Fire Hazards from self-heating at Composting and Waste Processing Sites

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Introduction

Fires involving materials being stored or processed in bulk can have severe impacts on the local communities and the environment. It is important that site managers at municipal recycling facilities (MRFs) are aware of all the potential fire hazards that exist on their sites in order for them to produce a comprehensive fire safety plan and an effective risk assessment. This article is intended to highlight the potential fire hazards that exist on sites that handle large quantities of combustible waste, focussing particularly on the hazards arising from self-heating leading to spontaneous combustion. It does not cover hazardous waste disposal facilities. The focus of this article is to outline common fire problems in material stockpiles. A future article will discuss fire risks from waste processing at MRFs.

Combustible materials stored and used in bulk that may be found on these sites include:

- Compost
- Tyres
- Wood chips/sawdust
- refuse derived fuel (paper/ plastic pellets or floc)
- raw refuse
- fractions of separated refuse (e.g. paper rich, plastic rich – these may have been compacted)
- textiles

Stockpiles are not the only potential source of fire risks. Other sources include processing steps, in particular pulverisation and shredding, and also biofilters – which are in effect stockpiles of compost or other materials such as woodchips.

It is not the purpose of this article to offer comprehensive guidance. All waste management facilities should undergo a comprehensive risk assessment for fire risks, which is the basis around which the latest fire safety legislation is written – see text box. In addition to complying with the various legislation concerning fires, additional regulations will need to be followed, such as planning permission and Pollution Prevention and Control Regulations 2000 (PPC), which also have aspects relating to fire safety and the limitation of damage to the environment from fires (e.g. the complete containment of fire water run-off in the event of a fire).

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Fire Safety Legislation

General health & safety legislation, and fire safety legislation is set out in EU Directives and UK regulations. The basis of European Health and Safety legislation is the Framework Directive:

- ***Council Directive 89/391/EEC 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work.***

This Directive contains general principles on employers duties. A risk assessment approach is specified that identifies potential hazards and sets out a series of measures that combine prevention of risks and protection of the workforce.

The Framework Directive is implemented in UK law by:

- ***Management of Health & Safety at Work Regulations 1999.***

The duties that an employer has in minimising the risk of an explosion in the workplace is set out in the EU ATEX 137 Directive:

- ***Directive 1999/92/EC on minimum requirements for improving the safety of workers potentially at risk from explosive atmospheres.***

This has been implemented, and extended, in UK law by :

- ***The Dangerous Substances and Explosive Atmospheres Regulations 2002.***

*DSEAR sets out UK law for the management of **fire** and explosion risks arising from dangerous substances in the workplace, this includes flammable gases, liquids and dusts and also materials that are liable to **self-heat**.*

Regulations concerning fire safety requirements in the workplace are implemented in the UK by the following:

- ***The Building Regulations. Part B Fire Safety. 2000.***
- ***The Fire Precautions (Workplace) Regulations 1997. (as amended 1999).***
- ***The Fire Precautions Act 1971.***
- ***The Supply of Machinery (Safety) Regulations 1992.***

Compost

There are a number of potential fire hazards at composting sites, resulting from the operations for compost preparation and refining, and the storage of materials. The possible sources of ignition include: sparks form vehicles and processing operations, lightening, arson, cigarettes and also the spontaneous combustion of materials stored in bulk.

Large compost heaps can generate temperatures of up to 80^{o}C as a result of biological processes of organic matter decomposition. Typically this requires large volumes of relatively fresh materials. The decomposition also requires the presence of moisture. There are a number of papers in the technical literature[1,2] suggesting that temperatures in large piles of organic material can then rise above 80^{o}C, as a result of chemical oxidation processes, to a level sufficient to cause ignition.

'Self-heating' is the occurrence of a rise in temperature in a body of material in which heat is being generated by biological and chemical processes taking place within the material[1,3,4]. In certain circumstances the temperature rise may increase both in magnitude and rate sufficiently to culminate in combustion; that is, there may be a 'self-ignition' or 'spontaneous ignition'.

In some materials biological heating is an indispensable prelude to self-ignition. The materials concerned are generally commodities such as hay, grains, oilseeds, vegetable and animal fibres. Compost heaps usually contain one or more of these types of materials and are hence susceptible to biological heating. For microbiological action to occur a moisture level of between 25 – 40% is required. However, the maximum temperatures achieved by biological action alone are only around 80ºC. At this stage, oxidation reactions take over, resulting from the chemical changes from the initial microbiological reactions, and lead to higher temperatures being generated.

The temperature rise associated with the biological and chemical oxidation reactions will depend on the difference between the rates of heat generation and heat loss to the surroundings. Hence, the geometry of the compost heap is a critical factor in determining the rate of heat loss. A single large pile has a small surface area to volume ratio that many smaller piles of the same volume of material, and hence is more likely to self-heat due to the less efficient heat loss capability.

<u>Internal charring characteristic of self-heating</u>

Spontaneous combustion has been suggested to be the cause of a number of fires at waste composting facilities in the USA and the UK[5,6]. Spontaneous combustion has even been suggested as a cause of domestic fires from home compost heaps. Other sources of ignition such as arson, discarded cigarettes and sparks from processing operations can also lead to fires involving compost, however the fires started in these instances will be surface fires that are relatively easy to control and extinguish. Deep-seated spontaneous combustion fires are much more difficult for fire-fighters to tackle and can take many weeks or months to extinguish.

Two recent incidents in the UK highlight the problem. A fire occurred at a large composting facility near St Albans[7]. The fire initially started in the summer of 1999 and required the closure of a road for a number of days. The smoke from the fire drifted across two motorways (M1 and M10) and required the attendance by the Hertfordshire Fire Service on more than one occasion as the fire burned for a number of months. The latest fire at the site occurred in August 2003 when the Fire Service was called to a deep-seated fire in the compost which took a number of weeks to control. In Swanley, a fire was reported[8] in September 2003 involving 100 tonnes of compost and rubbish that caught fire accidentally.

Tyres

Fires involving stacks of new or waste tyres can have an enormous impact on the local environment due to the production of :

- Toxic fumes composing: carbon monoxide, carbon dioxide, acrolein, benzene, sulphur dioxide, carbon disulphide and hydrogen sulphide.
- Particulates from the thick black smoke produced.
- Pollution from leachate run-off from the water used to fight the fire.
- Intense radiation produced from these fires which could cause ignition to surrounding materials/buildings.

Another feature of fires involving tyres is that they are extremely difficult to extinguish. A fire started in a tyre dump in South Wales in 1989[9] burned for at least 10 years. This was mainly due to its location and the size of the pile, making access to the seat of the fire very difficult. The geometry of the tyres also makes its difficult for water to penetrate into the centre of the pile, resulting in the outer tyres being extinguished but tyres in the centre continue to burn. The problem of access to the seat of the fire is a particular problem when the fire has started by spontaneous combustion, as the very nature of the ignition involves the initial fire growth being at the centre of the stockpile rather than on the surface.

Hence, when planning bulk storage, the location as well as quantities of materials need to be addressed in the risk assessment.

There are a number of potential sources of ignition of tyre stockpiles, these include:

- Arson
- Radiation from neighbouring fires involving buildings or other materials– tyres can ignite at as low a heat flux as $9kW/m^2$.[10]
- Naked flames from bonfires or repair/maintenance work
- Self-heating – rubber has the capacity to undergo self-heating reactions leading to spontaneous combustion. This particular hazard is associated with rubber crumb which may be produced during tyres shredding operations, but may also occur in large stockpiles of whole tyres stored for long periods.

Work undertaken by BRE/FRS for the UK Government on fires involving storage of rubber tyres produced recommendations on safe volume and spacing of stacks[10].

Waste tyres are now also being used in the form of “bales”. This involves compaction of whole waste tyres into a block, using 100 tyres, which are then tied to hold them together using steel wires. These tyre bales are then used in civil engineering works, such as in river embankments and coastal defences. The fire behaviour of these tyre bales has not been studied, particularly their ability to undergo self-heating reactions when in the compressed state. Hence, it should not be assumed that due to their compacted nature that the risk of ignition is necessarily less than that of loose tyres.

Wood Chips and Sawdust

Bulk quantities of woodchips and sawdust may be produced as a waste product from wood working activities on a site, or they may be produced on the site as part of the recycling processing of waste wood (e.g. from building sites), prior to removal for reuse. Wood chips and/or sawdust may also be stored for use as an amendment for composting some kinds of waste, for example sewage sludge or slurry.

There has been at least one major fire in the UK in the last few years involving a large stockpile of woodchips, the cause of which was most likely self-heating.

Potential sources of ignition for this type of material are:

- Arson
- Discarded smoking materials
- Naked flames from work/maintenance activities
- Placement of hot/smouldering materials into the stockpile from recycling machinery
- Self-heating
- Radiation from neighbouring fire

As with compost and rubber tyres, wood chips and sawdust material can undergo self-heating reactions, leading to spontaneous combustion, under certain storage conditions. Factors that will play a part in whether self-heating leading to combustion will occur are the size of the wood chips, the moisture content, the presence of other flammable waste materials within the stockpile that are easily ignitable, and the natural oil content of the wood. Sawdust has been tested extensively[1] over many years and it has been found that the greater the proportion of oil present in the wood, the lower the critical ignition temperature (the temperature at which a runaway reaction occurs).

Raw refuse/refuse derived fuel

Fires involving large quantities of refuse may occur in not only in municipal waste disposal processing facilities, but can also occur on landfill sites. As with compost, tyres and wood chips/sawdust, the potential sources of ignition are numerous and can include self-heating. Some of the hazards that can arise from refuse fires include:

- Hazardous materials that may be toxic/corrosive/irritant/carcinogenic or produce combustion products that have these properties.
- Pressurised containers/LPG cylinders – explosion and fire.

- Landfill gas containing methane and carbon dioxide mixtures, which produce flammable atmospheres.
- Biohazards
- Particulates (e.g. asbestos) that produce respiratory problems.

These hazards are in addition to the smoke produced from a fire involving these materials. Surface fires resulting from arson or accidental ignition can be fairly easily extinguished by sprinkler systems or fire-fighters. Fires started from self-heating, and hence are smouldering combustion mechanisms, are within the centre of the refuse and as such are difficult to access. For piles of refuse on the surface the stockpile would have to be excavated and pulled apart to obtain access to the seat of the fire. This needs to be done with extreme care as the initial ingress of additional oxygen could cause a flaming combustion from a previously smouldering combustion.

For landfill sites, the process of extinguishing a subterranean fire is very difficult and specialist advice and techniques will need to be employed which is beyond the scope of this paper. The Fire Division of BRE is able to provide further information on tackling fires of this nature.

Preventative measures

Some general preventative measures against the risk of a fire that should be considered are:

- Control of waste materials being stored
- Segregation of incompatible wastes
- Small stockpiles
- Safe distances between stockpiles.
- Continuous temperature monitoring of materials being stored for long periods
- Access for fire fighting activities

If materials are stored inside a building, then consideration should be given to installing fire detection and active fire protection systems such as sprinklers.

Risk Assessment

To adequately assess the hazards and risks from a fire involving storage and use of bulk materials a systematic approach is required. Risk assessment is the best and most widely used methodology employed to address fire risks and this technique should be used on all composting and waste processing sites.

One of the first requirements is to identify the combustible materials on the site and then to determine what potential ignition sources there are associated with that material. This article has highlighted four main types of material; compost; tyres; wood chips and sawdust and refuse and refuse fractions, which are regularly stockpiled in very large quantities. With each of these materials large fires have occurred, both in the UK and elsewhere in the world. One of the main causes of these fires has been self-heating. This is perhaps not surprising, as it is a phenomenon that is not well understood and consequently it is quite often overlooked by site owners when addressing fire safety. The risks from a fire resulting from self-heating can be greatly reduced by initially obtaining data on the self-heating behaviour of the material, and then applying this information to the storage volumes and conditions actually found on-site.

Quantitative procedures have been developed, using laboratory scale experimental procedures, that can ascertain whether a particular material has the potential to undergo self-heating leading to combustion. The tests can also be used to investigate in detail the self-heating behaviour of materials in different volumes. The data obtained from these tests can then be applied to practical problems of self-heating in the manufacture, storage and transport of susceptible materials. Information can be obtained that can lead to quantitative predictions of the conditions for the occurrence of ignition for different materials in different environments, the time taken to ignition and safe storage/transport volumes. This can then provide a firm basis for safe storage and handling.

Case study 1

A waste management company was involved in the stockpiling of waste wood, wood chips, plastic, paper, tyres and general earth/concrete rubble obtained from demolition sites.. The volumes of material stored was estimated to be 30,415m^3, of which 13,570m^3 was wood chips stored in four separate piles. During February 2002 a fire occurred in the largest of the stockpiled wood chips having a volume of 8780m^3 and a pile height of 8m.

BRE was commissioned to determine the likely cause of ignition of the wood chip pile.

It was already known from previous work and from a literature survey that wood chips had the potential to self-heat. The next task was to collect as much information about the types and volumes of waste materials involved in the fire. All the information and data was then examined in detail, along with eyewitness accounts, photographs and a video of the pile on fire. Unfortunately our involvement only commenced some time after the fire had been extinguished and the site cleared, and so useful evidence of the burning patterns within the pile was lost.

Consideration was given to all possible ignitions sources, such as arson, accidental ignition from smoking materials and on-site activities. All these were discounted from the examination of the evidence. The nature of the fire obtained from the video and witness statements, and also from the size of the pile and nature of the material, lead to the conclusion that self-heating was the most likely cause.

Case Study 2

A plastics manufacturing company used a waste recycling process to produce plastic crumb material. This material was then bagged and stockpiled outside the production facility by stacking the bags on top of each other. A fire occurred within the stockpiled recycled crumb which spread rapidly to the factory buildings causing substantial damage.

BRE’s investigation of the incident commenced with a site visit to examine the fire damage and obtain all relevant information on the fire and the recycling process from the employees. Security camera video footage was also a useful tool in piecing together the events leading to the fire. The severity of the fire damage made ascertaining the ignition source a difficult task. However, it was thought that self-heating was a probable cause, depending on whether the material properties would support self-heating leading to combustion.

A sample of the recycled material was taken away and a self-heating classification test was undertaken at the BRE Fire testing laboratories. The results of the test showed that an exothermic reaction occurred within the material at 160°C, leading to spontaneous combustion of the material. This indicated that the material could indeed self-heat, under specific storage conditions (geometry, volume, storage time, temperature of material and surroundings), which can was a very likely cause of the fire in the stockpiled material.

Conclusion

Thus the potential for spontaneous combustion as a fire hazard at UK composting and waste processing facilities is evident. There are, however, quantitative methods that can be used to provide information on the self-heating behaviour of materials, which can then be used as part of the overall exercise to ascertain the degree of risk posed by bulk storage of combustible materials. This information is vital if a fire risk assessment is to cover all the possible causes of ignition.

BRE/FRS offer a comprehensive fire risk assessment service. Please contact FRS Enquiries on 01923 664970 or e-mail: frsenquiries@bre.co.uk.

r³ environmental technology limited is a environmental consultancy specialising in waste and contaminated land management, particularly treatment based approaches.

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