ECOLOGICAL MODELING OF POLLUTANTS IN ACCIDENTAL FIRE AT THE LANDFILL WASTE

by

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Paper presents tire as flammable material and some examples of tire fires in the world. Uncontrolled tire fires produce a lot of smoke and air pollutants, including benzene and polycyclic aromatic hydrocarbons. Great heat leads to the generation of pyrolytic oil which, when mixed with the fire extinguishing agent, contaminates the surrounding soil, surface water, and underground water. Paper analyzes and presents in particular the emission factors of incomplete burning of waste car tires. Metal dust emissions have been presented, volatile organic compound emissions, slightly volatile organic compound emissions, and emissions of polycyclic aromatic hydrocarbons. Evaluation of the effect on the air quality has been graphically presented by modelling of uncontrolled tire burning by using EPA "SCREEN 3 MODEL".

Key words: *fire, pollutants, waste, modeling*

Background, aim, and scope

In the developed countries, the tires that cannot be used on vehicles are considered waste tires. They are recycled and turned into raw rubber and raw rubber products, they could be turned into fuel and some lesser portion is disposed on landfills [1]. Data from the states where cars are traditionally greatly used are credible indicators: The United States of America reported the production of over 290 million items of used rubber; the EU annually collects approximately 250 million and Japan 80 million such items, [2].

It is estimated that the legal and illegal landfills all over the world contain over four billion waste tires and the USA alone hold between 2 and 3 billion [2, 3], which are mostly relics from the past, since most part of waste tires have been processed into fuel in the past few years.

Waste tires, when properly disposed, do not cause pollution of soil, water nor air, because they are inert in interacting with these environments [4-6]. The derivatives derived by processing waste tires are used for construction of sports surfaces [7-9], as fuel [10-13], in the industry and construction [14, 15]. For example, in 2005, in the USA, 52% of waste tires were used as fuel, 16% in construction, 2% was exported, 4% was used in other ways, and 14% was disposed on the landfills [16].

However, there are several real, highly hazardous situations when possible damaging effect of waste tires on the environment exists and they are particularly related to the inflam-

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Table 1. Typical composition of tires for the motor vehicles

Material	Content, [%]
Styrene butadiene	46.78
Carbon black	45.49
Aromatic oil	1.74
Zinc oxide	1.40
Stearic acid	0.94
Antioxidant 6C	1.40
Wax	0.23
Sulphur	1.17
Accelerator CZ	0.75

mability of tires and the possibility of having fires on the landfills. Such fires usually emit highly damaging products into the environment, hence the long-term efforts of the developed countries to safely and thoroughly resolve the issue of waste tires [17, 18]. D. Clack, one of the leading experts in fire protection in the State Department of Ecology in Washington D. C., humorously addresses the seriousness of the matter of fire hazard even on the legal landfills saying: "Waste tires landfills are divided in two groups: landfills which have already burned and those that are waiting to burn."

Tires are a mixture consisting of vulcanized or cross-linked polymers, carbon black, dispersed oil, sulphur, synthetic fibres, pigments, chemical additives, and steel or fibreglass. Tire manufacturers use various formulation recipes for the production (tab. 1).

Tire is a very flammable material. Even when densely packed, there could be sufficient oxygen to make burning possible. Tire fires are most frequently started as deliberate, malicious acts, and they produce a great amount of heat, due to which it is very difficult to access the fire and extinguish it. The released heat energy from tire burning is extremely high 37600 kJ/kg compared to coal, which is 27200 kJ/kg.

There are examples of some tire fires that lasted for months, even in the developed countries that have the means and equipment to put them out. For instance, the Rhinehart car tire fire in Winchester, Va., USA, lasted almost nine months and the smoke plume was 100 m high and spread 80 km, causing pollution in three states. This uncontrolled tire fire produced a lot of smoke and toxic air pollutants, including benzene and polycyclic aromatic hydrocarbons (PAH). Great heat causes the generation of pyrolytic oil which, when mixed with the fire extinguishing agent, contaminates the surrounding soil, surface water, and ground water.

Tire fires may vary and pollutant concentrations cannot be accurately predicted. There are many factors influencing the dispersion of emissions generated in fires. Some of these factors depend on: the fuel quantity, flame temperature, meteorological conditions, area topography, *etc*.

Materials and methods

In our country, there had been no thorough researches that deal with this extremely important environmental issue of incomplete waste combustion, due to which we had to refer to foreign literature. In this manner, we are also drawing attention to the necessity of an urgent introduction of waste treatment without burning, and particularly to the catastrophic environmental consequences that uncontrolled and frequent waste burning at illegal and other dumping places may have.

In literature documents [19-24] have published two papers [21, 23] about emission factors for incomplete combustion of waste that includes waste tires as well.

The basis for the determination of the stated emission factors is in the paper used by U. S. EPA [19]. For particle matter (PM), mostly metals and soot, public literature offers numerous emission data that range from about 119 g/kg of incompletely combusted tire emission [24] to carbon monoxide (CO) emission estimated at 122.8 g/kg of burnt tire ([19] and NTIS PB90-126004). Data from the stated literature are presented in a more detailed way in tab. 2.

Additional researches have been conducted and published [22], from which we are presenting the following emission factors of a certain toxic matter separately in mg/kg of burnt tire (tabs. 3 and 4).

As it can be seen in the tables above, emitted quantities of toxic matter depend on the quantity of burnt tire. Based on the existing experience, we believe that a burning tire heap is practically impossible to put out. Emission analysis of the products of waste or recycled tire burning, if they are in one heap, would show environmentally unacceptable results.

Table 2. Metal dust emission during car tire burning

Pollutant	[$mgkg^{-1}$] of tire	Pollutant	[$mgkg^{-1}$] of tire
Aluminum	3.07	Iron	11.8
Antimony	2.94	Lead	0.34
Arsenic	0.05	Magnesium	1.04
Barium	1.46	Nickel	2.37
Calcium	7.15	Selenium	0.06
Chrome	1.97	Silicon	41.0
Copper	0.31	Sodium	7.68
TOTAL	81.24		

That is why additional protection measures have to be taken, that the tires are disposed in smaller heaps, which are sufficiently distanced from one another, but also with a limited height, so that transfer of fire from one heap to another would not occur. Table 5 presents the

Table 3. Emissions of volatile organic compound (VOC) and slightly volatile organic compound (SVOC) during uncontrolled car tire burning

Class	Compound	Emission [$mgkg^{-1}$]	Compound	Emission [$mgkg^{-1}$]
VOC SVOC	Benzaldehyde	314.4	Ethynylbenzene	160.75
	Benzen	2180.5	Ethynyl, methylbenzene	394.65
	Benzodiazine	15.55	Isocyanobenzene	318.55
	Benzofuran	12.55	Limonene	460.0
	Benzothiophene	20.5	Toluene	1367.7
	Butadiene	234.6	Methylindene	228.25
	Dihydroindene	41.7	Methylthiophene	9.05
	Xylenes	928.95	Methyl, ethenylbenzene	66.15
	Dimethylhexadiene	59.6	Methyl, methylethenylbenzene	390.75
	Dimethyl, methylpropyl benzene	7.45	Methyl, methylethylbenzene	197.45
	Dimethyldihydroindene	19.85	Methyl, propylbenzene	20.8
	Ethenylbenzene	776.6	Ethyleneindene	41.45
	Ethenylcyclohexene	66.90	Methylethylbenzene	152.15
	Ethenyl, dimethylbenzene	15.45	Propylbenzene	78.3
	Ethenyl, methylbenzene	16.8	Styrene	652.7
	Ethenyldimethylcyclohe xene	175.2	Tetramethylbenzene	127.85
	Ethenylmethylbenzene	131.25	Thiophene	41.25
	Ethylbenzene	377.95	Trimethylbenzene	60.90
	Ethyl, methylbenzene	405.15	TOTAL	10569.7

Table 3. (Continuation)

Class	Compound	Emission [mgkg^{-1}]	Compound	Emission [mgkg^{-1}]
	1-Methylnaphthalene	279.15	Ethyl, dimethylbenzene	136.2
	1,10-Biphenyl, methyl	5.55	Hexahydroazepinone	411.8
	2-Methylnaphthalene	389.95	Indene	421.3
	Benzisothiazole	86.95	Isocyanonaphthalene	4.7
	Benzo[b]thiophene	22.1	Methylbenzaldehyde	43.3
	Biphenyl	269.8	Phenol	533.05
	Cyanobenzene	370.25	Propenylnaphthalene	11.75
	Dimethylbenzene	620.05	Propenyl, methylbenzene	261.8
	Dimethylnaphthalene	109.6	Trimethylnaphthalene	157.9
	TOTAL			4135.2

Table 4. Polycyclic aromatic hydrocarbon (PAH) emissions during uncontrolled car tire burning

Class	Compound	Emission [mgkg^{-1}]	Compound	Emission [mgkg^{-1}]
PAH	Naphthalene	650.95	Benz[a]anthracene	92.3
	Acenaphthylene	711.55	Chrysene	81.2
	Acenaphthene	1368	Benzo[b]fluoranthene	78.9
	Fluorene	223.65	Benzo[k]fluoranthene	86.85
	Phenanthrene	245	Benzo[a]pyrene	99.35
	Anthracene	52.95	Dibenz[a, h]anthracene	0.55
	Fluoranthene	398.35	Benzo[g, h, i]perylene	112.7
	Pyrene	92.75	Indeno[1, 2, 3-cd]pyrene	68.55
	TOTAL			4363.6

Table 5. Minimum distance between tire heaps disposed in a safe manner

Length of opposite sides [m]	Height of disposed tires [m]						
	2.4	3	3.7	4.3	4.9	5.5	5.5
7.6	17.1	18.9	20.4	22.3	23.5	25	25.9
15.2	22.9	25.6	28.3	30.5	32.6	34.4	36
30.5	30.5	35.4	39	41.8	44.5	47.2	50
45.7	30.5	35.4	39	41.8	44.5	47.2	50
61	30.5	35.4	39	41.8	44.5	47.2	50
76.5	30.5	35.4	39	41.8	44.5	47.2	50

example of minimum distance between the heaps disposed in a safe manner, not permitting fire transfer.

These minimum distances depend on the height and dimensions of the heap [23].

Considering the vicinity of the neighbouring plants and landfill, we believe that the most favourable distance between the disposed tire heaps is 17.1 m, the maximum disposed tire heap height 2.4 m, and the maximum length of the opposite sides of the dumping area 7.6 m. In

Table 6. Pollutant emissions in case of tire burning

Group of emitted matter	Emission factor [gkg^{-1}]	Emission [kg]	Emission [gs^{-1}]	Emission [$gs^{-1}m^{-2}$]
Particle matter (mostly metals and soot)	119	1190	330	4.342
Carbon monoxide	122.8	1228	341	4.487
Volatile organic compounds	10.569	105	29	0.382
Slyghtly-volatile organic compounds	4.1352	41	11	0.145
Polycyclic aromatic hydrocarbons	4.3636	44	12	0.158

that case, about 10 t of tire could be burnt in one heap (7.6 m × 10 m), leading to emissions stated in tab. 6.

It has been estimated that the burning of a 10 t tire heap would last about 24 h, based on which emission in g/s has been calculated, which is a necessary input for the calculation of matter dispersion through air. For the calculation of dispersion of suspended matter with the most unfavourable conditions and vertical stability 6 (G) and wind velocity of about 1 m/s, EPA "SCREEN3 MODEL" Scenario 1.2. referring to surface emissions (tabs. 7 and 8).

Table 7. Data for TSCREEN model

File Access data from previous scenarios	CO	PM	PAH
Initial form of release	Gaseous release type	Fugitive/Windblown dust emission	Gaseous release type
Municipal solid waste landfills	Workbook scenario 2.9	Workbook scenario 1.2	Workbook scenario 2.9
Emissions from municipal solid waste landfills			
Source parameters			
Emission rate, [gs^{-1}] Enter emission rate (Qm), if unknown enter boxed variables below to calculate	341	330	12
Based on user input, SCREEN model has been selected SCREEN3 Model INPUT			
Release parameters			
Release height above ground (Hs), [m]	2	2	2
Area of the emitting source (A), [m^2]	76	76	76
Urban/rural classification	R	R	R
Fenceline distance, [m] Enter the minimum distance from the centre of the source to the plant fence line	10	10	10
Flag pole receptors, [m] Enter receptor height above ground (Zr)	2	2	2
Receptor locations Do you have specific locations where you would like pollutant concentrations to be calculated (Y/N)	N	N	N

Table 8. SCREEN3 model (inputs data)

Simple terrain inputs	CO	PM	PAH
Source type	Area	Area	Area
Emission rate [$gs^{-1}m^{-2}$]	4.48684	4.34210	0.157895
Source heighe [m]	2.000	2.000	2.000
Length of larger side [m]	8.7178	8.7178	8.7178
Length of smaller sider [m]	8.7178	8.7178	8.7178
Receptor height [m]	2.000	2.000	2.000
Urban/rural option	Rural	Rural	Rural

Table 9. Summary of SCREEN3 model results for CO

Dist [m]	Conc [mgm^{-3}]	Stab	U10M [ms^{-1}]	USTK [ms^{-1}]	Mix Ht [m]	Plume Ht [m]	Max dir [deg.]
10	65770	6	1.0	1.0	10000	2.0	45
100	5952.0	6	1.0	1.0	10000	2.0	45
200	2642.0	6	1.0	1.0	10000	2.0	45
300	1488.0	6	1.0	1.0	10000	2.0	31
400	959.30	6	1.0	1.0	10000	2.0	35
500	674.00	6	1.0	1.0	10000	2.0	38
Max 1-hour concentration at or beyond 10 m							
10	65770	6	1.0	1.0	10000	2.0	45

Legend for SCREEN3 (tabs. 9, 10, and 11): Dist – distance from centre of the area source; Conc – maximum ground level concentration; Stab – atmospheric stability class (1-A, 2-B, 3-C, 4-D, 5-G, 6-F); U10M – wind speed at the 10 m level; USTK – wind speed at stack height; Mix Ht – mixing height; Plume Ht – plume centreline height; Max dir – wind direction relative to long axis for maximum concentration

Table 10. Summary of SCREEN3 Model Results for PM

Dist [m]	Conc [mgm^{-3}]	Stab	U10M [ms^{-1}]	USTK [ms^{-1}]	Mix Ht [m]	Plume Ht [m]	Max dir [deg.]
10	63650	6	1.0	1.0	10000	2.0	45
100	5760.0	6	1.0	1.0	10000	2.0	45
200	2557.0	6	1.0	1.0	10000	2.0	45
300	1440.0	6	1.0	1.0	10000	2.0	31
400	928.30	6	1.0	1.0	10000	2.0	35
500	652.30	6	1.0	1.0	10000	2.0	38
Max 1-hour concentration at or beyond 10 m							
10	63650	6	1.0	1.0	10000	2.0	45

Pollutant dispersion has been determined per Gaussian puffs and plume model for immediate sources, eq. (1):

$$C(x,y,z)=\frac{Q}{\sqrt[3]{2\pi}\sigma_x\sigma_y\sigma_z}\exp\left\{-\left[\frac{(x-ut)^2}{2\sigma_x^2}+\frac{y}{2\sigma_y^2}\right]\right\}\cdot\left\{\exp\left[-\frac{(z-H)^2}{2\sigma_z^2}\right]+\exp\left[\frac{(z+H)^2}{2\sigma_z^2}\right]\right\} \quad (1)$$

Table 11. Summary of SCREEN3 Model Results for PAH

Dist [m]	Conc [mgm^{-3}]	Stab	U10M [ms^{-1}]	USTK [ms^{-1}]	Mix Ht [m]	Plume Ht [m]	Max dir [deg.]
10	2315.0	6	1.0	1.0	10000	2.0	45
100	209.50	6	1.0	1.0	10000	2.0	45
200	92.980	6	1.0	1.0	10000	2.0	45
300	52.370	6	1.0	1.0	10000	2.0	31
400	33.760	6	1.0	1.0	10000	2.0	35
500	23.720	6	1.0	1.0	10000	2.0	38
Max 1-hour concentration at or beyond 10 m							
10	2315.0	6	1.0	1.0	10000	2.0	45

Pollutant dispersion has been determined per Gaussian puffs and plume model for sources (routine emission), eq. (2):

$$C(x, y, z) = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left(\frac{-1}{2}\frac{y^2}{\sigma_y^2}\right)\left\{\exp\left[\frac{-1}{2}\frac{(z-H)^2}{\sigma_z^2}\right] + \exp\left[\frac{-1}{2}\frac{(z-H)^2}{\sigma_z^2}\right]\right\} \quad (2)$$

where $C(x, y, z)$ is the concentration at the point, Q – the emission rate of pollutant, H – the effective source height, σ_y and σ_z are standard deviation of the concentration of pollutants in the horizontal and vertical directions, and u – is the wind speed.

Equation (1) is used for calculating the pollutant concentration at the time of not controlled burning, while eq. (2) is used for calculating the pollutant concentration at the time of controlled burning. Of toxic gases, example of dispersion of CO, which is heavier than air, has been given. Calculation of carbon monoxide dispersion has been conducted for the most unfavourable conditions with the vertical stability of 6 (G) and wind velocity of 1 m/s, using EPA SCREEN3 MODEL in accordance with Scenario 2.9 referring to surface emissions, tab. 9.

Results

The results have been presented on the map of the town of Kovin, Serbia, showing that the ground concentrations of CO and suspended matter in the industrial zone are average 1000 and 2500 mg/m^3, respectively, which can be considered a catastrophic situation, considering that these values significantly exceed the prescribed concentration limit values for CO and PM of 5 mg/m^3 and 0.12 mg/m^3, respectively.

In the residential area, CO and PM concentrations model for the most unfavourable conditions can exceed 500 mg/m^3 during tire burning. Concentrations of PAH, being part of the tire fire emissions, have been included in the calculations fig. 1, tab. 12.

Figure 1. Presents the table of calculated concentrations of CO, PM, and PAH, and a graphical representation of concentrations in the town of Kovin

Table 12. Table of calculated concentrations of CO, PM and PAH ("worst case")

Distance [m]	CO [mgm^{-3}]	PM [mgm^{-3}]	PAH [mgm^{-3}]
100	5952.0	5760.0	209.50
200	2642.0	2557.0	92.980
300	1488.0	1440.0	52.370
400	959.30	928.30	33.760

Discussion

This methodology presents the application of EPA "SCREEN3 MODEL" for the dispersion of toxic pollutants that are generated during the uncontrolled burning of automobile tires that can occur due to improper tire storage. These results provide the evaluation of time and concentration of pollutant dispersion in the local atmosphere.

Results for the dispersion of pollutants CO, PM, and PAH for "worst case" are shown in tab. 12. "Worst case" deals with the most unfavourable conditions that produce the highest concentrations of pollutants in observed areas. Also, possibilities under different weather conditions are shown in tabs. 13-15.

Table 13. Table of calculated concentrations of CO (alternative case)

Stability	6	6	6	5	5	5	3	3	3	3
Wind velocity [ms^{-1}]	1	3	4	1	3	4	1	3	4	6
x [m]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]
10	65770	21920	1644.0	44310	14770	11030	23220	7739.0	5804.0	3870.0
100	5952.0	1984.0	1488.0	3537.0	1179.0	880.60	1071.0	356.90	267.70	178.50
200	2642.0	880.70	660.50	1326.0	442.10	330.20	319.40	106.50	79.850	53.230
300	1488.0	496.10	372.00	693.80	231.30	172.70	157.90	52.650	39.490	26.320
400	959.30	319.80	239.80	438.30	146.10	109.10	105.50	35.170	26.390	17.580
500	674.00	224.70	168.50	304.90	101.60	759.00	83.090	27.700	20.770	13.850

Table 14. Table of calculated concentrations of PM (alternative case)

Stability	6	6	6	5	5	5	3	3	3	3
Wind velocity [ms^{-1}]	1	3	4	1	3	4	1	3	4	6
x [m]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]
10	63650	21220	15910	42880	14290	10720	22470	7940.0	5167.0	3745.0
100	5760.0	1920.0	1440.0	3423.0	1141.0	855.70	1036.0	345.40	259.10	172.70
200	2557.0	852.30	639.20	1283.0	427.80	320.90	309.10	103.00	77.270	51.510
300	1440.0	480.10	360.00	671.40	223.80	167.90	152.90	50.950	38.210	25.480
400	928.30	309.40	232.10	424.10	141.40	106.00	102.10	34.030	25.530	17.020
500	652.30	217.40	163.00	295.10	98.350	73.760	80.410	26.800	20.100	13.400

The table presents the alterations of concentrations at certain distances, having different stabilities and wind velocities. Having seen the results, we concluded that the most unfavourable case is at the vertical stability of 6 and the wind velocity of 1 m/s. Concentration of

Table 15. Table of calculated concentrations of PAH (alternative case)

Stability	6	6	6	5	5	5	3	3	3	3
Wind velocity [ms^{-1}]	1	3	4	1	3	4	1	3	4	6
x [m]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]	[mgm^{-3}]
10	2315.0	771.50	578.60	1559.0	519.80	389.80	817.00	272.30	204.30	136.20
100	209.50	69.820	52.360	124.50	41.490	31.120	37.680	12.560	9.420	6.2800
200	92.980	30.990	23.240	46.670	15.560	11.670	11.240	3.746	2.810	1.8730
300	52.370	17.460	13.090	24.410	8.1380	6.104	5.538	1.853	1.390	0.9264
400	33.760	11.250	8.4390	15.420	5.1410	3.856	3.713	1.238	0.9282	0.6188
500	23.720	7.9070	5.9300	10.730	3.5760	2.682	2.924	0.9747	0.7310	0.4874

product for CO is 65770 mg/m^3, for PM is 63650 mg/m^3 and for PAH is 2315.0 mgm^{-3}. Programmes for the dispersion of pollutants in the air deal with the worst possible case, the so-called "worst case". From the tables we infer that the highest concentrations are produced at higher categories of instability and lower velocities. There is a substantial influence of input data and it is evident that the greatest influence on the results has the category of stability (higher category of stability and higher concentration) and the velocity of wind (lower velocity, higher concentration of pollutants). Other input results are strictly defined by the SCREEN3 programme that is a part of TSCREEN programme. Required input data are shown in tab. 7 and 8. The input data for the area of pollutant emissions influence the concentration to a small extent. Emission rate is literature data and it cannot be altered.

Despite the efforts to use successful solutions of managing used tires especially concerning reuse, recycling, processing, turning into fuel, *etc*., some of those tires, in less developed countries, end up on legal and illegal landfills suffering all the risks of such action.

Until recently, in Serbia, waste tires were disposed on the legal and illegal landfills, used as a fuel in the improper and technologically primitive manner in brick factories, lime factories, etc, and they were serious ecological problem. There was a unification of legal regulations in this field with the regulations of the EU in 2009, and the regulation of treating the waste tires as valuable resource of various rubber products production or as fuel in cement factories was introduced. The routine of disposal on the landfills was terminated. There is 1.4 billion waste tires in the world each year; and in underdeveloped countries they are disposed on the legal and illegal landfills but in the developed countries they are, directly or after being processed (retreaded), used on the vehicles, they are processed (recycled) into useful products or they become fuel.

As far as managing the used tires in 2009, the world leaders are the UE countries, which include Norway and Switzerland that are managing 95% of waste tires; they are followed by Japan with 91% and the USA with 89%. The remaining tires (differentiating to 100%) are disposed on the landfills. The three leaders are managing approximately 44% of the world production of used tires.

Disposal of the waste tires on the legal and illegal landfills is not damaging to the environment all by itself, but such landfills could cause great air, soil and underground water pollution should they burn and they would cause great damage subsequently.

Relative to the overall viability, it is most recommendable to process (retread) used tires and reuse them for their initial purpose. For the freight vehicles program in most developed countries used tires are retreaded and only after several retreading they are discarded as waste tires, and in transport vehicles, due to the different components of tires and greater moving velocities, such process is not possible.

Waste tires (entirely) have limited use and in limited areas, whereas recycling of waste tires produces raw materials and products that have appliance in construction and rubber products production, in production of steal, *etc*., which boost the market of rubber recycling products.

The use of waste tires as a fuel is ecologically more acceptable than the use of traditional fossil fuels because a pneumatic tire uses 30% of natural rubber, which is renewable energy source, and its chemical compounds do not pollute the environment more than fossil fuels while burning in controlled conditions.

Waste tires (entire or cut) are used as safe, alternative fuel in cement factories and as basic fuel in thermal power plants. Due to agreeable economical effect the demand of the cement factories for the waste tires as additional fuel continues to grow and the amounts of rubber which cement factories could spend are virtually limitless.

Conclusions

Based on the presented calculated values of PAH in the range from 23.79 mg/m^3 to 216.10 mg/m^3, it can be concluded that it is necessary to take very comprehensive and stringent measures that guarantee that burning of tires will not occur, and in case it does happen, fire has to be localized and extinguished as soon as possible, since otherwise, it may have catastrophic consequences on the life and health of the factory workers, the population, as well as the environment.

Recommendations and perspective

As a safety measure, safe distances have been proposed in the storage of tires, so that if fires occur, favourable conditions for extinguishing fire could be achieved. Most importantly, measures need to be implemented in reducing the quantity of waste tires that accumulate at the dumping/storage locations, which can be achieved by regulating the companies that recycle tires.

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