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Air pollution impacts from open air burning

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Abstract

As part of the air quality monitoring and assessment, emissions from open air burning of waste and biomass has proven important sources of impact to the population exposure. The emissions of a variety of air pollutants from different types of open-air burning have been evaluated. Simple model estimates are used to estimate the impact in areas downwind from backyard burning. Different models have also been used to estimate the importance of impact and the sources for odours detected downwind from waste dumping areas.

Data from major cities such as Cairo have been used to estimate the impact of emissions from agricultural waste burning. In several urban areas, especially in developing countries the contribution to the PM exposure from agricultural burning has been demonstrated to range between 30 and 50 % dependent upon weather conditions. The design and application of combined monitoring programmes and models may be part of the systematic evaluation of impacts and optimal control of the sources.

Keywords: Air pollution, waste burning

1 Introduction

Waste is a growing environmental, social and economic issue for all modern economies. Waste volumes are increasing at rates equalling and sometimes outpacing economic growth. The way that waste is generated and handled has an impact on everyone, from individual citizens and small businesses to public authorities and international trade.

The generation of more and more waste is a symptom of inefficient use of resources, which should actually have been utilised in a better way as a resource for energy and materials. The air pollution generated from waste causes impacts felt by a large part of the population living in and around major urban areas. The pollutants are partly emitted due to leakages and evaporation of gases causing annoying smells and partly generated by self-burning or active fires onset by humans at dumpsites.

In the following I will discuss emissions to the atmosphere and exposure to humans caused by dump sites, burning of household-, garden and agricultural waste as well as pollutants due to the use of waste in small industries.

2 Estimated emissions to the atmosphere

Air pollution emissions from waste deposits can be generated through leakages of gases or from combustion when waste is being burned. One of the major concerns at dumpsites is the leakage of methane and other green house gases. This subject will, however, not be covered in this paper.

The complete combustion and open air burning of waste require sufficient heat flux, adequate oxygen supply, and sufficient burning time. The size and quantity of the emissions of different compounds from this type of burning depends on a number of factors such as density, moisture and wetness, topography (slope and profile of underlying ground) and meteorological conditions (wind, precipitation etc.)

2.1 Waste deposit areas and dumps

From an environmental perspective, dumping or 'land filling' is the worst waste management option. It is space demanding and creates a future environmental liability and it represents a waste of resources. European legislation has introduced high standards for landfills to prevent soil and groundwater pollution, and to reduce emissions to air as for example of methane and other air pollutants. In some cases the legislation is poorly implemented and there are still thousands of mismanaged and unauthorised landfills across the member states.

Because of their high vapour pressures and low solubility, many toxic VOCs are observed in landfill gas. In a report by the State of California Air Resources Board, the average surface emission rate of hazardous chemicals was estimated to be 35 kg per million kg of refuse (Bennett, 1987).

Numerous investigations have been conducted with the objective of characterizing landfill gas emissions. Significant variation in landfill gas composition has been observed. A number of environmental parameters influence the production rate and the composition of landfill gas. The main

factors are waste composition, time since placement, pH, moisture content, availability of nutrients, and soil type. Temperature is also a key variable. Within a few days of placement, the temperature in the dump will rise due to aerobic decomposition. Intensive reduction of organic matter by putrefaction is usually accompanied by disagreeable odours of hydrogen sulphide and reduced organic compounds which contain sulphur, such as mercaptans. After the oxygen is depleted, the temperature drops back again because anaerobic processes are slower and less energetic. The optimal temperature for the production of methane and other organic pollutants is between 32 and 38 degC (Cooper et al., 1992).

NILU measured gases released from a landfill outside Oslo in 1989 (Braathen and Schmidbauer, 1989). Samples were taken at seven locations of VOC, Volatile aldehydes, H₂S and methanethiol. Concentrations measured at the side of the landfill were much higher than on top of the dump. It was thus concluded that most of the odours identified in the surrounding areas was due to old waste. In other studies ethyl benzene was found at concentrations more than 20 times the detection threshold (OU_{50D}). The H₂S concentrations on top of the deposit was between 120 and 450 µg/m³.

Tønnessen (2001) performed a specific study on a landfill to identify the reasons for complaints about odours in the surrounding areas. Calculations of gas emissions and dispersion of odorous gases were based upon measurements and models. At this specific site measurements showed that H₂S was the odorous component with highest release rate compared to the odour threshold.

At this relatively small deposit area, where 60 000 tons were deposited every year, the total amount of gases released was estimated at 590 m³/h. Measurements indicated average concentrations of H₂S at 0.9 ± 0.47 g/m³. For local adverse dispersion conditions, that occurred 6% of the time, odour from the landfill occurred in residential areas around the landfill. At these conditions the dispersion models gave half hourly concentrations of about 14 µg/m³ in one of the living areas. In conclusion it was stated that H₂S also could be used as an indicator for any odour problem occurring around landfills of this kind.

2.2 Burning of garden waste

Emissions to the atmosphere from ground level open burning of garden waste are affected by many variables, including wind, ambient temperature, composition and moisture content of the debris burned, and compactness of the pile. In general, the relatively low temperatures associated with open burning increase emissions of particulate matter, carbon monoxide, and hydrocarbons and suppress emissions of nitrogen oxides. Emissions of sulphur oxides are a direct function of the sulphur content of the material burned.

Field experiments were undertaken at NILU to study the amount of particles and polycyclic aromatic hydrocarbons (PAH) emitted when typical garden debris

was burned in Norway (NILU, 2003). PAH may be formed by the thermal decomposition of any organic material containing carbon and hydrogen. More than 30 PAH compounds and several hundred PAH derivatives have been identified to have carcinogenic and mutagenic effects, making them the largest single class of chemical carcinogens known (Bjørseth and Ramdahl, 1985).



Figure 1. The experimental layout of measuring emissions from bonfires and burning of rubbish (NILU, 2003).

In smoke from garden deposits it was found from the NILU experiments that the emission rates of CO could be as much as 3 to 4 times the emission rate from an idling car. Ten kilos of garden debris gave the following emissions to the atmosphere:

- 1 kg Carbon monoxide (CO)
- 1 kg PM (soot and ash)
- 25 g Aldehydes
- 5 g Polycyclic Aromatic Hydrocarbons (PAH)

PAH compounds have been studied in many countries. Fang et.al (1999) found that the total PAH concentration in smoke from biomass burning ranged from 7 to 46 ng/m³. The highest value of B(a)P was measured at 3 ng/m³ while the lowest was at the same site 0.1 ng/m³. These values are comparable to those measured at street level in urban centres such as Hong Kong.

Emissions of suspended particles have been investigated and reported over a number of years. Barley et al (1974) carried out both laboratory and field studies and concluded that moisture content of fuel residues was the most significant factor influencing emission levels.

At good burning conditions the particulate emission factors for some crops were:

- Orchard pruning, citrus, almond, grape 2-4 g/kg
- Rice, barley, wheat 3-5 g/kg
- Russian thistle 10-13 g/kg
- Asparagus 14-20 g/kg

2.3 Agricultural waste

Organic refuse burning consists of field crops, wood, and leaves, and the emissions are again dependent mainly on the moisture content of the refuse. In the case of the field crops the emission rates depends upon whether the refuse is burned in a head fire or a backfire. Head fires are started at the upwind side of a field and allow to progress in the direction of the wind, whereas backfires are started at the downwind edge and forced to progress in a direction opposing the wind.

Emission factors for open air burning of agricultural waste are presented in Table 1 as a function of the type of waste. The emission rates may also be a function of burning techniques and/or moisture content.

Table 1: Emission factors (g/kg) for some selected compounds when burning different type of agricultural waste.

Type of waste	PM	PM ₁₀	PM _{2,5}	SOx	NOx	CO	VOC
Municipal refuse 1)	8			0.5	3	42	6.5
Open air refuse 3)	37	37		0.5	3		
Agricultural waste 3)	10	5					
Rice1) 2)	4	3.7	2.9	0.6	2.6	29	3
Alfalfa 2)		14.5	13.6	0.3	2.3	60	12
Canopy & shrubs2)			10.7				
Grassland 2)		8.0	7.6	0.3	2.3	57	5.5
Forest 2)		10-15	8-14	0.05	1.8	75-150	10

1) Jenkins, 1996 AP42 2) Gaffney, 2000 3) Larssen et.al, 1995

Hays et.al. (2005) indicated that the PM_{2,5} mass emission factor from burning of wheat and rice were 4.7 ± 0.04 and 13.9 ± 0.3 g/kg of dry mass respectively.

2.4 Municipal waste burning



In contrast to municipal combustors, which operate under highly controlled conditions designed to reduce formation and emission of air pollutants, backyard trash burning is uncontrolled. The low temperature burning and smouldering conditions typical of backyard trash fires promote the formation of air pollutants including polychlorinated dibenzodioxins and dibenzofurans, sometimes collectively called “dioxins”, fine particulate matter and PAHs. These pollutants form during backyard trash burning regardless of the composition of the material being burned.

In 2001 a typical US County processes approximately 400,000 tons of waste/yr with an estimated emission rate of about 200 ng dioxins

per kg waste. This is equivalent to 72.6 g/yr of dioxins from backyard trash fires if all trash were domestically burned (Chlorine Chemistry Council, 2004)

3 Concentrations and impacts

Burning of trash and biomass such as leaves and wood is common practices throughout most of the developing countries. The impact to people in these areas are mainly due to high concentrations of $PM_{2.5}$ and PM_{10} , which also contain toxic and carcinogenic elements. Biomass burning often takes place after sunset, when the atmospheric dispersion conditions are poor. Very high concentrations of PM and other pollutants are measured in the smoke during these conditions.

The relative contributions to the total PM exposure have been estimated in several cities around the world. In Mumbai the contribution from refuse burning to the total PM_{10} urban exposure has been estimated to about 26 % (Larsen et al., 1995). Samples of PM were collected in a semi-residential area of Dhaka and in an urban area of Rajshahi, a city in the north-western region of Bangladesh. In Rajshahi it was found based on receptor modelling that biomass burning contributed about 50% of the $PM_{2.5}$ mass (Begum et.al., 2004). A number of source apportion studies have indicated that biomass burning often represents 30 to 50 % of the total PM load.

3.1 Concentrations downwind from back yard burning

Model estimated downwind concentrations of PM_{10} are presented in Figure 2 based on emissions of particles as a result of open air burning.

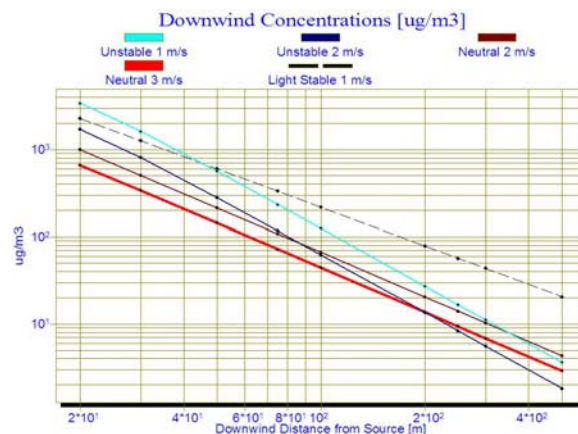


Figure 2. Estimated concentrations of PM_{10} downwind from open-air burning of backyard waste.

Assuming that a small waste dump is set on fire and that about 10 kg of waste is being burned during one hour the estimated emission rate of PM_{10} at around 0.1 g/sec may lead to concentrations of PM_{10} in the smoke plume around 100 m away from the fire of between 80 and 200 $\mu\text{g}/\text{m}^3$ depending on meteorological conditions.

At a distance of 200 m from a small bonfire of this kind the one-hour average concentration of PM_{10} may still be 20-30 $\mu\text{g}/\text{m}^3$ during neutral atmospheric conditions and up to 80 $\mu\text{g}/\text{m}^3$ in light stable conditions. The latter case is typical for the effect of open-air burning that is taking place in developing countries at sunset or in the early evening.

3.2 High PM_{10} concentrations from agricultural waste burning

Measurements of suspended particles in Cairo were undertaken during the season when rice waste and other agricultural waste were burned in the Nile Delta. Measurements in Cairo was taken downwind from these sources, and it has been shown that the burning of waste contributed considerably to the general air pollution load in Cairo, several tens of kilometres downwind (Sivertsen and Dreiem, 2004)

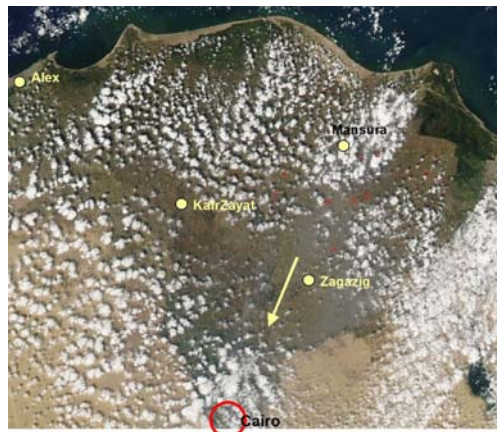


Figure 3. A satellite photo taken on 11 October 2004 shows plumes from burning of agricultural waste in the Nile Delta. The wind transported the plumes towards the city of Cairo.

On 11 to 12 October 2004 very high concentrations of PM_{10} were recorded at the monitoring stations at Abbaseya and at Fum-AIKhalig in Cairo as seen in Figure 4. The winds were from the north at 2 m/s at night and in the morning hours. Plumes of dust were observed moving into Cairo in the morning of 11 October 2004. The site Fum AIKhalig is located in the northern part of Cairo (closest to

the Nile Delta) and hourly average PM_{10} concentrations exceeded $400 \mu\text{g}/\text{m}^3$ at this site

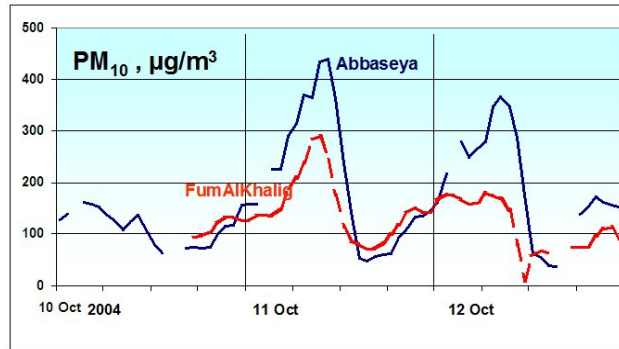


Figure 4. PM_{10} concentrations measured at Abaseya (north Cairo) and Fum AlKhalig (city centre) from 10 to 12 October 2004.

Gertler et al. (2004) performed a source attribution study to determine contributions from various sources in Cairo. Samples of PM_{10} , $PM_{2.5}$, PAH, and VOC were collected on a 24-hour basis to identify the importance of the burning of agricultural waste in the Delta. At a site in northern Cairo, close to the Delta, PM_{10} contribution from burning was estimated at 40 %, for $PM_{2.5}$ the contribution was 30 %. Inside the city centre the open-air burning contribution was estimated at 42% both for $PM_{2.5}$ and PM_{10} .

4 Conclusions

Leakages of gases from waste dumps have been shown to include a number of odorous compounds. Measurements undertaken in Norway indicated that H_2S and Ethyl Benzene had contributed to bad smell.

Burning of waste and biomass produces PM, PAH, dioxins and a number of toxic air pollutants. Concentrations downwind may frequently exceed limit values and air quality standards.

Air pollutants from biomass and agricultural burning have been demonstrated to contribute 30 to 50 % to the general PM exposure in urban areas dependent upon weather conditions.

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