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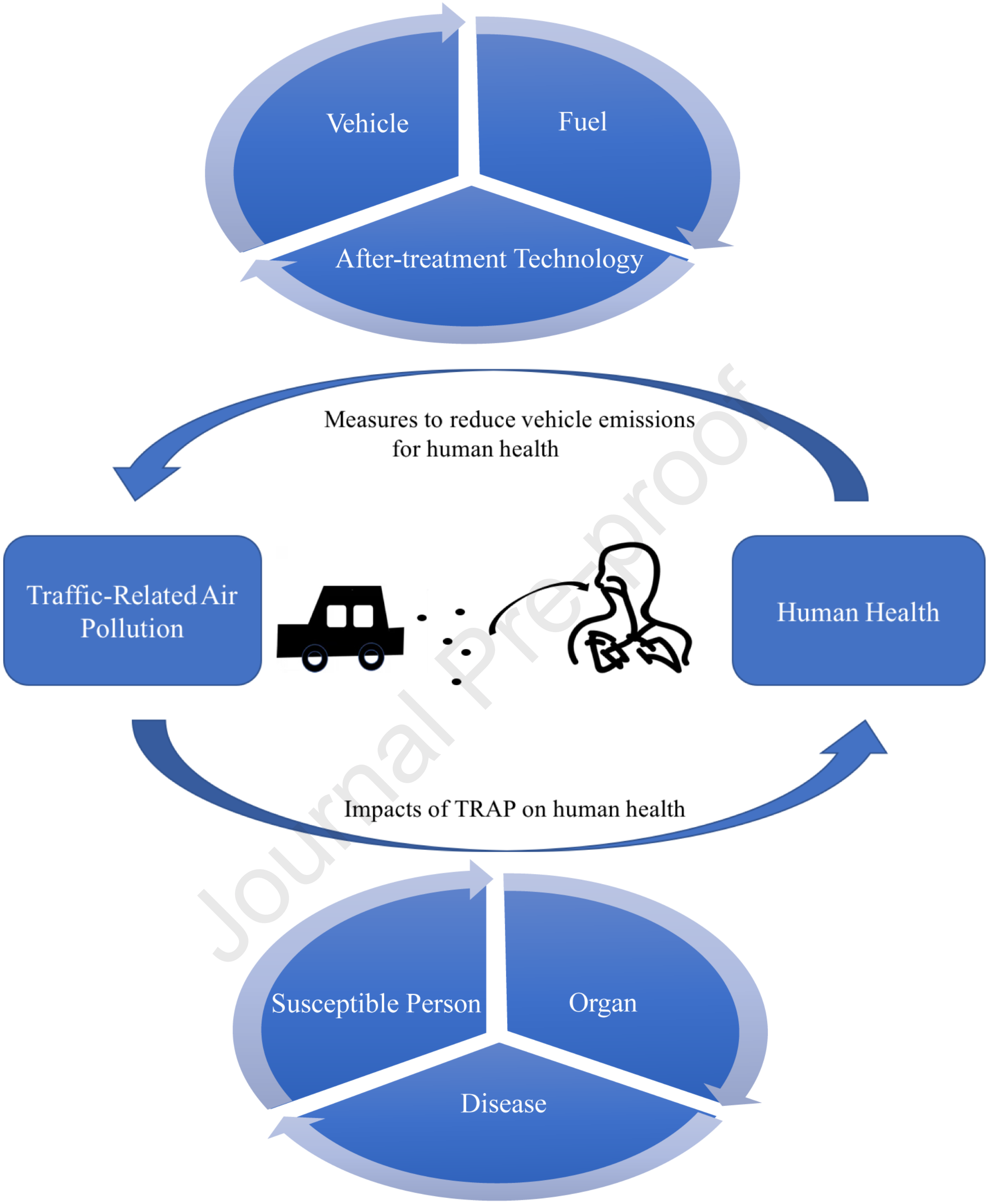
Vehicle
Fuel
After-treatment Technology
Measures to reduce vehicle emissions for human health
Traffic-Related Air Pollution
Human Health
Impacts of TRAP on human health
Susceptible Person
Organ
Disease

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Abstract

Traffic-related air pollution (TRAP) is global concern due to both the ecological damage of TRAP and the adverse health effects in Humans. Several strategies to reduce TRAP have been implemented, including the use of sustainable fuels, after-treatment technologies, and new energy vehicles. Such approaches can reduce the exhaust of particulate matter, adsorbed chemicals and a range of gases, but from a health perspective these approaches are not always successful. This review aims to discuss the approaches taken, and to then describe the likely health effects of these changes.

Keywords: Traffic-related air pollution, biodiesel, after-treatment technology, new energy vehicles, particulate matter

1. **Introduction**

Air pollution has risen to the fourth largest cause of early death, according to the ‘State of Global Air 2020 Report' (Institute 2020). This effect is likely to be observed for the foreseeable future as the majority of Asia, Africa, and the Middle East's middle- and low-income countries continue to have rising levels of air pollution, including increased particulate matter (PM), noxious gases, and various hazardous chemical compounds. (Bunger et al. 2012, Sinharay et al. 2018, Institute 2020).

Air pollution is characterised as either outdoor air pollution or indoor air pollution depending upon the pollutant source (Mannucci and Franchini 2017). Outdoor air pollution is made up of a variety of pollutants generated primarily by vehicle traffic, industrial sources, power plants, agriculture, and wildfires. Urbanisation and increased population density have both increased exposure to traffic-related air pollution (TRAP), resulting in increased health concerns in both developing and developed countries (Miller and Newby 2020). Outdoor air pollution causes considerable mortality, even in areas thought to have good air quality. For example in 2018 outdoor air pollution caused 84,300 deaths in Italy, and 78,400 in Germany, 47,300 in France and 41,900 in the U.K. (Carvalho 2019). TRAP is a major pollutant in cities, and can affect a large proportion of the population. In 2015 it was estimated that 66% of the population in Beijing, 41% of New Delhi, 67% of Paris, and 96% of Barcelona were exposed to high levels of TRAP (Barthelemy et al. 2020). Even in Australia, a country with one of the lowest exposure levels to PM (less than $8\mu g/m^3$ on average), 16.9% of the PM2.5 in Sydney is attributed to on-road vehicles. It is also worth noting that the peak concentration of PM in Sydney can reach up to $280\ mg/m^3$ (Broome et al. 2020, Forehead et al. 2020)

With the rising health concerns associated with TRAP, numerous studies have analysed the chemical components of TRAP in an attempt to find causation. However, when considering the health effects of constituents of TRAP it is worthwhile considering what it is feasible to measure in epidemiological studies, the likely biological causality of the individual pollutant, and where the collection occurred (the distance from the source). A simplistic overview of these questions leads to the following answers.

Commercially available equipment for assessing air pollution either assesses particulate matter (PM), gasses, or a mixture of the two. It is worth noting that the assessment and collection of PM smaller than 0.1 uM is technically difficult, and generally PM collection consists of PM1 (PM <=1uM), PM2.5 or PM10. PM can be analysed for chemical content, but with different analysis technologies and methodologies the range and sensitivity of detected constituents can be variable across studies. Typically assessed constituents of TRAP consist of elemental carbon, organic carbon, inorganic components (eg. metals, sulphate, and nitrate), and PM-bound organic components (eg. Polycyclic Aromatic Hydrocarbons, PAH). Typical gaseous measurements include nitrogen oxides and ozone; both are oxidants which can damage the lungs and other internal organs. Carbon monoxide, benzene, and formaldehyde are also frequently assessed. All components of TRAP exhibit distance-decay gradients, that is that their concentration is highest closest to the source. An elegant meta-analysis summarised this, components which have a rapid decay (e.g. CO) within 150M from the road, those which have a gradual decay over 500m from the road (e.g. nitrogen dioxide, and those which have no appreciable decay over this distance (e.g. PM2.5). It is also worth noting that PM, which has been identified as the main bioactive component of TRAP, will vary according to vehicle type and usage (Gupta and Elumalai 2019, Botero et al. 2020, Boongla et al. 2021). Compared to rural areas, the constituents of PM were more complex in the urban regions attributable to population growth and differences in vehicle usage (private vehicles, subway trains, light rails, and buses) (Ngoc et al. 2018). Driving patterns, such as frequent stopping due to congestion, aggressive driving with high velocities and acceleration, high-way traffic, and idling, can also have an impact on the amount and components of PM (Botero et al. 2020).

2. **PM and human health**

TRAP contributes to daily PM exposure, exerting an important role in human health. More than 10 % of the asthma cases were related to near road traffic-related pollution in 10 European cities (Perez et al. 2013). Even TRAP is attritubted to the development of hypertensive disorders of pregnancy (Sears et al. 2018). Bus, car, and bicycle are the most common modes of commuting in urban areas. Varoious studies have focused on the PM concentration in different travel modes, indicting highest PM exposure associated with cycling, followed by bus, and the lowest exposure car (Peng et al. 2021, Zheng et al. 2021). On average, the highest inhaled dose of PM2.5 was experienced while cycling (55 μg), followed by bus (20.9 μg) and the lowest in car travels (17 μg) during a daily commuting (Zheng et al. 2021). Apart from these common modes of transportation, heavy-duty trucks are also the main source of PM in our environment. Diesel is the predominant fuel for heavy-duty vehicles until now. A study have reveled that the level of 2-AFLU, major metabolites of disel-specific nitrated PAHs, was significantly associated with the buses and heavy-duty vehicles but not motorbikes, taxis, or coaches (Yang et al. 2021). Thus, reducing the PM from different types of vehicle is of primary importance to reduce environmental pollution and protect our health.

When considering the health effects of TRAP it is important to consider both the source of pollution (for example engine type) and the amount of pollution produced. Trucks contribute significantly to

TRAP. For example, emissions of BC, NO_X, and PM10 in TRAP were mostly attributed to heavy duty trucks and buses. The greatest producers of PM2.5 are heavy duty trucks, followed by passenger cars and bus, then light commercial vehicles. (Jiang et al. 2020). Furthermore, researchers have created emission factors to normalize production of TRAP from different types of vehicles. When considering PM2.5 the car's emission factor is 1.25 mg/km, while in trucks it is as high as 185 mg/km. The age or condition of the diesel engine also effects emissions. Generally newer diesel vehicles comply with emission standards such as EURO 5 or EURO 6 (Greim 2019) and have lower emissions, but a lack of maintenance increases emissions as can also be seen for engines which have been used more (Lin et al. 2019). Therefore, depending upon the composition of vehicles, the manufacturing standards used and actual engine use and militance the relative exposure to TRAP from cars or trucks will differ and therefore the relative contribution to TRAP associated health effects will also change.

Epidemiological studies have demonstrated that TRAP poses substantial risks to human health. (Hui-Tsung et al. 2021). When considering PM from TRAP, fine particles (less than 10 μm) and ultrafine particles (less than 0.10 μm) have large surface areas, which allows for more poisonous chemicals, like metals and PAH, to be absorbed on the surface (Kim et al. 2015, Schraufnagel et al. 2019). Metals and PM-bound organic components are the major constituents of TRAP PM, which can cause inflammation, oxidative stress, genotoxicity, and cell death (Schraufnagel et al. 2019, Arias-Pérez et al. 2020).

Epidemiological studies have demonstrated that TRAP poses substantial risks to human health, and that some people have increased vulnerabilities to these effects. The most obvious effects are seen when exposure occurs during pregnancy were exposure was related to low birth weight and preterm birth, and an increased risk of developing lifelong chronic diseases (Lin et al. 2021). Furthermore, people with preexisting diseases can have a disease flareup or exacerbation as a result of exposure to TRAP. For example, patients with allergic asthma patients were more susceptible to air pollution-induced exacerbations (Rosenquist et al. 2020), and TRAP levels are associated to coronary heart disease and the incidence of fatal cardiac events (Rosenlund et al. 2008).

TRAP PM directly effects more than the lungs, for example PM expelled from the lungs in mucus is often swallowed and therefore PM in respiratory mucous can potentially affect the gastrointestinal system as well. Coarse PMs (2.5 - 10 m) deposit in the trachea and bronchi (Fig.1), whereas fine particles, especially ultrafine particles, enter the lower airways and alveoli, where they reside for only a short period on the luminal side of the airway epithelium (Schraufnagel et al. 2019). They are then endocytosed and removed by alveolar macrophages or penetrate into the epithelial cells and have even been found inside mitochondria, where cell injury, reactive oxygen species (ROS) generation, and cell death can occur (Loxham et al. 2015, De Grove et al. 2018, Schraufnagel et al. 2019, Nääv et al. 2020, Sharma et al. 2021). Apart from airway injury, PM, especially ultrafine and fine particles, can penetrate through lung tissue and subsequently enter the bloodstream, reaching other organ systems of the body, leading to cardiovascular, neurological, and reproductive disorders (Schraufnagel et al. 2019, Chew et al. 2020). For example, air pollution contributed to the risk of developing central nervous system diseases (Kim et al. 2020). A study has reviled that exposure to PM was associated with the expression level of brain Aβ, suggesting a causative role in Alzheimer disease (Calderon-Garciduenas et al. 2020, Alemany et al. 2021). In addition, PM can increase the risk of liver toxicity, liver inflammation, and steatosis (E. G. Giannini, R. Testa et al. 2005). PM2.5 exposure-induced metabolic damage promotes the development of non-alcoholic fatty liver disease

(Chen et al. 2021). Furthermore, exposure during pregnancy is associated with increased liver enzymes levels, decreased birth weight and height in offspring (Bell et al. 2010). Even the occurrence of kidney parenchyma cancer has been found to be associated with exposure to TRAP (Raaschou-Nielsen et al. 2017).

3. TRAP reduction approaches

The health risks associated with exposure to air pollution are well known and the public is supportive of technologies which claim to have reduced pollutants. In recent years on average, 25% of urban ambient air pollution from PM is from traffic globally (Karagulian et al. 2015). At a regional level, traffic can be the major contributor to PM2.5 and PM10, for example 54% Africa. Similarly the transportation sector accounts for a large proportion of primary emissions of NO_X and PM10: 73% (NOx) and 42% (PM10) in Paris; 50% (NOx) and 50% (PM10) in London (Font et al. 2019). Fortunately, most countries now have measures in place to reduce industrial pollution, but unfortunately, vehicle emissions are now the new source of air pollution in most cities. Attempts have been made to decrease vehicular pollution. After-treatment technologies, renewable fuel, and the development of cars powered by alternative energy sources are only a few of the primary strategies for reducing TRAP PM (Fig.2). It has been suggested that future efforts to reduce TRAP should focus on cleaner sources of fuel such as biodiesel, natural gas, hydrogen or electricity (Bartra et al. 2007).

China announced *The Strategic Plan of the Mid-and Long-Term Development of Renewable Energy* in 2007, with the goal of increasing clean energy's share from 7.5 percent in 2005 to 15 percent by 2020 *(Du and Liu 2012)*. Because of its increased oxygen content and fewer aromatics and sulphur in its composition, biodiesel is viewed as a good choice for making the transition from diesel fuel to renewable fuel while simultaneously minimising the health effects (Arias et al. 2021). For instance, studies have shown that sustainable fuel can reduce PM-induced genotoxicity in lung cells and cytotoxic effects on human bronchial epithelial cells (BEAS-2B) (Martin et al. 2017, Yang et al. 2017). However, some studies reported that biodiesel has a greater potential to damage health compared to diesel, by evaluating oxidative stress, cytotoxicity, and mutagenicity (Kisin et al. 2013, Agarwal et al. 2018). Another potential method to reduce PM emissions is using after-treatment technologies, such as the diesel particulate filter (DPF) and the diesel oxidation catalyst (DOC), to filter most of the PM and assist with the oxidation of CO, unburned hydrocarbons, and NO, thereby reducing the adverse impacts on human health (Vaaraslahti et al. 2006, Lizarraga et al. 2011).

Diesel engines are the most common engines used by large vehicles, however, they produce more pollutants in comparison to the petrol engine (Jhalani et al. 2019). Alternative-energy vehicles are required to improve the current state of air pollution. Plug-in hybrid electric vehicles, battery electric vehicles, hybrid-electric vehicles, compressed natural gas vehicles, and hydrogen vehicles have all recently been launched to the market and are projected to dominate the market in the future, particularly if local legislation supports them (Plotz et al. 2017). However, there is a lack of information on the biological responses to the TRAP generated by these new energy vehicles, especially if the energy source to produce electricity or hydrogen is factored in. Despite many other factors that can influence the production of TRAP PM, such as operating conditions and weather, the aim of this review is mainly to summarise the current understanding of the impact of the above three factors, after-treatment equipment, renewable fuel, and new energy vehicles, on PM emissions and the effect of these PM on human health, in order to identify knowledge gaps to guide much needed future research in this field.

3.1 Fuel type

The global fuel crisis and the adverse health effects caused by vehicles powered by diesel or petrol have driven research into clean and renewable fuel. The finite supply of conventional fuels and the global interdependence on fuel supplies also contribute to innovation in the production of alternative fuel sources. Thus, the requirement of clean combustion and replacing diesel or petrol with biodiesel or another sustainable fuel have gained popularity in several countries, especially in the early 21st century (Yang et al. 2017). Bioethanol is considered a renewable fuel that can be used in a modified petrol engine, while biodiesel is the most popular alternative fuel for compression (diesel) engines (Bunger et al. 2012). Nowadays, biodiesel is mainly generated from palm oil (36%, mainly in Spain, Italy, and the Netherlands), rapeseed oil (16%, mainly in Europe), and waste cooking oils and soybean oil (11% and 26%, respectively, in the US and Brazil) (Botero et al. 2020).

Studies have shown the correlation between the source of the fuel and PM concentration and chemical constituent. Biodiesel mainly composed of unsaturated fatty acids is divided into the first generation fuel from different plants (soy, rapeseed), second-generation fuel from waste cooking oil, and hydrogenated vegetable oil, which results in a difference in the composition of metals, PAH, and other pollutants found on PM between diesel and biodiesel (Martin et al. 2017, Moller et al. 2020). The amount of metals (ie. S, Mg, K, Zn, Cu, Ca, and Fe) increases when waste grease is used as the fuel, while S, Na, K, Ca, Fe, Zn, and Pb decrease when biodiesel made from soybean/tallow methyl esters is used (Martin et al. 2017, Timmerman et al. 2019). In addition, blending biodiesel with diesel is often considered to be a sustainable fuel (Emiroglu and Sen 2018). However, there are fewer studies on PM derived from bioethanol and its blends with petrol, maybe due to the difficulty of collecting such samples (Almeida et al. 2015, Akansu et al. 2017, Chansauria and Mandloi 2018). Similarly, there is lack of knowledge on the health effects associated with different biodiesels and the resulting PM, which requires future research to address. From a health perspective, the key purpose of using renewable fuels is to provide cleaner sources of fuel, but the production of renewable fuels such as biodiesel and bioethanol is often driven by local economic and geopolitical factors. Therefore, investigating the health effects of different renewable fuels and corresponding emissions is urgently needed.

Several studies have reported that biodiesel is a good option to prevent adverse health effects compared to diesel (Larcombe et al. 2015, Emiroglu and Sen 2018). The reduction in ROS, and cellular cytotoxicity are related to the lower exhaust of Cu, as well as water-soluble organic carbon deposited in PM when waste grease was used as the fuel (Martin et al. 2019). Previous studies focused on the mutagenicity by PM produced from biodiesel and diesel using bacterial assays, which yielded inconsistent results (Kisin et al. 2013, Yang et al. 2017). Even in some animal studies, exposure to PM from biodiesel and diesel did not cause significant genotoxicity, while such PM can cause genotoxicity in cells *in vitro*, which may be due to the difference in dose, PM source, and susceptibility (Moller et al. 2020). Therefore, there is a need to further investigate genotoxicity due to PM exposure in animal models. It is worth highlighting that the difference in biological responses can be attributed to the proportion of mineral diesel in biodiesel. Inflammation was reduced *in vitro* when bronchial epithelial cells (BEAS-2B) were exposed to PM from 10% v/v biodiesel (coconut oil) blended with mineral diesel and 15% v/v biodiesel blended with mineral diesel, while it was increased when the fraction was high (20% v/v) (Cervena et al. 2017). Therefore, it is difficult to generalise the likely health effects of using biodiesel compared to diesel. However, to the best of our knowledge, there are no studies on the genotoxic effects of biodiesel emissions in the human population.

Some characteristics of biodiesel need to be improved, even if it is less harmful to human health. These include the low volatility, high density, and high viscosity, which prevent pure biodiesel from being directly used in most diesel engines. The addition of alcohol to biodiesel and diesel can modify these characteristics, reducing the density and viscosity of biodiesel, so that overall fuel properties of the fuel blend are improved (Emiroglu and Sen 2018). The mixture ratio of biodiesel to diesel can change the property of biodiesel, resulting in the differences in the amount of emissions and biological responses (Karavalakis et al. 2009). Compared with 20% v/v biodiesel blended with mineral diesel, 7% v/v biodiesel blended with mineral diesel generates more PAHs, leading to an increasing level of single-strand DNA breaks in BEAS-2B and A549 cells (Kowalska et al. 2017). The lower amount of PM generated from 20% v/v biodiesel blended with mineral diesel increased mutagenicity in TA98 bacteria, but reduced cytotoxicity and genotoxicity in A549 cells, compared to 10% v/v biodiesel blended with mineral diesel (Botero et al. 2020). Therefore, choosing the correct blend ratio is crucial to determine the biological response to PM from biodiesel.

Even though biodiesel is thought to be a more appealing alternative to gasoline, it has been reported that biodiesel can have similar, if not more, toxic effects than diesel.(Topinka et al. 2012, Agarwal et al. 2018). It has been demonstrated that the size of the PM from biodiesel can be smaller than that of diesel, allowing a large number of toxic components, such as PAH, to be retained on its surface.(Yanamala et al. 2013). A high concentration of PAH is suggested to be the major reason for the lymphocytic infiltrate, impaired clearance of PM, and increased inflammatory cytokines and chemokines, when corn-based fatty acid methyl ester is used as the fuel (Yanamala et al. 2013). These findings were echoed by another study in which the emission exhaust from biodiesel increased the cellular production of pro-inflammatory cytokines IL-8 and IL-6 in BEAS-2B cells (Swanson et al. 2016). In addition, PM from biodiesel exhibited higher genotoxic and mutagenic activity than diesel duo to a higher fraction of organic component and transition metals (Co, Cu, Ni, Zn) induced oxidative stress and toxicity (Kisin et al. 2013, Agarwal et al. 2018). The conclusion was almost the same when animals were exposure to PM from biodiesel, with more severe cardiovascular toxicity and inflammatory respond than traditional diesel fuel (Brito et al. 2010). The outcomes may vary depending on the source of the biodiesel, the difference in operating conditions, and the constituents of PM, meaning that more in-depth studies are needed to be explored on the relationship between biodiesel and human health in the future.

261 **Table 1 Biological responses in vitro and in vivo to exhausts from alternative fuels in comparison to diesel**

Biodiesel	**Constituents of the Emission**	**Biological model (in vitro and in vivo)**	**Biological Response**	**Reference**
Commercial-Grade B99	（↑） NO_x （↓） CO_x, Hydro-Carbon, PM, Elemental Carbon, Organic Carbon	NHBE cells (5, 20,60 min)	（-） Cytotoxicity （-） Oxidative stress: HO-1, and CYP1A1	(Hawley et al. 2014)
Soy-based Fatty Acid Methyl Ester	（↑） Co, Cu, Ni, Zn, organic compounds （↓） Elemental Carbon, PM	*Salmonella typhimurium* TA98 without S9 microsomal activation	（↑） Mutagenic activity	(Kisin et al. 2013)
Soy Ethyl Ester and Soy Methyl Ester	（↓） CO, Hydro-Carbon, PM （↑） NOx	BEAS-2B Cells	（↑） Inflammation:IL-8 and IL-6 （-） Cytotoxicity	(Swanson et al. 2016)

Soy Biodiesel	（↓）CO, PM （↑）NO_x, SO2, Hydrogen Carbon, metals, PAH	HEK293T cells (50, 100, and 250 μg/mL of PM), for 48h; *Salmonella Strains* TA98 and TA100 with and without S9 microsomal activation (500, 100, and 50 μg/mL)	（↑）Cytotoxicity （↑）Mutagenicity	(Agarwal et al. 2018)
Corn-based Fatty Acid Methyl Ester	（↑）Organic Carbon （↓）Elemental Carbon	C57BL/6 mice (8-10 weeks,20.0 ± 1.9 g); Pharyngeal Aspiration--0, 9, and 18 μg/mouse of total carbon(60ul), 24 h, 7 days, and 28 days	（↑）Inflammatory response: immune cells in BALF, MPO activity in tissue homogenates, cytokines and chemokines in the BALF and lung homogenates （↑）Oxidative damage: protein	(Yanamala et al. 2013)

			carbonyls and 4-HNE in tissue homogenates （↑）Lung permeability: total protein in the BALF and in tissue homogenates （↑）Pulmonary damage: cytotoxicity in the BAL and tissue homogenates	
Soybean Ethyl Esters	（↑）Organic Carbon, S, Mg, K, Zn, Cu, Ca, and Fe, Black Carbon, Inorganics （↓）PM, VOCs	Adult male Balb/c mice (6–8 weeks, ~25g), 550ug/m^3, for 1h; Heart rate, heart rate variability, and blood pressure were measured	（↑）Blood: Leucocytes and lymphocytes, platelets （↑）Bone marrow activation: Metamyelocytes （↓）Bone marrow activation: Monocytes	(Brito et al. 2010)

		before exposure, 30 and 60 min after exposure; Bronchoalveolar lavage, blood, and bone marrow were collected to evaluate inflammation 24h after exposure;	（↑） BAL and tissue homogenates: total cell, neutrophils, macrophages （↑） Heart rate variability, blood pressure	
Palm Oil	（↓） PM, PAH	A549 cells for 24h; *Salmonella typhimurium* TA98 with S9 microsomal activation (10 uL sample)	（↑） Cytotoxicity （↑) Mutagenicity (↑) Genotoxicity	(Botero et al. 2020)
Soybean and Tallow Methyl Esters	（↑） NO, NO_2, and NO_x （↓） S, Na, K, Ca, Fe, Zn and Pb, PAH	Adult male Balb/C mice (6-8 weeks, ~25 g);	**Biodiesel Group** (↓) In blood: IgG1, IgG2a, IgE (↓) Inflammatory cells in BALF	(Timmerman et al. 2019)

		House dust mite model from 1-9 day, daily exposure to house dust mite for 1 h; from day 9 to day 17 (Filtered air; 600 mg/m^3 PM2.5 of diesel; 600 mg/m^3 PM2.5 of biodiesel)	(↓) Cytokines: Th2 (IL-4, IL-5, and TSLP), Th1 (TNF-alpha and IL-2), and Th17 (IL17) in BALF **Diesel Group** (↑) In blood: IgG1 (↓) Cytokines: Th2 --IL-4 in BALF **Biodiesel+House Dust Mite Group** (-) In blood: IgG1, IgG2a, IgE (-) Inflammatory cells in BALF (↓) Cytokines: Th2 (IL-4, IL-5, and TSLP), Th1 (TNF-alpha and IL-2), and Th17 (IL17) in BALF **Diesel+House Dust Mite Group**	

			(↑) Blood: IgG1, IgG2a (↑) Cytokines: IL-4 in BALF (↑) Inflammatory cells in BALF	
Waste Grease	（↑） Mn, Zn, Cu, and Mo, Total N-PAH, PM （↓） Pb, Total PAH, Elemental Carbon （-） PM2.5 mass concentrations	BEAS-2B cells (300, 150, and 50 μg/mL), for 24h.	（↓） Cytotoxicity	(Martin et al. 2017)
Waste Grease	（↓） Cu, Cr, and Zn, Water-soluble organic carbon and elemental metals	BEAS-2B cells (0,15, 30, and 60 μg PM/mL) for 24h	（↓） ROS levels （↓） Oxidative potential	(Martin et al. 2019)

Waste-Cooking-Oil and Butanol	（↓）NO$_x$, PM, Organic Carbon （↑）CO	A549 cells, for 24h CHO-K1 cells, for 3h	（↓）Mutagenicity （↓）Genotoxicity	(Yang et al. 2017)
Rapeseed Methyl Esters	（↓）PM	BEAS-2B cells (0−200 μg/mL), for 24 h	（↓）（-）Oxidative Potential （↑）Cytotoxicity （↑）Inflammation: IL-6	(Gerlofs-Nijland et al. 2013)
Coconut Oil	（↓）NO$_x$, NO2 （↑）CO, Hydro-Carbon	BEAS-2B cells, for 24h and 48h; 1, 10 and 25 ug/ml for organic matters; 25, 100 and 200 uM for B[a]P; 1, 5 and 10 uM for 3-NBA; and 1, 5 and 50 uM for 1-NP;	（-）DNA damage **Low Fractional** （↓）Inflammation （↑）Antioxidant **High Fraction** （↑）Inflammation （↓）Cytotoxicity	(Cervena et al. 2017)

Coconut Oil/Triacetin and Coconut Oil	Coconut Oil-Diesel （↑） NO_x, CO2 （-） Particulate mass and number Coconut Oil-Triacetin （↓） NO_x, Particulate mass （↑） Particulate number	pHBECs cells, for 30 min	**Coconut Oil-Diesel** （↑） Cytotoxicity （↑） Antioxidant: HO-1 mRNA （↑） Inflammation：IL-8 （↑） Xenobiotic metabolism：CYP1a1 mRNA **Coconut Oil-Triacetin** （↑） Cytotoxicity （↑） Antioxidant: HO-1 mRNA （↑） Inflammation：IL-8 （↑） Xenobiotic metabolism：CYP1a1 mRNA	(Vaughan et al. 2019)

Fatty Acid Methyl Esters/Hydrotreated Vegetable Oil	No Analyze	BEAS-2B and A549 cells (1, 10, 25, and 50 μg/mL), for 6, 24, or 48 h	（↓）Oxidative DNA damage and double-strand breaks. （↑）Single-strand breaks	(Kowalska et al. 2017)
Sewage Methyl Esters	（↑）　(-) NO （↑）NO$_2$ （↓）PM2.5	Adult male Balb/C mice (6–8 weeks, ~25 g), for 2 h; Filtered air (FA); DE-PM2.5: 600 and 1200 μg/m^3; BD-PM2.5: 600 and 1200 μg/m$^{3;}$ HR, HRV, and BP were determined 30 min after exposure; Bronchoalveolar lavage,	(-) Heart rate (↑) In Bone marrow: Eosinophils (↑) In blood: Leukocytes, Lymphocytes, Reticulocytes (↑) In BALF: Total cells, neutrophils, and macrophages (↑) Cardiovascular effects: ET-Ar and ET-Br in the peribronchiolar vessels (↑) Pulmonary endothelial	(de Brito et al. 2018)

		blood, Bone marrow, and lung tissue were collected after 24 h	dysfunction: ET-Br and VCAM-1 in bronchial epithelium	

↑ for increase, ↓ for decrease, - for no change

3.2 After-treatment technology

Numerous studies have examined the exhaust from biodiesel to determine whether they meet the requirements of clean combustion and low levels of pollutants, such as PM, PAH, HC, CO, NO, and NO_X (Agarwal et al. 2018). Because of the global push for zero-emissions, sustainable fuel has grown in popularity in recent years. However, emission technology is a critical component in accomplishing this. As a result, post-combustion after-treatments such as DOC, lean NOx trap (LNT), and selective catalytic reduction (SCR) are typically used in conjunction with DPF to control emission exhausts.(Ayodhya and Narayanappa 2018).

After-treatment technologies are the most effective way to reduce exhaust pollutants from conventional engines (Fig.3). The DPF is one of the most widely used technologies for removing PM from emissions, thereby significantly reducing the risk of developing cardiovascular and pulmonary diseases, which increases by 1.3 percent and 1.1 percent, respectively, for every 10 ug/m3 increase in PM2.5. (Lucking et al. 2011, Ji and Zhao 2015, Bengalli et al. 2019). Furthermore, CO, NO, unburned HC, and non-regulated emissions, such as aldehydes and PAH, are all toxic pollutants that need to be removed. The DOC is a device used to oxidise these emissions by a chemical reaction, leading to a high level of NO_2 and CO_2 (Castoldi 2020). Increased levels of NO_2 also has negative effects on biological responses (Timmerman et al. 2019). To solve this problem, LNT and SCR were introduced to turn NO_2 and NO into gasses found naturally in ambient air, N_2, H_2O, and CO_2, by adding reductants or catalysing other chemical reactions (Moos 2010, Zhao et al. 2020). Hence, to meet the upcoming stricter emission standards, the refinement of the after-treatment technologies is needed in the future.

Improving engine technology has the potential to reduce PM emissions and, as a result, the negative effects on health. Over the last few years, it has been demonstrated that emissions from traditional diesel engines containing carbon particles with PAHs retained to them cause inflammation and carcinogenicity in the lung (N. Yanamala, M. K. Hatfield et al. 2013); whereas emissions from modern diesel engines with after-treatment are not as carcinogenic but still induce inflammatory responses in the lung due to NO_2 (Timmerman et al. 2019). The new technology, DPF and DOC in combination with ultra-low sulphur diesel fuel, made a major contribution to the reduction of emissions by using the cooled exhausted gas recirculation system (Hesterberg et al. 2012, Akopian et al. 2016). Furthermore, this technology was upgraded in 2016, named SCR, which was installed on the engine directly. By increasing the temperature, this can be more efficient in reducing PM emissions and increasing NOX conversion efficiency (Granger et al. 2019, Greim 2019). As a result, the exhaust from engines installed with DOC and DPF showed less mutagenic and genotoxic in TA98 and TA102 than that from the conventional engine (Andre et al. 2015).

It has been reported that the efficiency of PM mass reduction can reach 90% by using DPF (Hawley et al. 2014). However, the efficacy would be even better using multiple after-treatments rather than single one alone (Akopian et al. 2016, Greim 2019). Studies have reported that even the exhaust from the biodiesel or processed by the DPF was reduced, the markers of oxidative stress (HO-1) and aromatic hydrocarbon response (CYP1A1) in human bronchial epithelial cells were still higher than that from the engine without DPF due to NO_2 and organic carbon component in filtered exhaust (Hawley et al. 2014). The DPF is thought to reduce the majority of the PM and HC in exhaust gases; however, the small amount of gas-phase PAH compounds or NO2 are potent enough to exert a similar or even greater cellular response than unfiltered exhaust (Brito et al. 2010, Botero et al. 2020). A second study alos found that the level of NO_2 in the exhaust was increased when the engine was installed with DPF, leading to a stronger inflammatory response (Karthikeyan et al. 2013). It is suggested that increased levels of HO-1 or TNF-α were due to NO_2 using a rat model of exposure to the exhaust generated from the SCR diesel engine (Tsukue et al. 2010). Nevertheless, the toxic emissions can be reduced significantly when multiple after-treatments are used in combination. The biological responses were compared between exhausts from different engines, either a combination of a DOC and a DPF, or the DOC alone (Douki et al. 2018). Superoxide dismutase was only induced when rats were exposed to the exhaust from the engine with DOC, rather than that equipped with both DOC and DPF. Therefore, the combination of these after-treatments will be better to reduce the adverse health impact of engine exhaust.

3.3 Vehicle type

Recently, government decision-makers and transportation authorities have emphasised the importance of developing a green transportation system in order to focus on energy conservation and emission reduction policies. New vehicle technologies have aided in the reduction of glasshouse gas emissions. Hybrid-electric vehicles, plug-in hybrid electric vehicles, compressed natural gas vehicles, and battery electric vehicles were introduced into the market with the goal of introducing sustainable and clean energy. (Hassouna and Assad 2020).

Considering the cost, energy, and environmental protection regulations, the usage of the hybrid-electric vehicles went up to 3% of all the on-road passenger vehicles since the large-scale promotion in 2000 (Holmen and Sentoff 2015). It is estimated that the low emission vehicles, including hybrid-electric vehicles, battery electric vehicles, plug-in hybrid electric vehicles, and other energy-saving and emission reduction vehicles, will increase up to nearly 50% in 2040 (Holmen and Sentoff 2015, Plotz et al. 2017). A study of real world usage 73,000 plug-in hybrid electric vehicles and 49,000 battery electric vehicles in the US and Germany, which also considered emissions generated during manufacture found that over the lifespan of the vehicle both had reduced CO2 emissions, but for battery electric vehicles over a 4 year span their CO emissions were greater than conventional vehicles (Plotz et al. 2017). In New York City, shared automated electric vehicles were introduced in 2017, which are expected to dominate most of the market share of vehicles by 2050 (Bauer et al. 2018). The economic and environmental impact of green house gases will be smaller than conventional internal combustion engine vehicles, with a reduction in green house gas emissions by 73% and energy consumption by 58% (Bauer et al. 2018). The use of electric vehicles is incfeasing globally, for example in Malaysia, plug-in hybrid electric vehicle usage is improving year by year, but driving range, vehicle ownership costs, and charging time are the major barriers to the widespread use of plug-in hybrid electric vehicles by consumers. (Adnan et al. 2017).

Conventional vehicles are powered by the internal combustion engine, while hybrid-electric vehicles are loaded with a larger battery and an electric motor. Plug-in hybrid electric vehicles are different from conventional vehicles and hybrid-electric vehicles, with an additional plug-in charger in addition to the standard engine (Sovacool 2010). Battery electric vehicles, a state-of-the-art innovation in the transportation sector, are considered superior due to the minimal greenhouse gas emission and the use of only electricity as energy. However, whilst there are no exhaust emissions, there are still some other factors (eg. the source of electricity and the number of charging station) influencing the implementation of these vehicles (Fig.4). To enable the wide use of battery electric vehicles, technologies to improve combustion efficiency of coal or gas power stations and improvements to the electric grid and charging stations should occur (Hassouna and Assad 2020). Furthermore, the additional emissions from power generation impede the widespread use of the battery electric vehicles from an air quality perspective. PM generated in coal-based power generators can contribute more than 70% of the total PM emitted by battery electric vehicles (Huo et al. 2013). Although battery electric vehicles are the best choice considering the energy saving compared to compressed natural gas vehicles, they produced more PM10 and PM2.5 in most provinces in China due to electricity generation derived air pollution (Huo et al. 2010) . In the future, if the proportion of coal-based electricity can be reduced and/or the combustion efficiency of coal-fired power plants can be increased, PM emissions related to battery electric vehicles energy supply can be reduced in countries which rely on coal fired power stations for electricity generation (Plotz et al. 2017). When it comes to other types of air pollution from electric vehicles, greenhouse gas emissions are mostly neglected due to the difficulty to measure (Wu et al. 2019).

Given environmental regulations and the negative health effects of petrol and diesel, compressed natural gas has been widely used in a variety of new types of vehicles (J. M. Luk, B. A. Saville et al. 2015). Compressed natural gas can also be used as a source of electricity generation for battery electric vehicles. However, although compressed nature gas can reduce emissions, the demand for natural gas will increase by 70% if electricity demand increases by only 5%. A 5% increase corresponds to electric vehicles traveling 18000km/year. The likely flow on effect would be an increase in the cost of natural gas power generation. As a result, lowering the cost of electricity production is a top priority. Clean energy, such as wind farms and solar panels, may be preferable to petrol fuels for producing electricity with low air pollutant emissions (B. K. Sovacool 2010).

Although the introduction of hybrid-electric vehicles, battery electric vehicles, and plug-in hybrid electric vehicles will increase the amount of PM generated by power stations, the impact on human health may be minimised because power stations are typically located outside or urban areas. Furthermore, recharging is frequently done at night, avoiding peak times when the power plant will not turn off to store spare capacity. As a result, it will not increase the load on the power plant, implying that there will be few additional emissions as a result of these vehicles (Sovacool 2010).

The environmental impacts of the batteries in electric vehicles have attracted significant attention in recent years. Lithium-ion batteries have been widely used in most electric vehicles, which can produce 5.1kg CO_2 e/kg. $LiMn_2O_4$, Al, and Cu are the main materials that need to be recycled to reduce the costs. However, during hydrometallurgical, intermediate physical, and direct physical recycling, there are risks that the metals may leak out and contaminate the water or atmosphere, posing a great threat to human health (Dunn et al. 2012). Although it is known that TRAP is harmful to human health, leading to pulmonary diseases, few studies have focused on the potential health impact of vehicles with new technologies. In addition, while tailpipe emissions from the engine may be reduced (Sommer et al. 2018), a significant amount of PM is produced by the brakes and tyres, which exist in all vehicles, including the electric vehicles (Sommer et al. 2018, Wahid 2018, Piscitello et al. 2021)

4. Conclusion

Human health is affected by TRAP. While sustainable fuels, after-treatment technologies, and new types of vehicles have been developed and implemented to reduce emissions, the chemicals contained within can still cause inflammatory responses, oxidative stress, and genotoxicity. However, available study limited, it is not fully discussed in this review that the other types of air pollution may have additional or synergistic effects on human health with traps, which still needs further study.In addition，there is still a significant gap in the relationship between air pollution caused by the use of renewable fuels and various after-treatment modes and the corresponding health risks. Even though tailpipe emissions have been decreasing as a result of various mitigation techniques, the percentage of non-exhaust emissions is increasing, indicating that more attention should be paid to driving conditions, traffic flow, and road and vehicle materials. As a result, given the situation to promote global environmental quality, the evidence presented in this review emphasises the need for future studies to focus not only on the implementation of various policies, but also on a deeper understanding of these new technologies and mitigating strategies.

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Declaration of competing interest

The authors declare no conflice of interest.

Figure legends

FIGURE 1. Particulate matter deposit in different locations in the lungs dependent upon the size of the particles, damaging the function and structure of the lung. PM can enter the bloodstream and damage other organs (eg. brain, liver, kidney, and intestine), along with cell death, genotoxicity, inflammation, and oxidative stress.

FIGURE 2. To alleviate the damage of TRAP PM to human health, sustainable fuel, after-treatment technology, and vehicle using new types of energy are widely used to perform emission shifting and fuel switching.

FIGURE 3. The combination of after-treatments (DFP: diesel particulate filter, DOC: diesel oxidation catalyst, SCR: selective catalytic reduction, LNT: lean NOx trap) is more effective to reduce the exhaust PM than either alone.

FIGURE 4. Exhaust emission and non-exhaust emission are the main sources of TRAP. Tire, road wear particles (TRWPs), and sand are major components of non-exhaust traffic emissions. The mitigation of emissions can be promoted with new types of electric vehicles. With the popularity of electric vehicles, the additional potential hazards to human health are caused by the battery recycling process and emissions from power plants.

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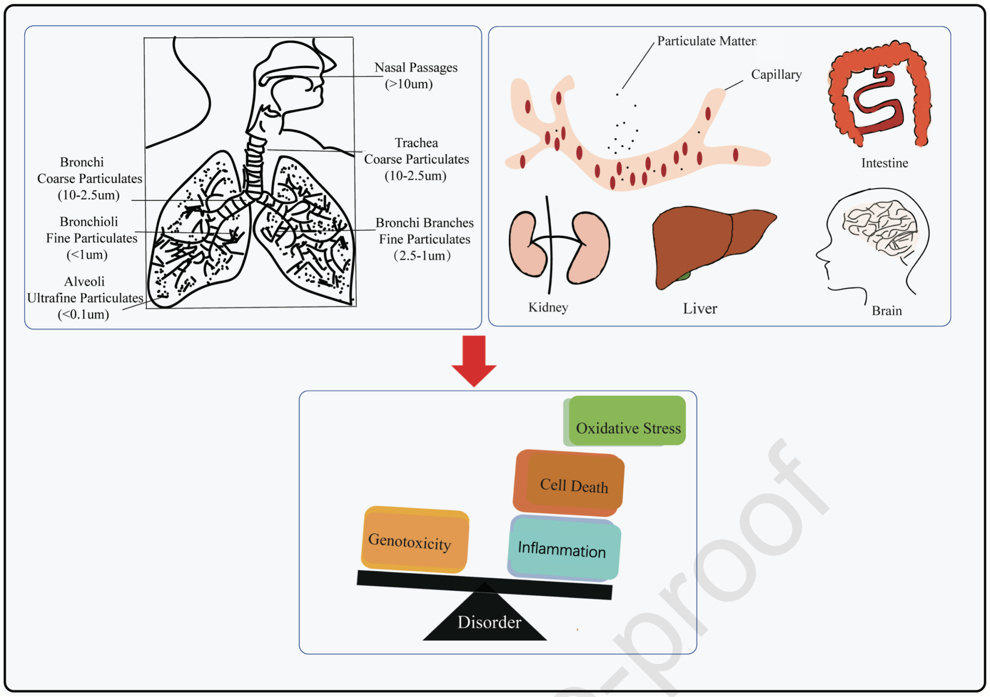
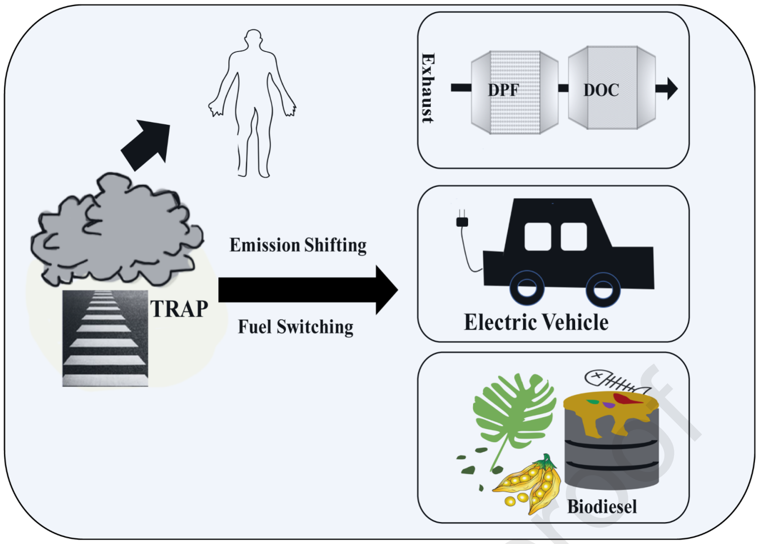
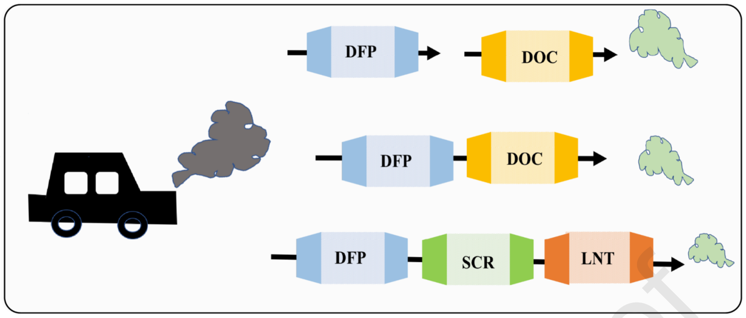
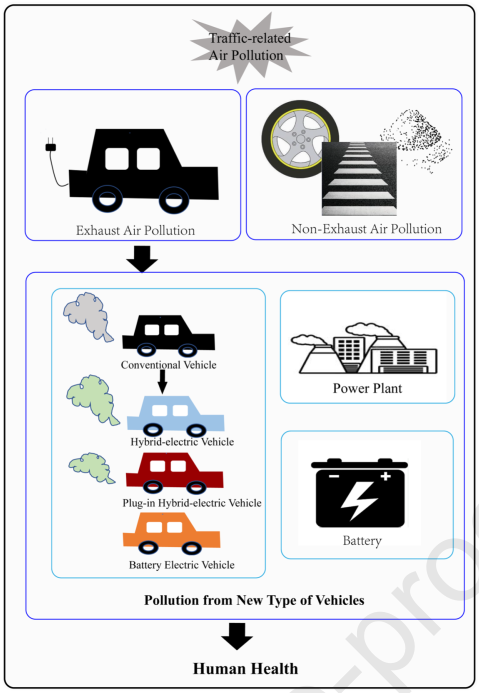

Nasal Passages
(>10um)
Trachea
Coarse Particulates
(10-2.5um)
Bronchi
Coarse Particulates
(10-2.5um)
Bronchioli
Fine Particulates
(<1um)
Bronchi Branches
Fine Particulates
(2.5-1um)
Alveoli
Ultrafine Particulates
(<0.1um)
Particulate Matter
Capillary
Intestine
Kidney
Liver
Brain
Oxidative Stress
Cell Death
Genotoxicity
Inflammation
Disorder


Exhaust
DPF
DOC
Emission Shifting
TRAP
Fuel Switching
Electric Vehicle
Biodiesel


DFP
DOC
DFP
DOC
DFP
SCR
LNT


Traffic-related
Air Pollution
Exhaust Air Pollution
Non-Exhaust Air Pollution
Conventional Vehicle
Hybrid-electric Vehicle
Plug-in Hybrid-electric Vehicle
Battery Electric Vehicle
Power Plant
Battery
Pollution from New Type of Vehicles
Human Health

Highlights

- TRAP has been targeted as important contributor to human health.
- Several strategies are emerging in the prevalent subject of reducing TRAP.
- The prevalence of technologies to reduce TRAP may increase the burden on other environmental pollution.
- The decrease of TRAP is supported to be accompanied by the low incidence of disease.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper