults following a scripted car commute**. *Air Quality, Atmosphere and Health* 11(2) 123-136.
7. Krall, J. R., Ladva, C. N., Russell, A. G., et al. 2018. **Source-specific pollution exposure and associations with pulmonary response in the Atlanta Commuters Exposure Studies**. *J Expo Sci Environ Epidemiol* 28(4) 337-347.
8. Wahid, S. M. S. 2018. **Automotive brake wear: a review**. *Environ Sci Pollut Res Int* 25(1) 174-180.
9. Adamiec, E. 2017. **Road Environments: Impact of Metals on Human Health in Heavily Congested Cities of Poland**. *Int J Environ Res Public Health* 14(7).
10. D'Souza, J. C., Kawut, S. M., Elkayam, L. R., et al. 2017. **Ambient coarse particulate matter and the right ventricle: The multi-ethnic study of atherosclerosis**. *Environmental Health Perspectives* 125(7).
11. Dehghani, S., Moore, F., Keshavarzi, B., et al. 2017. **Health risk implications of potentially toxic metals in street dust and surface soil of Tehran, Iran**. *Ecotoxicol Environ Saf* 136 92-103.
12. Jan Kole, P., Lohr, A. J., Van Belleghem, F. G. A. J., et al. 2017. **Wear and tear of tyres: A stealthy source of microplastics in the environment**. *International Journal of Environmental Research and Public Health* 14 (10) (no pagination)(1265).
13. Kumar, P., Rivas, I. & Sachdeva, L. 2017. **Exposure of in-pram babies to airborne particles during morning drop-in and afternoon pick-up of school children**. *Environ Pollut* 224 407-420.
14. Peikertova, P., Kuricova, M., Kazimirova, A., et al. 2017. **Toxicity of the Airborne Brake Wear Debris**. *SAE International Journal of Materials and Manufacturing* 10(1) 19-25.
15. Pun, V. C., Tian, L. & Ho, K. F. 2017. **Particulate matter from re-suspended mineral dust and emergency cause-specific respiratory hospitalizations in Hong Kong**. *Atmospheric Environment* 165 191-197.
16. Segersson, D., Eneroth, K., Gidhagen, L., et al. 2017. **Health Impact of PM10, PM2.5 and Black Carbon Exposure Due to Different Source Sectors in Stockholm, Gothenburg and Umea, Sweden**. *Int J Environ Res Public Health* 14(7).
17. Smith, R. B., Fecht, D., Gulliver, J., et al. 2017. **Impact of London's road traffic air and noise pollution on birth weight: Retrospective population based cohort study**. *BMJ (Online)* 359 (no pagination)(j5299).
18. Carey, I. M., Anderson, H. R., Atkinson, R. W., et al. 2016. **Traffic pollution and the incidence of cardiorespiratory outcomes in an adult cohort in London**. *Occup Environ Med* 73(12) 849-856.
19. Hwang, H. M., Fiala, M. J., Park, D., et al. 2016. **Review of pollutants in urban road dust and stormwater runoff: part 1. Heavy metals released from vehicles**. *International Journal of Urban Sciences* 20(3) 334-360.
20. Rajhelová, H., Peikertová, P., Vaculík, M., et al. 2016. **Lipid peroxidation caused by the brake wear debris and chosen constituents of friction composites**. *8th International Conference on Nanomaterials - Research and Application, NANOCON 2016* 632-637.
21. Bernstein, D. M., Rogers, R. A., Sepulveda, R., et al. 2015. **Evaluation of the fate and pathological response in the lung and pleura of brake dust alone and in combination with added chrysotile compared to crocidolite asbestos following short-term inhalation exposure**. *Toxicol Appl Pharmacol* 283(1) 20-34.
22. Bilenko, N., Brunekreef, B., Beelen, R., et al. 2015. **Associations between particulate matter composition and childhood blood pressure--The PIAMA study**. *Environ Int* 84 1-6.
23. Desikan, A., Crichton, S., Hoang, U., et al. 2015. **The effect of exhaust and non-exhaust**

related components of particulate matter on long-term survival after stroke in South London. *International Journal of Stroke* 5) 61-62.
24. Grigoratos, T. & Martini, G. 2015. **Brake wear particle emissions: a review**. *Environmental science and pollution research international* 22(4) 2491-2504.
25. Jalava, P. I., Happo, M. S., Huttunen, K., et al. 2015. **Chemical and microbial components of urban air PM cause seasonal variation of toxicological activity**. *Environmental Toxicology and Pharmacology* 40(2) 375-387.
26. Straffelini, G., Ciudin, R., Ciotti, A., et al. 2015. **Present knowledge and perspectives on the role of copper in brake materials and related environmental issues: A critical assessment**. *Environmental Pollution* 207 211-219.
27. Zhao, J., Lewinski, N. & Riediker, M. 2015. **Physico-chemical characterization and oxidative reactivity evaluation of aged brake wear particles**. *Aerosol Science and Technology* 49(2) 65-74.
28. Bernstein, D. M., Rogers, R., Sepulveda, R., et al. 2014. **Evaluation of the deposition, translocation and pathological response of brake dust with and without added chrysotile in comparison to crocidolite asbestos following short-term inhalation: interim results**. *Toxicol Appl Pharmacol* 276(1) 28-46.
29. Dadvand, P., Ostro, B., Amato, F., et al. 2014. **Particulate air pollution and preeclampsia: A source-based analysis**. *Occupational and Environmental Medicine* 71(8) 570-577.
30. Cassee, F. R., Heroux, M. E., Gerlofs-Nijland, M. E., et al. 2013. **Particulate matter beyond mass: recent health evidence on the role of fractions, chemical constituents and sources of emission**. *Inhal Toxicol* 25(14) 802-12.
31. Denier van der Gon, H. A. C., Gerlofs-Nijland, M. E., Gehrig, R., et al. 2013. **The PolicyRelevance of WearEmissions fromRoad Transport,Nowand in the Future-An InternationalWorkshop Report and Consensus Statement**. *Journal of the Air and Waste Management Association* 63(2) 136-149.
32. Kam, W., Delfino, R. J., Schauer, J. J., et al. 2013. **A comparative assessment of PM<inf>2.5</inf> exposures in light-rail, subway, freeway, and surface street environments in Los Angeles and estimated lung cancer risk**. *Environmental Sciences: Processes and Impacts* 15(1) 234-243.
33. Vedal, S., Campen, M. J., McDonald, J. D., et al. 2013. **National Particle Component Toxicity (NPACT) initiative report on cardiovascular effects**. *Res Rep Health Eff Inst*(178) 5-8.
34. Kelly, F., Anderson, H. R., Armstrong, B., et al. 2011. **The impact of the congestion charging scheme on air quality in London. Part 2. Analysis of the oxidative potential of particulate matter**. *Res Rep Health Eff Inst*(155) 73-144.
35. Kelly, F., Armstrong, B., Atkinson, R., et al. 2011. **The London low emission zone baseline study**. *Res Rep Health Eff Inst*(163) 3-79.
36. Happo, M. S., Hirvonen, M. R., Halinen, A. I., et al. 2010. **Seasonal variation in chemical composition of size-segregated urban air particles and the inflammatory activity in the mouse lung**. *Inhal Toxicol* 22(1) 17-32.
37. Kukutschová, J., Roubíček, V., Malachová, K., et al. 2009. **Wear mechanism in automotive brake materials, wear debris and its potential environmental impact**. *Wear* 267(5-8) 807-817.
38. Moretti, E., Dal Bosco, A., Mourvaki, E., et al. 2009. **In vitro effects of tyre debris organic extract on the kinetic and morphologic traits of rabbit spermatozoa**. *World Rabbit Science* 17(4) 213-220.
39. Gottipolu, R. R., Landa, E. R., Schladweiler, M. C., et al. 2008. **Cardiopulmonary responses of intratracheally instilled tire particles and constituent metal components**. *Inhal Toxicol* 20(5) 473-84.
40. Gustafsson, M., Blomqvist, G., Gudmundsson, A., et al. 2008. **Properties and toxicological effects of particles from the interaction between tyres, road pavement and winter traction material**. *Sci Total Environ* 393(2-3) 226-40.

41. Gerlofs-Nijland, M. E., Dormans, J. A., Bloemen, H. J., et al. 2007. **Toxicity of coarse and fine particulate matter from sites with contrasting traffic profiles**. *Inhal Toxicol* 19(13) 1055-69.
42. Lipfert, F. W., Wyzga, R. E., Baty, J. D., et al. 2006. **Traffic density as a surrogate measure of environmental exposures in studies of air pollution health effects: Long-term mortality in a cohort of US veterans**. *Atmospheric Environment* 40(1) 154-169.
43. Gualtieri, M., Andrioletti, M., Mantecca, P., et al. 2005. **Impact of tire debris on in vitro and in vivo systems**. *Particle and Fibre Toxicology* 2.
44. Paustenbach, D. J., Finley, B. L., Lu, E. T., et al. 2004. **Environmental and occupational health hazards associated with the presence of asbestos in brake linings and pads (1900 to present): A "state-of-the- art" review**. *Journal of Toxicology and Environmental Health - Part B: Critical Reviews* 7(1) 25-80.
45. Riediker, M., Devlin, R. B., Griggs, T. R., et al. 2004. **Cardiovascular effects in patrol officers are associated with fine particulate matter from brake wear and engine emissions**. *Particle and Fibre Toxicology* 1.

Screening and manual search

From the above studies, only those that reported health impacts associated with the exposure to non-exhaust particles were included in the review, i.e. the studies 2, 3, 4, 5, 6, 7, 9, 10, 14, 15, 16, 17, 18, 20, 21, 22, 23, 25, 28, 29, 30, 31, 32, 33, 36, 38, 39, 40, 41, 42, 43, 45 from the list above were further reviewed.

In addition to the papers identified by the Library search, papers from manual searches and from the references of the originally identified papers were included in the review, namely:

- Rajhelová et al., Determination of Oxidative Potential Caused by Brake Wear Debris in Non-Cellular Systems, J Nanosci Nanotech 95:2869, 2019.
- Puisney et al., Brake wear (nano)particle characterization and toxicity on airway epithelial cells in vitro, Environ. Sci.: Nano 5:1036-1044, 2018.
- Malachova et al., Toxicity and mutagenicity of low-metallic automotive brake pad materials, Ecotoxicol Environ Saf 131:37-44, 2016.
- Shirmohammadi et al., The relative importance of tailpipe and non-tailpipe emissions on the oxidative potential of ambient particles in Los Angeles, CA, Farady Discuss 189:361-80, 2016.
- Heo et al., Fine particle air pollution and mortality: importance of specific sources and chemical species, Epidemiology 25(3):379-88, 2014.
- Peikertova et al., Airborne Brake Wear Debris: Characterization and the Effect on Immune Response. Nanobase proceedings: Nanotechnology - the Basis for International Cooperation. VŠB-TU Ostrava, pp. 41–44. ISBN 0–13–981176–1, 2014.
- Bell et al., Associations of PM2.5 Constituents and Sources with Hospital Admissions: Analysis of Four Counties in Connecticut and Massachusetts (USA) for Persons >= 65 Years of Age, Environmental Health Perspectives 122(2) DOI: 10.1289/ehp.1306656, 2013.
- Kreider et al., Evaluation of potential for toxicity from subacute inhalation of tire and road wear particles in rats. Inhal Toxicol 24: 907-917, 2012.
- Marwood et al., Acute aquatic toxicity of tire and road wear particles to alga, daphnid, and fish, Ekotoxicol. 20(8):2079-2089, 2012.
- Lall et al., Distributed Lag Analyses of Daily Hospital Admissions and Source-Apportioned Fine Particle Air Pollution, Environmental Health Perspectives 119(4):455-60, 2011.

- Godri et al., Increased oxidative burden associated with traffic component of ambient particulate matter at roadside and urban background schools sites in London, PloS One 6:e21961, 2011.
- He et al. Identification of benzothiazole derivatives and polycyclic aromatic hydrocarbons as aryl hydrocarbon receptor agonists present in tire extracts, Environ Toxicol Chem 30(8):1915–25, 2011.
- Karlsson et al., Wear particles from studded tires and granite pavement induce pro-inflammatory alterations in human monocyte-derived macrophages: a proteomic study, Chem Res Toxicol 24:45-53, 2011.
- Cakmak et al., Components of Particulate Air Pollution and Mortality in Chile, International journal of occupational and environmental health 15(2):152-8, DOI: 10.1179/107735209799195844, 2009.
- Halonen et al., Particulate Air Pollution and Acute Cardiorespiratory Hospital Admissions and Mortality Among the Elderly, Epidemiology 20(1):143-53, 2009.
- Mantecca et al., Comparative acute lung inflammation induced by atmospheric PM and size-fractionated tire particles, Toxicol Lett 198:244-54, 2010.
- Mantecca et al., Lung toxicity induced by intratracheal instillation of size-fractionated tire particles, Toxicol Lett 189:206-14, 2009.
- Gasser et al., Toxic effects of brake wear particles on epithelial lung cells in vitro, Particle and Fibre Toxicology 6:30, doi:10.1186/1743-8977-6-30, 2009.
- Sarnat et al., Fine Particle Sources and Cardiorespiratory Morbidity: An Application of Chemical Mass Balance and Factor Analytical Source Apportionment Methods, Environmental Health Perspectives 116(4):459-66, 2008.
- Gualtieri et al., Organic compounds in tire particle induce reactive oxygen species and heat-shock proteins in the human alveolar cell line A549, Environ. Int. 34:437-442, 2008.
- Andersen et al., Ambient particle source apportionment and daily hospital admissions among children and elderly in Copenhagen, Journal of Exposure Science and Environmental Epidemiology 17:625–636, 2007.
- Beretta et al., Organic extract of tire debris causes localized damage in the plasma membrane of human lung epithelial cells, Toxicol Lett 173:191-200, 2007.
- Lindbom et al., Wear particles generated from studded tires and pavement induces inflammatory reactions in mouse macrophage cells, Chem Res Toxicol 20:937-46, 2007.
- Karlsson et al., Comparison of genotoxic and inflammatory effects of particles generated by wood combustion, a road simulator and collected from street and subway, Toxicol Lett 165:203-11, 2006.
- Lindbom et al., Exposure to wear particles generated from studded tires and pavement induces inflammatory cytokine release from human macrophages, Chem Res Toxicol 19:521-30, 2006.
- Lipfert et al., Traffic density as a surrogate measure of environmental exposures in studies of air pollution health effects: Long-term mortality in a cohort of US veterans, Atmospheric Environment 40(1):154-169, 2006.
- Schreuder et al. Ambient Woodsmoke and Associated Respiratory Emergency Department Visits in Spokane, Washington, INT J OCCUP ENVIRON HEALTH12:147–153, 2006.
- Gualtieri et al., Toxicity of tire debris extracts on human lung cell line A549, Toxicology in vitro 19:1001-1008, 2005.

Finally, we also examined two relevant studies that were published soon after the Literature search, in particular:

- Kreider et al., Human health risk assessment of tire and road wear particles (TRWP) in air, Human and Ecological Risk assessment: An International Journal doi: https://doi.org/10.1080/10807039.2019.1674633, 2019.

- Poma et al., Exposure to particle debris generated from passenger and truck tires induces different genotoxicity and inflammatory responses in the RAW 264.7 cell line. PLoS ONE 14 (9): e0222044, 2019.

By including the studies selected after the Literature search to the above list, 61 studies were considered and reviewed (Annex B and D).