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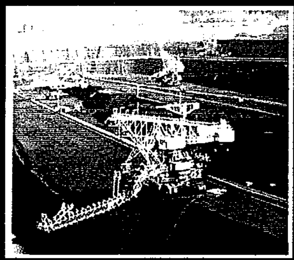


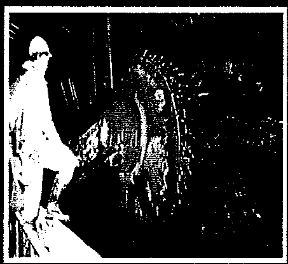

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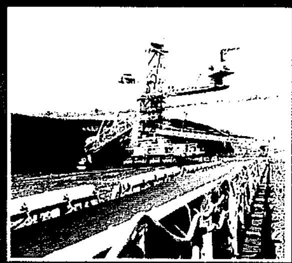

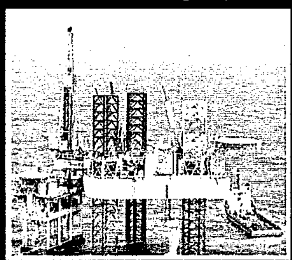
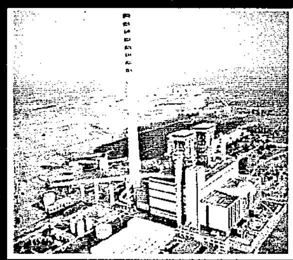

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FUGITIVE DUST FROM COAL MINING - EMISSION ESTIMATION TECHNIQUES AND SAMPLING METHODS

FIGUTATIVNA PRAŠINA IZ RUDNIKA UGLJA – METODI PROCENE EMISIJE I UZIMANJA UZORAKA

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Abstract: *This paper presents the Emission Estimation Techniques for fugitive dust emissions from coal mining using the Emission Factors. It also provides information on the sources of the emission factor equations and emission factors. These are mainly developed by the United States Environmental Protection Agency (USEPA), the European Environment Agency (EEA), and by the Australian National Pollutant Inventory (NPI). Also, an alternative estimation methodology for groups of point sources, area sources, and volume sources is presented. This methodology may be suitable if the specific emission estimation techniques given in this paper are considered unsuitable for application to a particular situation. This methodology may also be applied to area and volume sources not covered in this paper (such as ponds and buildings).*

Keywords: *Emission factors, PM_{10}, Emission control techniques, Area sources, Volume sources.*

Apstrakt: *Ovaj rad prestavlja metode procene emisije figutativne prašine iz rudnika uglja upotrebom faktora emisije. Pored gore pomenutog, rad obuhvata informacije vezane za jednačine izvora emisije i faktora emisije. U većini slučajeva one su razvijene od strane Američke Agencije za zaštitu životne sredine (USEPA), Evropske agencije za zaštitu životne sredine (EEA), i Austalijskog nacionalnog registra (NPI). Takođe, alternativna metoda za procenu tačkastog zagađenja, površine zagađenja, i zapremine zagađenja je predstavljena u radu. Ova metoda procene emisije prašine je primenjliva u situacijama kada ostale metode koje su prezentovane u ovoj studiji nisu primenljive, kao i za površine i zapremine koje nisu obuhvaćene u radu (pondovi, zgrade).*

Ključne reči: *faktori emisije, PM_{10}, tehnike kontrole emisije, površina izvora, zapremina izvora.*

1 INTRODUCTION

The main emissions to the air environment consist of wind-borne dust, and the products of combustion from mine transportation, mine power generation (if any), and blasting. In most cases fugitive emissions can be estimated using emission factors which, when combined with site-specific information (e.g. the silt and moisture content of material being handled) can be used to determine emissions from the particular operation being analyzed.

Most of the work in developing emission factors for fugitive emissions has been undertaken in the United States (see USEPA (1985) and USEPA (1998)). Some work has also been undertaken in Australia (see SPCC (1986) and NERDDC (1988)). The emission factors defined in those works should be used with caution and attention must be paid to the range of conditions under which the factors were developed. Proper application of EEF is possible only after careful examination if they are suitable for the particular activity being considered proper corrections executed. Finally, it is worth pointing out that the USEPA emission factors are published in a large number of references, and are often referred to in different ways.

Many published emission factors have an associated emission factor rating (EFR) code. These EFR codes are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). When using emission factors, the one should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or category is not representative of the source type.

These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the eqi pment/process selected in applying the factor, and the target eqipment/process from which the factor was derived. The EFR system is as follows:

A – Excellent	B - Above Average	C - Average
D - Below Average	E – Poor	U - Unrated

There may, however, be cases in which none of the available EEFs are suitable for a particular application. In such cases, different methods of sampling are used to characterize emissions.

A number of generic methods exist for estimating emissions from area and volume sources. These methods vary greatly in accuracy and difficulty and may not always be applicable. The paper gives general preview of estimation methodologies for open cut coal mining and alternatives (sampling methods) for one of the air pollutants of the main concern TSP and PM_{10}.

2 EMISSION ESTIMATIONS

Emission factors can be used to estimate emissions to the environment from various sources. Emission factors relate the qantity of a substan ce emitted from a source to some measure of activity associated with the source. Common measures of activity include distance travelled, qantity of material handled, or the duration of the activity.

Emission factors are used to estimate a facility's emissions by the general eqation:

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)] \quad (1)$$

where: $E_{kpy,i}$ = emission rate of pollutant i, kg/yr;
A = activity rate, t/h;
OpHrs = operating hours, h/yr;
EF_i = uncontrolled emission factor of pollutant i, kg/t;
CE_i = overall control efficiency for pollutant i, %.

If no emission controls are used, Eqation 1 reduces to:

$$E_{kpy,i} = A * OpHrs * EF_i \quad (2)$$

where: $E_{kpy,i}$ = emission rate of pollutant i, kg/yr;
A = activity rate, t/h;
OpHrs = operating hours, h/yr; and
EF_i = uncontrolled emission factor for pollutant i, kg/yr.

Mining operations can be considered as a series of unit operations (e.g. dragline operations, shovel operations, truck haulage of materials). Table 1 provides emission factor eqations and default emission factors for emissions of both TSP and PM_{10} from coal mining.

The emission eqations should be used where site-sp ecific data such as silt and moisture content is available. Otherwise, the default emission factors can be used.

Table 1. *Emission Factor Equations and Default Emission Factors for Various Operations at Coal Mines*

Operation/Activity	TSP Equation	PM_{10} Equation	TSP Default Emission Factor	PM_{10} Default Emission Factor	Units	EEF's Rating
Draglines	$EF = 0.0046 * d^{1.1} * M^{-0.3}$	$EF = 0.0022 * d^{0.7} * M^{-0.3}$	0.06	0.026	kg/bcm	B
Excavators/Shovels/Front-end loaders (on overburden)	$EF = k * 0.0016 * (U/2.2)^{1.3} * (M/2)^{-1.4}$, using **k=0.74**	As for TSP, using **k=0.35**	0.025	0.012	kg/t	C
Excavators/Shovels/Front-end loaders (on coal)	$EF = k * 0.0596 * M^{-0.9}$ using **k = 1.56**	As for TSP, using **k=0.75**	0.029	0.014	kg/t	C
Bulldozers on coal	$EF = 35.6 * s^{1.2} * M^{-1.4}$	$EF = 6.33 * s^{1.5} * M^{-1.4}$	102	32.5	kg/h	B
Bulldozer on material other than coal	$EF = 2.6 * s^{1.2} * M^{-1.3}$	$EF = 0.34 * s^{1.5} * M^{-1.4}$	17	4	kg/h	B
Trucks (dumping overburden)	--	--	0.012	0.0043	kg/t	
Trucks (dumping coal)	--	--	0.010	0.0042	kg/t	
Drilling	--	--	0.59	0.31	kg/hole	B
Blasting	$EF = 344 * A^{0.8} * M^{-1.9} * D^{-1.8}$	As for TSP, Multiplying by 0.52	--	--	kg/blast	C
Wheel and bucket	--2	--2	--2	--2		
Wheel Generated Dust from Unpaved Roads	$EF = k * (s/12)^{A} * (W/3)^{B} / (M/0.2)^{C}$, where **k = 2.82**	As for TSP, using **k= 0.733**	3.88	0.96	kg/VKT	
Scrapers	$EF = 7.6 * 10^{-6} * s^{1.3} * W^{2.4}$	$EF = 1.32 * 10^{-6} * s^{1.4} * W^{2.5}$	1.64	0.53	kg/VKT	A
Graders	$EF = 0.0034 * S^{2.5}$	$EF = 0.0034 * S^{2.0}$			kg/VKT	B
Loading stockpiles	--	--	0.004	0.0017	kg/t	
Unloading from stockpiles	--	--	0.03	0.013	kg/t	
Loading to trains	--	--	0.0004	0.00017	kg/t	
Miscellaneous transfer points	$EF = k * 0.0016 (U/2.2)^{1.3} * (M/2)^{-1.4}$, where k = 0.74	As for TSP, using **k = 0.35**	0.00032	0.00015	kg/t	
Wind erosion	--	--	0.4	0.2	kg/ha/h	

Where: d = drop distance in metres;
M = moisture content in %;
U = mean wind speed in m/s;
A = area blasted in m^2;
D = depth of blast holes in metres;
VKT = vehicle kilometres travelled;
s = silt content in %;
W = vehicle gross mass in tonnes;
S = mean vehicle speed in km/h;
L= road surface silt loading in g/m^2;
bcm = bank cubic metres;
t = tonne;
-- = negligible

Exponents for "Wheel Generated Dust from Unpaved Roads"

A = 0.8 (for PM_{10}) & 0.8 (for TSP) ;
B = 0.4 (for PM_{10}) & 0.5 (for TSP);
C = 0.3 (for PM_{10}) & 0.4 (for TSP).

2.1 Calculation of PM_{10} Emissions

All emission factor eqations and default emission factors listed in Table 1 are for uncontrolled emissions. Section 2.2 provides information on the efficiency of control methods. This information can be incorporated into the calculation of emissions as outlined in Eqation 1. Calculating emissions of PM_{10} becomes a five-step process:

1. Identify sources of emissions.
2. Obtain information on the scale of the activity (i.e. the basic data reqired to apply the eqation)
3. Apply the relevant PM_{10} emission factor eqation or default emission factor from Table 1 to the activity data (using Eqation 2). A suitable surrogate for calculating vehicle kilometres travelled (VKT) emissions may be to determine the fuel consumption in various items of eqipment. Using typical fuel efficiencies, it should then be possible to determine total VKT.
4. Where applicable, apply control efficiency reduction factors in Section 2.2 (using Eqation 1). With regards to emission controls for PM_{10}, in the absence of measured data, or knowledge of the collection efficiency for a particular piece of eqipment, an efficiency of 90% should be used in the emission estimation eqation to calculate actual mass emissions. This default should only be used if there is no other available control efficiency.

2.2 Control Techniques

There are a number of ways in which dust emissions from mining operations can be controlled. Most dust control techniqes involve the u se of water sprays to keep surfaces damp, but there are also other methods. Table 2 summarizes the methods used and the effect they have on reducing dust emissions (Holmes Air Sciences, 1998). These are drawn from control factors documented in USEPA (1998) and Buonicore and Davis (1992: Table 3, p 794).

The emission reductions presented in Table 2 can be applied to the predicted uncontrolled emissions (derived using the emission factors and eqations presented in Table 1) using Eqation 1, as described above.

Table 2 Emission Factor Equations and Default Emission Factors for Various Operations at Coal Mines

Operation/Activity	Control method and emission reduction[1]
Scrapers on topsoil	50% control when soil is naturally or artificially moist
Dozers on coal or other material	No control
Drilling	99% for fabric filters 70% for water sprays
Blasting coal or overburden	No control
Loading trucks	No control
Hauling	50% for level 1 watering (2 litres/m²/h) 75% for level 2 watering (>2 litres/m²/h)
Unloading trucks	70% for water sprays
Draglines	Control dust by minimizing drop height
Loading stockpiles	50% for water sprays 25% for variable height stacker 75% for telescopic chute with water sprays 99% for total enclosure
Unloading from stockpiles	50% for water sprays (unless underground recovery then, no controls needed)
Wind erosion from stockpiles	50% for water sprays 30% for wind breaks 99% for re-vegetation (overburden only) or total enclosure
Loading to trains	70% for enclosure 99% for enclosure and use of fabric filters
Miscellaneous transfer and conveying	90% control allowed for water sprays with chemicals 70% for enclosure 99% for enclosure and use of fabric filters

Source: Holmes Air Sciences (1998)

*[1] Controls are multiplicative when more than one control is applied to a specific operation or activity. On stockpiles, for example, water sprays used in conjunction with wind breaks give an emission that is 0.5 * 0.7 = 0.35 of the uncontrolled emission (i.e. 50% of 70% of the total uncontrolled emissions).*

3 ALTERNATIVE ESTIMATION METHODOLOGY

Three methods have been described in this section. Each of these methods has been taken from A Review of Methods for Measuring Fugitive PM_{10} Emission Rates (USEPA, 1993) and reqires:

1. Sampling for the pollutant of interest at various points in relation to the source; and
2. Application of an engineering eqation or model.

If the pollutant of interest can be easily measured at ambient conditions, these methods may be useful. A summary of the methods presented in this Manual is presented in table below

***Table 3**. Alternative Estimation Methods for Area and Volume Sources*

Method	Applicability	Sampling Required	Additional Modelling Required
Quasi-Stack	Small Sources such as individual pieces of eqipment	Sampling of hooded source	No
Roof Monitor	Buildings	At each exit point of buildings	No
Upwind-downwind	Area Sources	Upwind and downwind	Yes

3.1 Quasi-Stack Method

This method has been taken from A Review of Methods for Measuring Fugitive PM_{10} Emission Rates (USEPA, 1993). The qasi-stack method is suited to small materials handling operations and small components of industrial processes. If a particular unit operation or piece of eqipment is the major source of fugitive emissions, this method may also be useful.

This method consists of enclosing or hooding the fugitive source to be measured. The source is ducted away from the source at a known velocity by using a fan and the exhaust is sampled isokinetically (uniform velocity profile). If the qasi-stack me thod is used it should satisfy the following criteria:

1. Reynolds Number ≈ 200 000 (turbulent flow) for typical ducts with smooth walls.
2. A minimum straight duct run of three duct diameters upstream and downstream of the sampling port.
3. If measuring particulates, air velocity in the vicinity of the hood or enclosure must be sufficient to entrain an entire PM_{10} plume without being fast enough to cause excess emissions.
4. If measuring particulates, there must not be significant deposition of PM_{10} within the duct work or enclosure

[Source: USEPA, 1993]

USEPA Method 201 (EMTIC, 1999a) and USEPA Method 201A (EMTIC, 1999b) may be used as protocols for standard stack sampling trains. Methods of sampling may be obtained from USEPA Method 1 (EMTIC, 1999c), where applicable. This method is probably the best method for estimating emissions from enclosable sources. However, there are difficulties when trying to demonstrate that the enclosure of a source does not alter the characteristics of its emissions. This is a case-specific issue that cannot be covered in a paper such as this.

3.2 Roof Monitor Method

This method has been taken from A Review of Methods for Measuring Fugitive PM_{10} Emission Rates (USEPA, 1993). If processes are located inside a building, the roof monitor method may be the best way of estimating emissions from the building. In this method, pollutant concentration and air velocity measurements must be made at each opening of the building through which pollutants may be emitted. The cross-sectional area of each opening is also reqired. The pollutant emission rate is the sum of all the individual opening pollutant rates and is given by:

$$E_i = \sum_{i-1}^{N} V_a \cdot C_i \cdot A$$

where: E_i = Emission from building (kg/s);
N = Number of openings;
V_a = Velocity of air through opening (m/s);
C_i = Concentration of pollutant i in air flowing through opening (kg/m^3);
A = Cross-sectional area of opening (m^2).

Isokinetic sampling may be difficult and it may not be possible to use stack-testing methods. Ambient sampling devices may have to be used. Concentrations of pollutants may vary across the cross-section of the opening and it may be useful to measure at several points across the cross-section. It may also be difficult to access every opening in the building. It is important to sample at times that are representative of normal and peak emissions. It is recommended that, whenever possible, stack sampling trains be used to measure emissions. See USEPA Method 201 (EMTIC, 1999a) and USEPA Method 201A (EMTIC, 1999b) for acceptable protocols for these measurement techniqes.

To discriminate between different sources under one roof, tracer tests are reqired (USEPA, 1993). Alternatively, one process at a time may be operated to obtain an emission rate from each process. This method is thought to be less accurate than the qasi-st ack method (USEPA, 1993). Usually, the only issue of concern is the final emissions to the environment, so the identification of specific sources of emissions within a facility is not reqired.

This method may be the best way to estimate emissions from buildings. Sampling problems may include difficulties in sampling large openings, as well as variable flow through openings.

3.3 Upwind-Downwind Method

This method has been taken from A Review of Methods for Measuring Fugitive PM_{10} Emission Rates (USEPA, 1993). In the upwind-downwind method, at least one ambient concentration is obtained upwind of the pollution squrce, and several concentrations are obtained downwind. The difference between the upwind and downwind concentrations is considered to be the contribution of the source.

Wind speed, wind direction and other meteorological variables are monitored during the sampling procedures. Methods for sampling for this method may be obtained from the USEPA (USEPA, 1993). Using a dispersion model and available meteorological information, the net concentration is used to solve for the emission rate. Air dispersion models such as AUSPLUME may be used to estimate emissions from volume and area sources in this manner to obtain downwind concentrations for this method.

Care should be exercised with this method because only a tiny fraction of the greatly diluted plume is actually sampled. A large number of samples are usually reqired for the data to accurately represent ambient concentrations. The modelling tends to be the greatest cause of error in this method and should be carefully applied. In many cases however, this may be the only estimation techniqe available.

3. CONCLUSION

It should be noted that the EETs presented or referenced in this paper relate principally to average process emissions. In the absence of other information, default emission factors can be used to provide an estimate of emissions. Emission factors are generally derived through the testing of a general source population (e.g. boilers using a particular fuel type). This information is used to relate the qantity of material emitted to some general measure of the scale of activity (e.g. for boilers, emission factors are generally based on the qantity of fuel consumed or the heat output of the boiler).

An emission factor is a tool used to estimate emissions to the environment. In this paper, it relates the qantity of substances emitt ed from a source, to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted, divided by the unit weight, volume, distance, or duration of the activity emitting the substance (e.g. kilograms of sulfur dioxide emitted per tonne of fuel burned).

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. Should a company have several processes of similar operation and size, and emissions are measured from one process source, an emission factor can be developed and applied to similar sources in this situation.

There may, however, be cases in which none of the available EETs are suitable for a particular application. In such cases, a general guidance on the use of sampling to characterise emissions may be of use to facilities in helping them meet their reporting reqirements. A number of generic methods exist for estimating emissions from area and volume sources. These methods vary greatly in accuracy and difficulty and may not always be applicable. They are presented in this paper and are intended as an alternative to the commonly used methods.

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