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A review of environmental emissions from asphalt plants and paving

Abstract

Asphalt is a black, thermoplastic, hydrocarbon material extracted from crude oil and widely used in road construction all over the world. In order to meet the requirements of construction technology, asphalt always needs to be heated to flow state in the process of mixing and paving, during which a large amount of asphalt fume is released. Asphalt fume is a complex mixture of inorganic compound gases, volatile organic compounds and particulate matter, which poses a serious threat to the natural environment and the health of practitioners.

This review presents HMA and WMA constituents and the potential health effects of criteria and Hazardous pollutants generated from asphalt pavement construction. Hot mix asphalt (HMA) and warm mix asphalt (WMA)are a major construction materials used for highway roads, building roads, airport runways, parking, and other pavement repairs in the worldwide. During HMA construction, a considerable number of volatile organic compounds (VOCs) are generated during asphalt pavement construction, and present negative effects on workers health.

Accurate identification, quantification and measurement of emissions during HMA and WMA paving operations were used to identify and quantify VOCs, SVOCs, hazardous air pollutants (HAPs) and polycyclic aromatic hydrocarbons (PAHs) in asphalt fumes during production and paving activities.

Keywords: asphalt pavement hot mixed asphalt, air pollutant emissions, transportation, warm mix asphalt

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Abbreviations: APHMA, asphalt pavement hot mixed asphalt; APE, air pollutant emissions; WMA, warm mix asphalt, HMA, hot mixed asphalt (HMA); WMA, warm mix asphalt; APE, air pollutant emissions; VOCs, volatile organic compounds ; HAPs, hazardous air pollutants

Introduction

Asphalt pavements have been produced since the late 1800s, in fact; asphalt occurred naturally has been used as a waterproofing agent for thousands of years. Asphalt plants are an important link in the nation's transportation infrastructure. Previous studies in USA mentioned that, more than 94% of the paved streets and highways were surfaced with asphalt. That's due to federal road highway departments have found that asphalt pavements were cost-effective to construct and maintain, smooth, exceptionally durable, and 100% recyclable. In addition, asphalt pavements can provide solutions for multiple forms of transportation, including bus rapid transit lanes; cycle tracks, walking trails, and airport runways.[1–3] Emulsified and Cutback asphalt were liquid asphalt materials utilized in repair, maintenance, and improvement roads, and various road constructions, such as: road mix, plant mix, maintenance mix and surface treatment. These products were prepared by mixing petroleum solvent like Kerosene and water with asphalt cement to make emulsified and Cutback asphalt.[4]

Hot mixed asphalt (HMA)

Hot-mixed asphalt is the principal raw material of paving roads. Asphalt was consisted of various hydrocarbon compounds and its derivatives, which has complicated species and different chemical stability, playing as anti-adhesion, water-proof and anti-corrosion.[5–7] HMA create greenhouse gas (CO_2, N_2O, and CH_4) and volatile organic compounds (VOCs) emissions in pressure and at ambient or infrared temperature, ultraviolet may promote the release of VOCs, directing to the deterioration of its performances.[8–10] The particulate matter (PM) concentration levels emitted from HMA plants contain PM10 and PM2.5 (PM less than 10 and 2.5 µm in diameter, respectively), hazardous air pollutant (HAP), metals, and HAP organic compounds. Gaseous emissions related with HMA plants include the criteria pollutants carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), and volatile organic compounds (VOC), as well as volatile HAP organic compounds.[11]

HMA was utilized mostly as paving substance and made up of a combine of liquid asphalt cement and aggregate; it had been mixed in metrical quantities and heated. HMA facilities can be generally categorized as either batch or cylinder mix plants, according to process by which the raw materials were mixed.[12] In a batch mix plant, the aggregate was dried first, and then transferred to a mixer where it was mixed with liquefied asphalt cement. In a cylinder mix plant, a cyclical dryer dried the aggregate and mix it with the liquefied asphalt cement. After mixing, HMA was transferred to a storage bin or silo, where it was stored temporarily. From the silo, the HMA was emptied into trucks, which ship the substance to the job positions.[13]

Asphalt pavement mixing facilities

Asphalt was generally mentioned as bitumen, asphalt material or road oil, asphalt cement or filler, and was mainly produced in oil refineries.[14] Asphalt plants, or asphalt mixing facilities were considered as industrial activity, in which mix liquefied asphalt ligament (likewise named asphalt filler or concrete) with crushed rocks, gravel, and sand (together named aggregates) for create paving substance. Asphalt ligament was adhesive substance that binds the aggregates with each other, also it was obtained from distillation process in oil refining activity.[15]There was quantity of emissions released from asphalt pavement mixing facilities, which may be create health or environmental risks.[16] Figure 1 presents plot showed production and use of asphalt.[17]

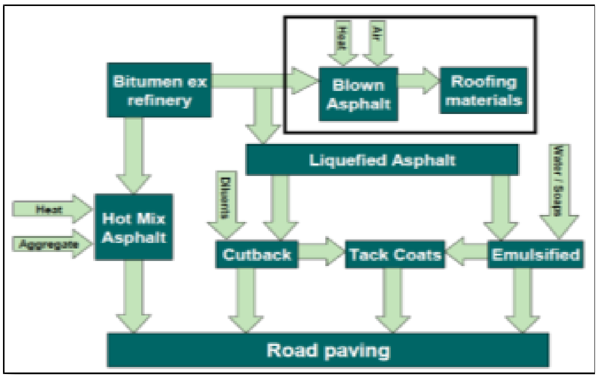

Figure 1 Overview of the production and use of asphalt.

In fact, over a decade ago, EPA reviewed emissions from asphalt plants and mentioned that such facilities are not main source of air pollution and was subsequently delisted by EPA.[18] Consequent studies by different regulatory agencies had verified that emissions from asphalt pavement mixing facilities do not comprise an environmental or public health risks.[19]

The majority of emissions at asphalt mixing facilities arise from the combustion of fuel, such as natural gas, that were utilized to dry and heat aggregate and to maintain the temperature of the asphalt hot. At times, observable emissions may be coming from an asphalt plant's chimney, but in most all circumstances this was just water steam from the drying of aggregate at high temperatures (NAPA).[20]

In USA, Asphalt material was the majority recycled and reusable substance; it could be reused once more in new mixtures of the asphalt pavement.[21] Reclaimed asphalt pavement materials (RAP) contains asphalt ligament and aggregates, which act as raw substance for new asphalt. The ligament and aggregate were reactivated by exchange part of the glue and aggregate substance needed for new asphalt.[22] EPA mentioned that RAP were unexpected to make hazardous fugitive particulates[23] and could really utilize to minimize PM from unpaved roads. Previous studies had mentioned that draining water from RAP storage was not trouble[24–28] also RAP was generally utilized as filler substance in paving highway roads.[29] Add to that, RAP materials from another industries had been practice recycled into asphalt cement, such as: rubber of utilized tires, glassware, and furnace slag. Tools and equipment used in paving roads might involve biggest silos (which was utilized to storage asphalt substance), environmental control (which was limit chimney emissions), and stockpiles for raw materials (which was store RAP and aggregates). Also, asphalt pavements tools had include liquid tanks (which were stored both liquefied asphalt and fuel).[30–33] Other pieces of biggest equipment contain the aggregate dryer cylinder (which was utilized to hot and remove water from the aggregate). Finally, asphalt substance used in pavement was store in silos for limit periods of time before it was loaded into trucks and transferred into work places.[34–36]

The environmental impact of asphalt plants and pavement

Asphalt plants may be found in rural, suburban, and urban areas, and most of them were identified as acceptable neighbors who were intermeshed with their district and dedicated to sustainable developments. However, there was a lot of misleading and often daunting information about asphalt plants and asphalt products. Hence, it was important to realize what fact was, what fiction was, and what the differences were between various types of asphalt products. As with any industrial factory, it was useful to interpret what happens behind the gates at an asphalt plant (NAPA, 2014). Several information around emissions from asphalt during hot utilization set by Occupational Safety and Health Administration (OSHA), which concened on occupational exposure studies; although, there were no studies had focused on pollutants source profiles and emission rates.[37–43] Measurements related to occupational exposure during asphalt paving had recorded high concentration levels of PM, VOCs, and PAHs which released from hot-mix asphalts.[44–51]

HMA was effective guideline in most countries, though modern technologies were obtainable to make asphalt specified with lower temperature.[52] Warm mix asphalt mixtures (WMA) were usually generated at temperatures 20 to 40ºC lower than classic HMA.[53] Various techniques were used to make various WMA types, such as usage of additives like wax, foam bitumen, zeolites, modifiers.[54–55] Temperature change was suitable way to limit emission rates of pollutants from paving road operation. In addition, old early studies had been confirmed effect of temperature change on limit emissions rate.[56–58] Asphalt in the high temperature mixing and paving operations will create a lot of fume, which is risk to the health of employees and the natural environment. The irritating odor of asphalt fume seriously affects the air quality of life of nearby residents (Zhou).[59] Moreover, additives of different chemical constituents were mixed with various types of WMA, might be lead to occupational risks for workers and surrounding environment.[60–61] Also, RAP was utilized in WMA techniques. RAP was contaminated with tar, which include high levels of harmful PAHs, more than 200 VOCs, and cyclic alkanes, which were released to some extent during road pavement.[62,63]

Literature review

Connolly (2001) compared emissions from an asphalt plant to emissions from site of industrial and residential sources. The study mentioned that "the low annual emissions from an asphalt plant were equal or below some other common sources: such as VOCs emissions from one bake house working for around two weeks or from household fireplaces during one year".[64]

Volatile organic compounds (VOCs) and asphalt

VOCs are volatile organic compounds that act in the formation of ground-level ozone (O_3) through photochemical reactions with nitrogen oxides (NOx), in the presence of sunlight. They also encourage formation of PM via composite chemical reactions including emissions of other smog precursors, such as nitrogen oxides (NOx), ammonia (NH_3) and sulphur dioxide (SO_2). PM and O_3 were the main components of smog.[65] Environmental agencies had categorized VOCs as hazardous pollutants because of their harmful and risk effects on human health.[66]Moreover, it affecting the formation of ground ozone levels.[67] During paving processes, the oil solvent or the water evaporate after the liquid asphalt was applied, leaving the asphalt cement down. This evaporation of oil solvent resulted in the emission of VOCs. The use of cutback asphalt generated many VOCs emissions than emulsified asphalt as it contained larger quantities of oil solvents.

USEPA regulates both indoor and ambient VOCs emissions and each province set its own VOCs emission regulations, source tracking, and caps. Solvents Emissions Directive was major agency in Europe for limit VOCs concentration levels.[42] Ministry of Environmental Protection in China had legislated numerous guidelines for organic

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emission levels in air showed that "asphalt materials had emitt VOCs, which were hazardous to workers and the surroundings environment. VOCs or non-methane hydrocarbons (NMHC) were organic compounds that had a high vapor pressure and easy evaporation properties at usual room temperatures" showed that "VOCs released from asphalt substances occurred not only during the manufacturing activity but also during the work period. Emissions of VOCs from hot bitumen had fast and short effect on workers during bitumen creation, transport of asphalt mixes, and road pavement" verified that "workers with weekly exposure to bitumen fumes had more health problems". In addition showed that "VOCs emissions were not only hazardoud to the pavement workers and the surroundings environment, but they also degrade the behavior of the bituminous binder". From this thought, limitation of VOCs emissions from bituminous fumes requires the use of bituminous materials with lower VOCs emissions studied emission rates for RAP; the results showed that a high decrease in odor was nearly reached at value around 40% RAP.[68] found that "increase of VOCs emissions from RAP by at higher temperatures.

Recent studies presented that emission of VOCs and other non–combustion-related sources, in USA megacities These VOCs emissions were principal for ground O_3 formation, secondary organic aerosol (SOA), and a main constituent of PM2.5 with considerable public health effects. They can be categorized into three pathways: (i) solvent evaporation, (ii) volatilization of solutes, and (iii) off-gassing of compounds not existing in product formulations (e.g., degradation by-products) as was the case with asphalt-related emissions.[69] Studies of point source asphalt manufacturing facilities had calculated emission factors (EF) for criteria pollutants, greenhouse gases, VOCs, PAHs, and total organic carbon reported that "the resulting VOCs emissions from liquid asphalt manufactured were lower than that found in 2017. In 2019, the overall VOCs were 19.4 kg/ton asphalt, while in 2017 they were 20.7 kg/ton asphalt ".

Material and methods

Sampling and analysis

Photo Ionization Detection (PID) and Flame Ionization Detection (FID) techniques were utilized to quantify VOCs concentration levels. Morever, Ambient Volatile Organic Canister Sampler (AVOCS) and Gas Chromatograph/Mass Spectrometer (GC/MS) were utilized to collect and quantify individual VOCs PM, VOCs, and 16 EPA-PAHs were collected by adsorption charcoal tubes and/or membrane filters Sampling had used calibrated vacuum pump with flow rate (2 l/min). Table 1 & Figure 2 showed schematic figure for sampling points utilized during the emission measurements.

Table 1 Emission factors for source category asphalt road paving, batch mix hot mix asphalt plant, drum mix hot mix asphalt plant, and cutback asphalt

Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
Road paving with asphalt					
NMVOC	16	g/mg asphalt	3	100	USEPA, 2004
TSP	14 000		10	140 000	
PM10	3 000		4	10 000	
PM2.5	400		1	2 000	
BC	5.7	% of PM2.5	2.8	11	USEPA, 2011
Batch mix hot mix asphalt plant					
NMVOC	16	g/mg asphalt	3	100	USEPA, 2004
TSP	15 000		10	100 000	
PM10	2 000		4	10 000	
PM2.5	100		4	1 000	
BC	5.7	% of PM2.5	2.8	11	USEPA, 2011
Drum mix hot mix asphalt plant					
NMVOC	15	g/mg asphalt	3	100	USEPA, 2004
TSP	13 000		10	140 000	
PM10	3 000		20	10 000	
PM2.5	700		1	2 000	
BC	5.7	% of PM2.5	2.8	11	USEPA, 2011
Cutback asphalt					
NMVOC	30 kg/mg asphalt		10	100	VDI (2007)

Figure 2 Hot mix asphalt (HMA) and Warm mix asphalt mixtures (WMA).

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Adsorption charcoal tubes and filters were extracted and analyzed individually. Filters were extracted twice in ultrasonic water bath using 2 ml toluene, then filtered solution and completed into 3 ml by toluene (called Solution A). The resin of the PAH adsorption tubes was extracted twice in ultrasonic water bath within a 30 minute period using 2 ml of toluene, then filtered solution and completed into 5 ml by toluene (called Solution B) Solution were added to standard of 16 EPA-PAH, then analyzed by GC/MS according to ISO 16000-6.

Results and discussion

A case study-1 (VOCs concentrations at worker breathing zones)

Cui mentioned that "the paving process used paver for loading trucks by asphalt concrete. Rolling process was final procedure, in which compactors roll asphalt material many times to get hard, fixed, and smooth road ". Machine and working force wanted for each phase were shown in Table 2. In rolling process, concentration levels of VOCs monitored in air surrounding the driver and at the pavement surface was equal zero VOCs emissions were occur from machines, vehicles and equipment utilized for pavement. VOCs resulted from the machines were 0 - 16 ppm During the paving process, measured VOCs were occured from two sources (as shown in Figure 3) Volatilization of asphalt from the truck into the paver, and 2) Volatilization of asphalt during paving.[67–70]

Table 2 Equipment and working force wanted for each phase[5]

Phase	Equipment	Working force
Milling	Milling machine	I driver
	Trucks (several)	I driver per
	Bulldozer	I driver
	Cleaner machine	I driver
Paving	Paver	I driver
		2 operators
		2-3 Laborer
Rolling	Trucks (several)	I driver per
	Rollers (several)	I driver per
	Blower	I operator

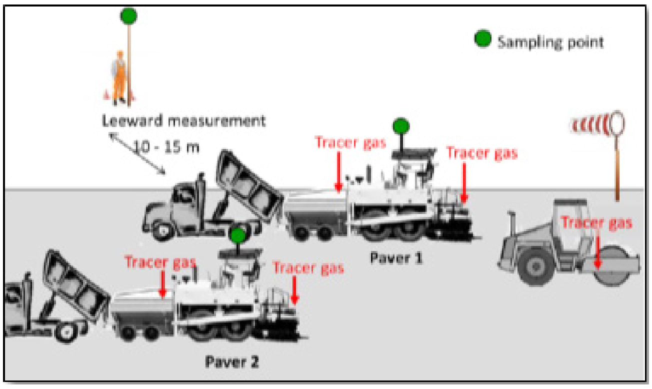

Figure 3 Schematic for sampling points used during the emission measurements.

Table 3 was summarizing the VOC concentrations which detected at worker breathing zones during the asphalt paving process The VOCs concentrations were measured at different positions around the workers as shown in Figure 3.

A case study-2 (comparative study)

Presented a comparative study between the measured VOCs before and after asphalt pavement in four streets in Giza, Egypt during summer (high temperature) and winter (low temperature), Table 4. It showed a significant increase of VOCs concentration levels after asphalt pavement in all measured sites.

A case study-3

Jackson and Zarus presented a summary of pollutants concentrations which measured at different sites surrounding road paving with asphalt (μg/m^3), Table 5.

A case study-4

Table 6 presented emission factors formulated for HMA sources. Table 7 showed annual emissions of criteria pollutants, VOCs, PAHs, and Heavy metal for regular cylinder and batch mix HMA plants in Figure 4. The emissions recorded in Table 7 were focused on emission factors formulated for HMA plants and following assumptions:

I. Dryers of cylinder and Batch mix plants were fueled with either fuel oil or natural gas.

II. PM emissions from load-out and silo material were totally PM10.

III. Average loss amount of asphalt due to heating was about 0.5 %.

IV. Average temperature of HMA load-out was equal 325°F = 162.8°C.

Figure 4 Workers during the asphalt paving process.

The regular HMA plant had 2 asphalt storage tanks, which were equal 50ft=15.24 m long and 8ft=2.43 m in diameter. It was mentioned that storage tanks need heating capacity around 200,000Btu/hr=50399.15kcal/hr, loss of temperature equal 60Btu/ft2=0.19kW/m² of tank surface area. The asphalt storage tanks were kept at 325°F=162.8°C continuously for 5 months the HMA plant operates.

A case study-5 (Annual emissions from HMA facilities)

Table 8 summarizes annual emissions for regular cylinder and batch mix HMA plants The Table 8 mentioned to emission sources of pollutants released from cylinder and batch mix plants. It summarized emission levels from the load-out operations, dryer/mixer, loaded trucks, asphalt storage, diesel fumes, paved and unpaved road dust, and aggregate processing (RAP crushing, screening, and conveyor)

Criteria air pollutants comprise PM10, NOx, SO_2, CO, and VOCs (USEPA, 2000). Emissions were estimated using emission factors formulated for HMA plants and the following assumptions (USEPA):

Dryers used fuel oil or natural gas (estimates were presented for both types).

I. PM emissions from load-out and silo material were totally PM10.

II. Annual production rate of asphalt from HMA plants; where batch mix plant was 100,000ton/yr.

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III. Annual production rate of asphalt from HMA plants; where cylinder mix plant was 200,000ton/yr.

IV. HMA plants had 2 asphalt storage tanks with capacity 18,000gallon.

Table 3 VOC concentration levels at worker breathing zones (mg/m^3)

Worker title	Position	Case No.	1	2	3	4	5	6	7	8	9	10
		max	9.03	6.77	0	2.26	4.52	0	4.52	0	18.06	0
Driver	A	mean	5.42	2.48	0	1.13	1.81	0	2.48	0	9.26	0
		St. Dev.	2.89	2.13	0	1.13	1.97	0	1.58	0	4.09	0
		max	0	0	4.52	6.77	2.26	0	0	0	0	4.52
	B	mean	0	0	1.35	2.48	1.35	0	0	0	0	2.48
		St. Dev.	0	0	1.81	2.36	1.11	0	0	0	0	1.88
Operator		max	6.77	2.26	9.03	20.32	2.26	4.52	2.26	0	2.26	0
	B0	mean	3.16	0.9	4.97	9.93	0.9	2.48	1.13	0	1.58	0
		St. Dev.	1.81	1.11	3.32	8.28	1.11	1.88	1.13	0	1.03	0
		max	4.52	0	42.89	13.55	6.77	2.26	2.26	0	0	4.52
	C	mean	2.48	0	24.38	5.87	2.26	1.58	1.13	0	0	2.93
		St. Dev.	1.88	0	11.77	3.8	2.26	1.03	1.13	0	0	1.45
		max	2.26	15.8	33.86	24.83	11.29	2.26	20.32	2.26	22.58	9.03
	C0	mean	13.77	14.67	71.79	30.25	16.03	2.26	7.9	0	4.97	32.96
		St. Dev.	9.65	7.09	22.95	16.96	8.94	2.26	3.39	0	3.61	13.05
Laborer		max	27.09	24.83	101.59	51.92	33.86	6.77	11.29	0	9.03	54.18
	D	mean	1.13	7.68	16.03	11.96	7.9	1.35	6.32	1.58	9.71	5.87
		St. Dev.	1.13	4.42	10.17	6.85	4.43	1.11	7.87	1.03	8.14	2.89
		max	27.09	54.18	139.97	90.3	47.41	18.06	36.12	6.77	79.01	121.91
	D0	mean	19.19	29.35	81.27	50.12	22.58	7.22	18.96	3.84	50.79	62.99
		St. Dev.	5.99	17.66	38.33	26.9	15.8	4.6	8.58	1.76	22.96	29.09

Table 4 Concentration of VOCs in Maryoutia St. and El Zomor St. before and immediately after asphalt per ppm

Time (min.)	Before asphalt				After asphalt			
	Summer season		Winter season		Summer season		Winter season	
	Maryoutia	El Zomor	El Orouba	Feisal	Maryoutia	El Zomor	El Orouba	Feisal
1	130	159	149	115	1753	1985	1730	1550
2	128	158	150	116	1770	1990	1753	1561
3	136	156	154	117	1790	1993	1770	1573
4	120	169	159	119	1810	1999	1790	1575
5	126	165	143	125	1810	2011	1794	1576
6	115	172	146	121	1820	2195	1810	1590
7	124	179	147	123	1821	2196	1810	1597
8	146	175	149	130	1823	2200	1810	1597
9	129	178	148	128	1823	2201	1813	1598
10	134	188	149	127	1830	2212	1820	1603
11	138	182	144	131	1833	2215	1820	1610
12	146	184	159	133	1834	2215	1821	1613
13	147	185	156	134	1834	2230	1823	1619
14	138	189	156	135	1834	2239	1825	1621
15	145	190	160	137	1835	2243	1830	1621
16	137	193	167	138	1838	2243	1833	1625
17	129	199	168	131	1840	2249	1834	1630
18	135	210	169	131	1841	2251	1834	1635
19	139	205	161	132	1841	2254	1835	1636
20	145	209	160	129	1843	2259	1841	1639
21	131	212	154	125	1843	2260	1843	1639
22	167	215	153	127	1843	2264	1843	1640
23	162	213	154	124	1844	2279	1844	1643
24	160	206	149	129	1849	2284	1848	1656
25	154	217	160	123	1851	2290	1849	1660
26	169	219	164	124	1854	2295	1851	1660
27	154	224	163	126	1856	2297	1854	1661
28	169	225	160	133	1860	2310	1860	1667
29	159	215	155	132	1864	2315	1891	1669
30	145	220	150	130	1895	2310	1895	1680

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Table 6 Matrix of emission factors developed for HMA sources

Plant type	Source	Criteria pollutants	HAPs	Other pollutants
Batch mix	Dryer, hot screens, and mixer	PM10, NOx, CO, SO_2, VOC	24 organic HAPs 9 metal HAPs	CO_2 4 other organics 3 other metals
	Hot oil heaters		22 organic HAPs	
	Load-out	PM, CO, VOC	41 organic HAPs	3 other organics
	Yard emissions	VOC	19 organic HAPs	
Drum (Cylinder) mix	Dryer	PM10, NOx, CO, SO_2, VOC	58 organic HAPs 11 metal HAPs	CO_2 15 other organics, 6 other metals
	Hot oil heaters	22 organic HAPs		
	Load-out	PM, CO, VOC	41 organic HAPs	3 other organics
	Silo filling	PM, CO, VOC	28 organic HAPs	3 other organics
	Yard emissions	VOC	19 organic HAPs	

Conclusion

This review is conducted to reflect the characteristics of asphalt materials and its fumes in ambient air. The results can be summarized as follows:

I. Asphalt pavement was engineered as product possessed of 95 % aggregates (sand, gravel, and crushed rocks), and 5 % liquefied asphalt.

II. Asphalt paving produced complex mixtures of organic compounds, including hazardous pollutants.

III. Case studies summarized emission levels from central and batch mix asphalt plant operations.

IV. Hot mixed asphalt (HMA) was formed at lower temperature and release all types of volatile organic compound (VOCs) pollutants during paving, but there are few studies on VOC emissions from in situ asphalt pavement mixtures.

V. Warm mix asphalt (WMA) was formed at lower temperature.

VI. When asphalt heated, it would produce a large number of poisonous fumes, greatly threatening the natural environment and practitioner's health.

VII. Emission levels were affected by different factors, such as temperature, asphalt fume, and wind speed and direction.

VIII. During the asphalt pavement, VOC and HAPs emissions would have risk impacts on workers and surrounding environment.

IX. To quantify and characterize the emitted fumes, gas chromatography-mass spectrometry (GC/MS) technique has been used.

X. ATSDR reviewed the AP-42 emission factor for Asphalt plants and pavement to determine air pollutants emissions.

XI. Workers who were responsible for cleaning job of pavement surface beside the paver would suffer highest risks with cancer, followed by the paver driver and operators.

XII. VOCs and HAPs concentration levels at workers breathing zones, worker positions, hours of work, and body weight were factors affecting carcinogenic risk.

XIII. ND: Not detected. (detection levels varied) ; NS: Not Sampled

XIV. EMEG: Environmental Media evaluation Guide comparison value

XV. MRL: Minimal Risk Levels

XVI. NAAQS: National Ambient Air Quality Standards

XVII. RBC: Red Blood Cell

XVIII. OSHA-PEL: Occupational Safety and Health agency - Permissible Exposure Limits

XIX. E PA: Environmental Protection Agency

XX. ATSDR: Agency for Toxic Substances and Disease Registry

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Conflicts of interest

There are no conflicts of interest.

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