Environmental Hazard Identification Technique Developing of Territorial Administrations Strategy as Exemplified in Siberian Federal District

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Abstract. This work, on the example of the Siberian Federal District of the Russian Federation, presents a method for determining mass airbursts of combustion gaseous eco-toxicants, as a technique for assessing the contributory environmental load on the atmosphere. Potential environmental hazards are analyzed by mass of contaminated airbursts. A comparison of specific gross toxicants' emissions in territorial entities of the Russian Federation is made.

1. Introduction

Currently, the scale of human activities' impact on the biosphere is compatible with the scale of geological and geochemical processes. At the same time the environmental fire hazards in industrial plants, urban infrastructure, rural areas and municipalities are among the most frequent and important for their long-term effects; as they are accompanied by airbursts of harmful substances and produce extremely high levels of pollution in some territories.

In Russia, annually, average number of fires is 160.000 with damage over 13 billion rubles. About 11.000 people are killed and more than 12 000 people are traumatized on fires. Fires destroy and damage more than 30 000 pieces of equipment, 127.000 buildings, with a total area of over 6.5 million m^2; 4.8 million m^2 being residential areas, capable of providing accommodation of about 200 thousand people [1,2].

In fire conditions, burning action usually occurs in diffusion mode. Substances and materials do not burn out completely and, along with soot particles, are emitted into the environment in the form of gaseous and liquid products of combustion. Heat fluxes, regulating gas exchange and fire spreading, ensure transfer of pollutants in space. It is found that combustion products contain from 50 to 150 different types of toxic chemical compounds. These agents affect both biocenosis components and human health [3-5]. The most common atmospheric fire pollutants are oxides of carbon, sulfur, nitrogen, chloride and cyanide hydrogen, various classes of hydrocarbons, alcohols, aldehydes,

benzene and its homologues, polyaromatic compounds (PAC) and dioxins. Most of these chemicals are harmful to living organisms. For example, dioxins, PAC and others can cause cancer in humans, and sulfur oxides cause the death of vegetation.

In addition, the fire heat factor has a negative effect on humans, flora and fauna (a temperature of 70 °C is critical for humans). In the burning zone temperature can rise to 800–1500 °C, and sometimes higher (firestorm, burning of metals).

Smoke from severe fires causes changes in daylight and air temperature, affects the amount of precipitation. In addition, smoke aerosol and gaseous products, interacting with air moisture, cause acid rains or fogs [6]. Contaminated fumes, dews and rains cause illness and death of plants. Huge smoke air pollutions (forest fires, oil well fires) reduce the amount of solar radiation reaching the Earth's surface, which leads to climate changes lasting several days, weeks, months. These factors affect growth of plants, particularly if they coincide with the growing season [7].

Given the magnitude of environmental effects of fires and urgency of the problem, in this paper a retrospective analysis of fire statistics in regions of the Siberian Federal District is performed; total environmental load on the atmosphere from industrial fires is estimated on priority toxic substances.

2. Objects and methods of research

The Siberian Federal District (SFD) was founded in 13 of May, 2000, and is one of the largest districts of Russia, with the area of 5.114.8 thousand km^2 (30 % of the country), with a population of 20.207.400 people, the population density of 3.9 persons per km^2; the share of urban population is 71.1 %. On the district territory 12 sub-federal entities of the Russian Federation are located: 4 Republics (Altai, Buryatia, Tyva, Khakassia); 3 Territories (Altai, Trans-Baikal, Krasnoyarsk); 5 Regions (Irkutsk, Kemerovo, Novosibirsk, Omsk, Tomsk). Table 1 shows some of social indicators of sub-federal entities of the SFD.

Table 1. Social indicators

Sub-federal entity	Population, thous. people	Area, thous. km^2	Urban population, thous. people	Rural population, thous. people	Population density, people per km^2	Industrial facilities, thous. units
Altai Republic	211.6	92.9	62.3	149.3	2.2	54.3
Buryatia Republic	973.8	351.3	577.4	396.4	2.8	181.8
Tyva Republic	311.7	168.6	163.5	148.2	1.8	75.4
Khakassia Republic	534.0	61.5	374.4	159.6	8.8	127.2
Trans-Baikal Territory	1090.3	431.8	626.3	464.0	2.7	206.4
Krasnoyarsk Territory	2852.8	2366.7	2131.8	721.0	1.3	520.2
Altai Territory	2390.6	167.9	1170.3	1220.3	15.4	325.7
Novosibirsk region	2731.1	177.7	2060.7	670.4	15.1	421.5
Tomsk region	1070.1	314.3	732.1	338.0	3.3	253.6
Irkutsk region	2418.3	774.8	1762.7	655.6	3.4	439.3
Kemerovo region	2734.1	95.7	2348.5	385.6	30.4	488.2
Omsk region	1973.8	141.1	1323.0	650.8	14.9	457.3

In the SFD there are large industrial enterprises of chemical, petrochemical, food, timber, woodworking, pulp and paper industry, energy, machine building, metallurgy, and many others, more than 3.5 million of industrial and technosphere objects.

The SFD takes 30 % of the area of Russia, and a large area of the District is covered with woods; the population is about 20 %. Therefore, the state of fire safety in the District significantly affects fire national safety statistics [8].

For the convenience of research, all objects of technosphere are combined in 4 large groups in view of fire hazard's features.

1. Residential objects – 2196.6 thousand: hostels, residential buildings of state (municipal use), private houses, yurts, garden and dacha communities, mobile residential facilities (trailers), outbuildings.

2. Industrial objects – 473.2 thousand: warehouses of flammable and combustible liquids, flammable gases; timber and lumber, and other combustible materials; factories and warehouses, boiler rooms; critical infrastructure; gas stations; mills; grain elevators; enterprises of cargo and passenger transportation; vehicle maintenance facilities.

3. Public buildings – 795.4 thousand: Commercial and residential (markets, shops, distribution centers); educational institutions (universities, academies, colleges, schools, boarding schools); child care institutions (day care, camps, orphanages; schools of sports, music, arts, additional education); cultural institutions (theaters, museums, philharmonics, libraries) and leisure activities (movie theaters, night clubs, circuses, zoos, gyms); medical institutions (hospitals, clinics, dispensaries, pharmacies, medical and health centers, spas, health resorts); administrative building of the Executives; buildings of tax service, research institutions, banks, post offices, objects of public services, utilities, catering, hotels, objects of social services and other administrative buildings.

4. Other facilities – 35.3 thousand buildings. These are: religious objects, buildings under construction or reconstruction, buildings for agricultural purposes (vegetable stores, hothouses), livestock, farming, poultry, as well as other objects that are not city properties.

Analysis of statistical data submitted in annual reports of Siberian regional center of EMERCOM of Russia, shows that the SFD has 16 fires for every 10 thousand inhabitants; about 12 people are killed in fires per every 100 thousand of inhabitants. Out of every 100 facilities, where fires have occurred, 20 units burn down completely and can not be restored. Average damage caused by a fire is 52.8 thousand rubles.

Table 2. Averaged general indicators of fire hazards in regions of the SFD in 2001–2014

Sub-federal entity	Основные показатели последствий пожаров			
	Fires, thous. per year^{-1}	Direct material damage, mln. rub. per year^{-1}	Killed in fires, persons, per year	Fired objects (buildings) units per year^{-1}
Buryatia Republic	1548.2	148.2	134.5	292
Altai Republic	391.7	19.1	22.7	79
Tyva Republic	531.9	25.7	24.5	112
Khakassia Republic	770.5	37.5	55.6	125
Trans-Baikal Territory	2111.4	102.8	142.5	395
Krasnoyarsk Territory	4784.1	238.9	371.9	339
Altai Territory	4321.3	210.8	314.4	887
Novosibirsk region	4146.3	202.1	301.5	823
Tomsk region	1594.1	77.9	129.1	329
Irkutsk region	4341.5	263.3	343.6	837
Kemerovo region	4574.2	224.2	316.8	902
Omsk region	3171.6	156.1	239.8	760
SFD	32286.8	1706.6	2396.9	6480

Calculation of the mass of burnt material and the amount of toxic substances, emitted to the atmosphere, was made using L.K. Isaeva's method, enhanced by the authors [4,9]. We proposed the use procedural documents for estimating of the mass of burned materials, namely: Technological certificate, fire certificate with the facility layout; fire Description; fire site inspection Protocol; expert's findings; Act of official investigation; Certificate of property damage; reference from insurance companies about material damage; explanatory memorandum of the owner / responsible person; eyewitness testimonies.

When estimating the amount of burnt materials, they were divided into the following groups:

- Wood (construction and decoration materials: logs, timber, lumber, plywood, chipboard and fiberboard, wood sculpture, wood waste: sawdust, wood chips, wood);
- Fossil fuels (coal, lignite, peat);
- Petroleum (crude oil, petrol, diesel, fuel oil, bitumen, oil);
- Rubber products and materials;
- Styrofoam, polystyrene (structural, thermal insulation finishing materials);
- Paintwork materials (paints, varnishes, drying oil, solvents, thinners, hardeners);
- PVC (linoleum, floor tiles, insulation of wires, cables, finishing plastics);
- Cellulose (paper, wallpaper, cardboard);
- Synthetic, wool, cotton, fabrics;
- Products and materials from leather, synthetic leather;
- Polyurethane foam (thermal insulation and composite materials);
- Roofing and waterproofing materials (roofing, synthetic coatings, plastics, mastics);
- Cereals, industrial crops, fodder products for animals;
- Combustible gases.

Table 3 shows the average values of burnt materials' mass in the regions of the SFD.

Table 3. Average mass of materials burnt in fires at technosphere facilities in regions of the SFD (2001–2014)

Object of study	Amount of burnt materials, tonnes per year^{-1}
Buryatia Republic	68704.2
Altai Republic	13509.5
Tyva Republic	19821.3
Khakassia Republic	35594.0
Trans-Baikal Territory	89251.4
Krasnoyarsk Territory	224118.8
Altai Territory	128880.6
Novosibirsk region	109040.7
Tomsk region	63240.5
Irkutsk region	181786.3
Kemerovo region	126631.4
Omsk region	88412.0

Having known the mass of burnt materials and specific emissions of toxic substances during combustion of various materials, we calculated airbursts of toxicants.

3. Results and Discussion

It is established that, during technosphere fires, average of 211.204 tons of pollutants emit annually into atmosphere of towns and cities of the Siberian Federal District. Mass of priority fires' pollutants, emitted into the atmosphere, is shown in Table 4.

Table 4. Mass of priority fires' pollutants, emitted into the atmosphere in the SFD (2001–2014)

Toxicant	Mass of pollution, ton per year^{-1}	Toxicant	Mass of pollution, ton per year^{-1}
Acrolein	32.7	Nitrogen monoxide	1067.2
Ethanol	5.4	Carbon monoxide	57909.3
Ammonia	14.8	Pyridine	1.4
Acetaldehyde	47.5	Propylene	4.3
Acetylene	107.8	Propyl alcohol	10.6
Acetone	132.2	Vanadium pentoxide	$1.8 \cdot 10^{-2}$
Benzpyrene	$2.9 \cdot 10^{-4}$	Soot	35152.6
Benzene	27.2	Hydrogen sulphide	15.5
Ethylene	5.4	Styrene	4.9
Vinyl chloride	6.6	Toluene	5.2
Nitrogen dioxide	380.8	Toluene diisocyanate	4.2
Sulphur dioxide	104.7	Acetic acid	5.9
Carbon dioxide	43131.7	Phenol	21.2
Smoke (ultrafine particles)	72950.1	Formaldehyde	4.3
Cresol	5.5	Phosgene	2.1
Xylene	9.8	Hydrogen chloride	28.2
Naphthalene	6.2	Hydrogen cyanide	23.9

Ecotoxicants are usually divided into four classes of hazard to humans and biota components. Calculations revealed that, as a result of fires in the Siberian Federal District, 9.4 tons of highly toxic substances, 1234.1 tons of highly hazardous substances, 111,033.7 tons of moderately hazardous substances and 98,926.8 tons of little hazardous substances are annually polluted into the atmosphere. Table 5 shows the averages of air pollution from fires by toxic substance hazard categories.

Table 5. Averages of air pollution from fires in cities of SFD classified by toxic hazard (2001–2014)

Object of study	Total pollution, ton per year^{-1}	Air pollution by toxic substance hazard categories, ton per year^{-1}			
		1	2	3	4
Buryatia Republic	12914.0	$4.6 \cdot 10^{-1}$	68.8	6731.2	6113.6
Altai Republic	2303.2	$1.0 \cdot 10^{-2}$	13.1	1190.2	1099.9
Tyva Republic	2859.6	$6.8 \cdot 10^{-2}$	14.5	1488.3	1356.8
Khakassia Republic	5514.6	$1.1 \cdot 10^{-1}$	24.1	2967.2	2523.2
Trans-Baikal Territory	14639.4	$8.1 \cdot 10^{-1}$	93.4	8178.0	6367.2
Krasnoyarsk Territory	38779.2	2.1	221.0	19635.5	18920.6
Altai Territory	24698.4	1.3	144.4	13026.1	11526.6
Novosibirsk region	21583.3	1.2	134.5	10430.2	11017.4
Tomsk region	12726.4	$5.4 \cdot 10^{-1}$	69.8	6770.3	5885.8
Irkutsk region	30211.2	1.7	185.9	16518.7	13504.9
Kemerovo region	26952.3	1.4	160.6	14286.4	12503.9
Omsk region	18022.8	$9.0 \cdot 10^{-1}$	104.0	9811.6	8106.3
The SFD	211204.0	9.4	1234.1	111033.7	98926.8

Let's compare the following data on the mass of air pollutants from stationary emitters in the Siberian Federal District in 2013 [10].

Entity	Mass of air pollutants, thous. ton
Krasnoyarsk Territory	2497.3
Kemerovo region	1356.3
Irkutsk region	685.9
Tomsk region	306.1
Omsk region	213.6
Altai Territory	201.2
Novosibirsk region	195.7
Trans-Baikal Territory	127.1
Buryatia Republic	114.1
Khakassia Republic	90.4
Total	5787.7

Calculations have revealed that uncontrolled fires' airbursts are on average 35–40 % of stationary emitters.

A ranking of SFD entities by specific unaccounted environmental load with toxic fire products has been performed; and it has been found that the highest specific unaccounted load is recorded in Kemerovo region: 0.28 ton/km^2 per year^{-1}

Next, in descending order, Krasnoyarsk and Altai Territories (0.16 and 0.15 ton/km^2 per year^{-1}, respectively) and Novosibirsk region (0.12 tons/km^2 per year^{-1}) are ranged.

In other SFD constituent entities unaccounted specific load ranges from 0.01 to 0.04 ton/km^2 per year^{-1}.

4. Conclusion

Development of new technologies has led to creation and growth of the technosphere, and, with it, a growing number of fires, causing damage to property, wildlife and environment; besides, increasingly threatening lives and health of people.

Russian official reports on State of Environment present data on stationary and mobile air-pollutant emitters; but the contributions of fires in pollution are not taken into account.

Based on the obtained data we can draw the following conclusions:

1. Airburst fire ecotoxicants make an unaccounted contribution to air pollution; they are significant threats for human health and environment.
2. It is established that fires pollute the atmosphere with more than 211 000 tons of pollutants per year.
3. Environmental risks of fires should be considered when developing a territories' administration strategy.

5. References

[1] Social, economic and environmental impact of fires in municipal centers of the Siberian Federal District: analysis, evaluation, forecast: monograph / S Timofeeva [et al.] *FSEI HPE ESI Russian Interior Ministry* – Irkutsk Asprint, 2010 – 169 p

[2] Airburst pollutions from fires and accidents at industrial sites in Baikal region: assessment, forecast, prevention measures: monograph / S Timofeeva [et al.]. – Irkutsk: ISTU Publishing House, 2009 – 192p.

[3] Isayeva L K Environmental effects of air pollution from fires in residential buildings / L K Isayeva, B B Serkov // *Problems of safety in emergency situations* – M.: RISTI, 1992 – No2 pp 39-49

[4] Mal'chik A G, Litovkin S V, Rodionov P V Investigations of physicochemical properties of bottom-ash materials for use them as secondary raw materials // *IOP Conference Series: Materials Science and Engineering.* – 2015 Vol 91 Article number 012081

[5] Isayeva L K Ecological and economic evaluation of damage caused by pollution from fires: tutorial / L K Isayeva – M: USSR Interior Ministry, 1996 – 25 p
[6] Grishagin V M, Safronova A B Solid components of welding fumes as a synthetic composites filler // *Applied Mechanics and Materials* – 2014 – Vol 682 – pp 369-374
[7] Burkanov A K Fires: impact on environment: review Inf. / A K Burkanov, I G Egorov, V V Volohov – M.: Institute of Fire Prevention, 1992. – 18 p
[8] Brushlinskii N N Fire prevention management in Russian Federation entities on basis of fire risks analysis / N N Brushlinskii [et al.] // *Problems of safety and emergencies* – M.: RISTI – 2010 - No3 – pp 104 – 114
[9] Garmyshev V V Air pollution from fires in urban municipalities of Siberian Federal District / V V Garmyshev, S A Hismatulin, S S Timofeeva // *Bulletin of Irkutsk State Technical University* - 2013 No3 (74) – pp 48-53
[10] Government report "On State and Environmental Protection of the Russian Federation in 2013" http://www.mnr.gov.ru/upload/iblock/6c7/gosdokladeco.pdf