MINISTRY OF ECOLOGICAL AND SOLIDARITY TRANSITION

Fires in waste composting activities

Risk factors and prevention measures: lessons learnt from feedback

May 2018

Source: SDIS 73

Ministère de la Transition écologique et solidaire
BARPI
DGPR SRT

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Introduction

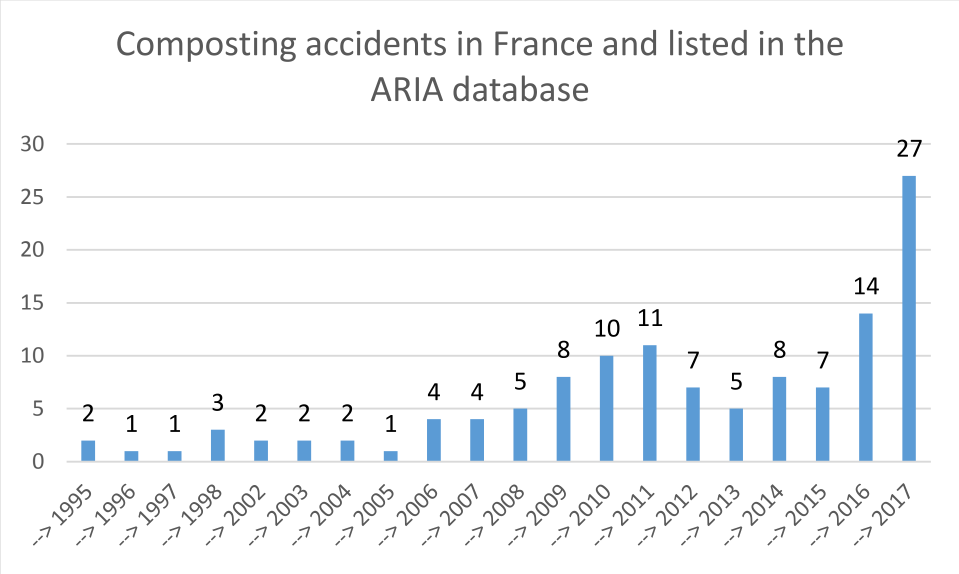
The relative increase in disposal costs and regulatory requirements (an overall reduction in landfilling by 2025, and sorting at source of bio-waste) allow biological treatment processes (composting, methanisation) to continue to grow in France. This development is highly beneficial from an environmental standpoint, but it is accompanied by a significant increase in accidents in these activities. This highlights a sector that is currently undergoing structuration. The ARIA database operated by the BARPI (the French Office of Risk and Industrial Pollution Analysis of the Ministry of Ecological and Solidarity Transition) thus records a 229% increase in composting accidents and a 119% increase in methanisation accidents in 2017 compared to the average over the previous 5 years.

This document focuses on the accidentology of waste composting activities, and more specifically on fires, the dominant hazardous phenomenon. The aim is to identify the vulnerabilities of these activities and propose measures to prevent and protect against accidents. A quick update is also given on intervention strategies and the consequences of accidents. The comments are illustrated by references to the events listed in the ARIA database.

Source: SDIS 73

1. Accident sample

The study is based on accidents involving composting activity in France before 31/12/2017 and which are listed in the ARIA database, i.e. 124 accidents. The oldest accident was in 1995, but of the 124 accidents reported, half occurred in the last five years (2013-2017).



Of these accidents, 115 involved fire (93% of the cases). **This sample is the basis of the study.**
The other accidents recorded in composting activities concern environmental pollution as a result of accidental releases (for example, ARIA 51171) or various events such as the flooding of a site (ARIA 48230) or the collapse of a leachate basin (ARIA 42901).

Source: SDIS 13

2. Analysis of vulnerabilities in the composting process and of accidents

2.1. Some reminders about the composting process

Composting is a process that involves transformation by aerobic fermentation, i.e. in the presence of oxygen, of fermentable materials under controlled conditions. During this process, microorganisms break down organic matter and produce CO_2, ammonia, water, heat, and a stabilised fertilizer rich in humic compounds, compost, which can be used as an organic amendment.

Note: Fermentation can also take place under anaerobic conditions, i.e. in the absence of oxygen. However, this process (which intervenes at a relatively low temperature and involves microorganisms other than those involved in the aerobic mechanism) generates foul-smelling compounds (methane, hydrogen sulphide, etc.), some of which are phytotoxic. On the other hand, composting under aerobic conditions generates a material without the risk of phytotoxicity, whose pathogens have been destroyed as a result of being exposed to high temperature, and without the release of bad smells.
Control of the composting process, therefore, consists in creating and maintaining over time, conditions conducive to the aerobic sequence of the process.
Only aerobic composting will be discussed in this document.

Composting can be performed on various organic materials: green waste, sludge, raw household waste, biowaste... and systematically follows several steps, shown in the diagram below:

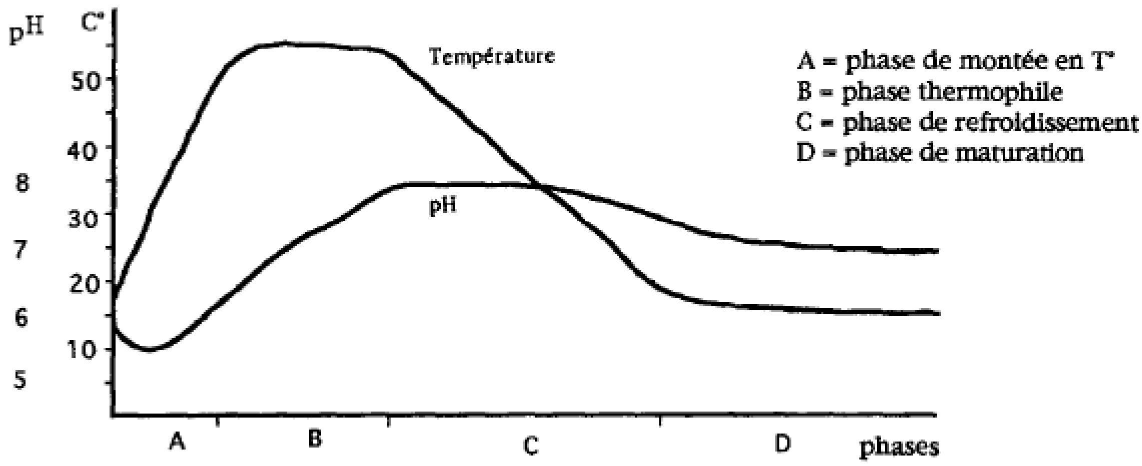
Source: ADEME

- receiving: quality control of incoming waste.
- shredding: shredding of the woody parts of the waste provides a greater surface area for the microorganisms responsible for the composting mechanism.

- fermentation: this phase, which lasts a few weeks, allows the temperature to gradually rise (mesophilic phase) and the degradation of the cellulose by bacteria. After the peak temperature (thermophilic phase) has been reached, the temperature gradually drops (cooling phase) and the fungi colonize the material.
- curing: this phase, which lasts a few months, allows the fungi to stabilise the organic matter.
- screening: sifting at the end of the curing process allows refuse to be recovered that would otherwise be reintroduced into the composting process. It also makes it possible to eliminate undesirable elements (metals, plastics) which may not have been identified during the sorting process at reception.
- storage of mature compost: preferably performed in a hangar or under a tarp. Mature compost is a dark brown to black, homogeneous material with a texture close to that of soil.

The curve below schematically shows the changes in temperature and pH parameters during the composting process.

- At the temperature level, a distinction is made between the temperature rise phase (mesophilic phase), the temperature peak phase (thermophilic phase), then a cooling phase before the curing step.
- As far as pH is concerned, following an acidic phase, due to microbial activity, the pH becomes neutral again and stabilises at maturity with a pH around 7.5-8.5.



Source: B. Joliet

What follows is a summary of the main factors influencing the aerobic composting process (control of these factors makes it possible to avoid switching to anaerobic mode).

- aeration: Aerobic composting requires significant amounts of oxygen, especially in the early stages. When there is an insufficient supply of oxygen, the growth of aerobic microorganisms is limited, which slows decomposition. Aeration, by inversion or displacement (the materials tend to become compacted under their own weight), not only allows for this oxygen supply but also allows the excess heat to be removed and elimination of water vapour and other gases trapped in the heaps. Removal of heat is particularly important in hot climates, given the higher risk of overheating and fire.

- humidity: Moisture is required to ensure the metabolic activity of the microorganisms, but must be finely regulated. If the heap is too dry, the composting process is very slow, while above 65% humidity, anaerobic conditions appear.
- nutritive elements: Microorganisms need carbon, nitrogen, phosphorus and potassium as the main nutrients. The C:N ratio is a particularly important factor.
- temperature: The composting process involves two temperature ranges: mesophile and thermophile. While the ideal temperature for the initial composting phase is 20 to 45 °C, thereafter a temperature between 50 and 70 °C is ideal. High temperatures characterise aerobic composting processes and are indicators of significant microbial activity. Pathogens are generally destroyed at 55 °C and above, while the critical point for eliminating weed seeds is 62 °C. Turning and ventilation can be used to regulate the temperature.
- heap size and porosity of the compost: When the heap is too big, anaerobic areas can form which slow down the process in these areas. However, undersized heaps quickly lose heat and do not reach a temperature high enough to evaporate water and eliminate pathogens and weed seeds. The physical properties (porosity, granulometry) of the materials must also be taken into account to define the optimal heap size (more porous materials make it possible to create larger heaps, whereas this should be avoided with heavy materials that are likely to become compacted). Finally, the climate is a factor to be taken into account: in order to minimise heat loss, large heaps are appropriate for cold climates while the risk of overheating is significant in warmer climates.

Composting activities are regulated by section 2780 of the French nomenclature for classified installations for the protection of the environment.
See https://aida.ineris.fr/consultation_document/10755 for details on submission thresholds and the applicable texts.

2.2. Typology of fires encountered in composting activities

Two types of fires can occur in composting operations. Deep-seated fires can arise, following a self-heating reaction, and surface fires with more diverse (external) causes.

- **Deep-seated fires**

Composting is an activity that is prone to deep-seated fires for the following reasons:

- The materials treated have a self-heating potential.

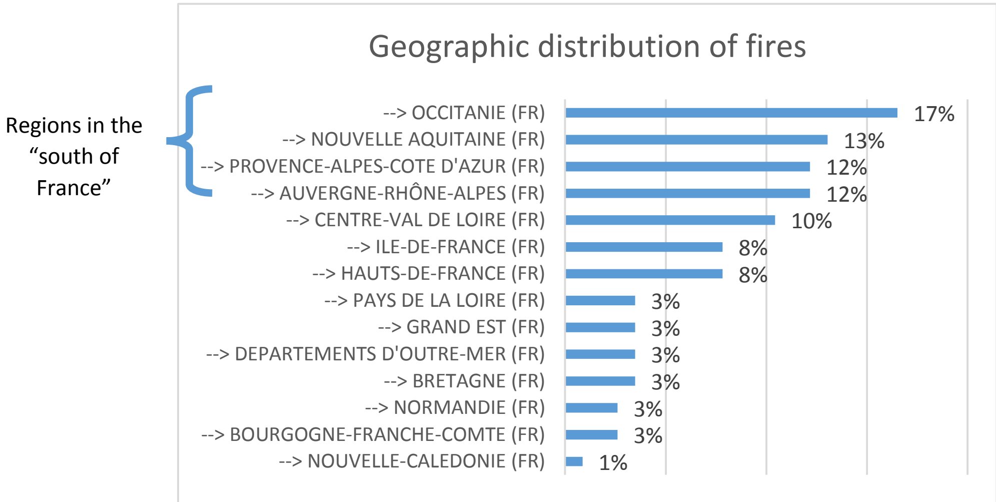
  As mentioned in section 2.1, the heating phenomenon of materials is an integral part of the composting process and is in fact desired. Based on current regulations, the installations subject to authorisation under section 2780 (Ministerial Order of 22 April 2008) must ensure that a temperature of at least 55 °C is maintained for at least 72 hours.
  However, this spontaneous self-heating phenomenon may deviate. When more heat is produced than can be dissipated, the temperature can rise to a potential combustion temperature (between 150 and 200 °C) without any external energy input. A smouldering fire can then form, which can cause flames to appear. This phenomenon is referred to as **self-combustion**.

  The risk of going from self-heating to self-combustion depends on the chemical composition of the substrates (possible impurities acting as a catalyst), humidity, storage size, temperature

of the heap and ambient temperature, air diffusion efficiency in the heap (related to the granulometry of the waste), oxygen content in the heap, and storage time, etc.
Thus, while this risk is present throughout the composting process, it is particularly high during certain phases. The risk remains relatively low during the curing process because the humidity of the materials is quite high, but it is much higher during the storage of mature compost as it is much drier. In other words, the susceptibility to self-combustion increases during the composting process, as the humidity decreases: the humidity range [20-45%] is favourable to self-heating, knowing that the optimum humidity for the composting process is in the 40-55% range.

Examples of accidents during the curing phase: ARIA 22780, 34221, 44943, 41366, 47656, 48018, 49628, 49940.
Examples of accidents during compost storage: ARIA 32498, 33903, 38235, 39042, 39502, 44360, 47925, 48604, 49614, 49853.
The storage of sifted waste product, elements that are often dry, are also regularly the seat of the fire: ARIA 25345, 35796, 41008, 50334.

Logically, the susceptibility to self-heating is increased during heat wave/drought periods which make the compost particularly dry (ARIA 45868, 49853) and/or in case of strong winds: air movements increase heap oxygenation and stimulate combustion (ARIA 46799, 50309, 42148, 50321, with fire spreading to four operators in the last example). The regions in the south of France are thus particularly represented in the accident sample. It is also understandable why the height of the heaps must be adapted according to the climate in the geographical area where composting activity is located.



Note that an uneven level of moisture within the waste is a risk factor. Thus, an uneven distribution of water (rain…) on a dry windrow promotes heating (ARIA 47358, 45722).

- Large volumes of waste, stored in large heaps, come into play (commonly in windrows of 500 to 1,500 t).

- The site's activity is often discontinuous (no permanent staff present). In fact, many accidents occur outside normal working hours and the fire is often detected by a local resident or a third party. Examples: ARIA 48018, 48759, 49614, 49943, 50873, 50334, 50321.

- Storage is often over long periods of time: several weeks to several months.

- Smouldering fires, without flames, are difficult to detect (ARIA 48447, 48759).

- Compost fires are difficult to extinguish since the water has difficulty penetrating the compost bed. See section 3 on emergency response in the event of a fire.

Beyond the risks of self-heating inherent with composting (the nature of the waste handled, the large volumes treated, the incompressible duration of the process), poorly adapted operating methods, often corresponding to a **disregard for regulatory requirements**, significantly increase the probability of this phenomenon occurring (but also the severity of the consequences of the accidents and the emergency resources often prove insufficient). Thus, in a large number of cases, the accidents reveal inappropriate practices that are all aggravating factors:

- Exceeding authorised stock volumes/heights (ARIA 47656, 50875, 49894), sometimes due to technical constraints (ARIA 44878: e.g. accumulation of compost to be sorted due to a screen filter malfunction), sometimes as part of an irregular operation of the activity (ARIA 43269, 50873). The larger the windrows, the greater the inertia and the more difficult it is to dissipate the heat. As already mentioned, this also causes anaerobic zones to appear. As far as the regulations are concerned (see ministerial orders applicable to installations subject to authorisation, registration and declaration under section 2780), the maximum height of heaps and windrows of fermentable material is limited to 3 meters (or even 5 meters if a waiver is granted) during the fermentation and curing phases.
- Inappropriate consideration or a misunderstanding of the hazard potential of the substances involved: ARIA 46021 (misunderstanding of the self-heating potential of a new type of waste), ARIA 45722 (supply of additional shredded material to materials already being composted for a certain time and formation of a “layering effect”), ARIA 47920 (insufficient mixing of waste containing very dry straw), ARIA 49614 (heterogeneous distribution of green waste in the row)…
- Lack of/insufficient temperature, watering control: ARIA 48064, 47656, 47920.
- Insufficient row turning/aeration and formation of anaerobic zones.

Surface fires

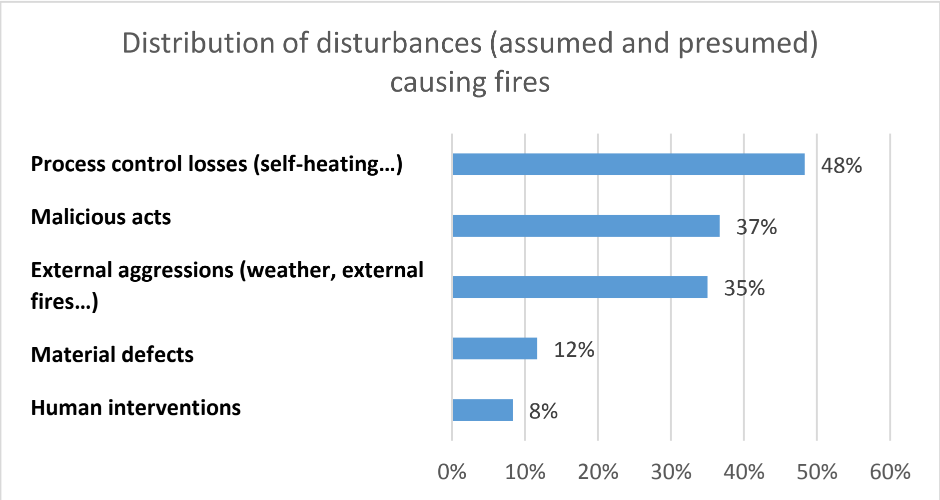
Surface fires can concern static phases (fermentation, maturation, storage of mature compost), following accidental contact of stored waste with an ignition source (spark, lightning, cigarette...). The risk also exists during the mechanical phases (shredding, screening, conveying, etc.), in connection with the presence of combustible dust which can heat up, for example in the event of electrical equipment failure.

The table below summarises the main risk (deep-seated fire due to self-heating or surface fire) according to the stage of the composting process.

Step in the process / Nature of the risk	Receiving	Shredding	Fermentation	Curing	Screening	Storage
Elevated self-heating, giving rise to a deep-seated fire	+	-	++	++	-	+++
Inflammation of stored plant material, giving rise to a surface fire (cigarette, spark, malicious act, etc.)	++	-	++	++	-	++
Inflammation of plant dust, giving rise to a surface fire (electrical problem, etc.)	-	+++	-	-	+++	-

2.3.Hierarchy of causes involved in the fires

The histogram below shows the distribution of the root causes of the fires. The percentages expressed in relation to the total number of accidents for which information is known: out of 115 accidents, there are 60 (i.e. 52% of the cases) for which we have a certain understanding (actual or assumed) about the causes of the event.
The sum of the various entries in the histogram is greater than 100% because several causes may be involved simultaneously in an accident (e.g. loss of process control: uncontrolled self-heating, resulting from inappropriate human intervention: (e.g. lack of temperature control or watering).



- “Process control losses”, involved in almost half of the cases, correspond to self-heating phenomena. This is the most common primary cause of fire. In composting operations, deep-seated fires are thus encountered more frequently than surface fires.
  Examples: ARIA 47358, 49853, 35796, 47656, 49020, 49878.

- The “material defects” correspond to breakdowns, electrical problems, etc. occurring on the shredding, screening, conveying and loading equipment, etc. and resulting in heating up of plant dust. They are involved in more than 10% of the cases.

Examples: ARIA 43922, 45055, 49175, 50309, 50976, 49943.

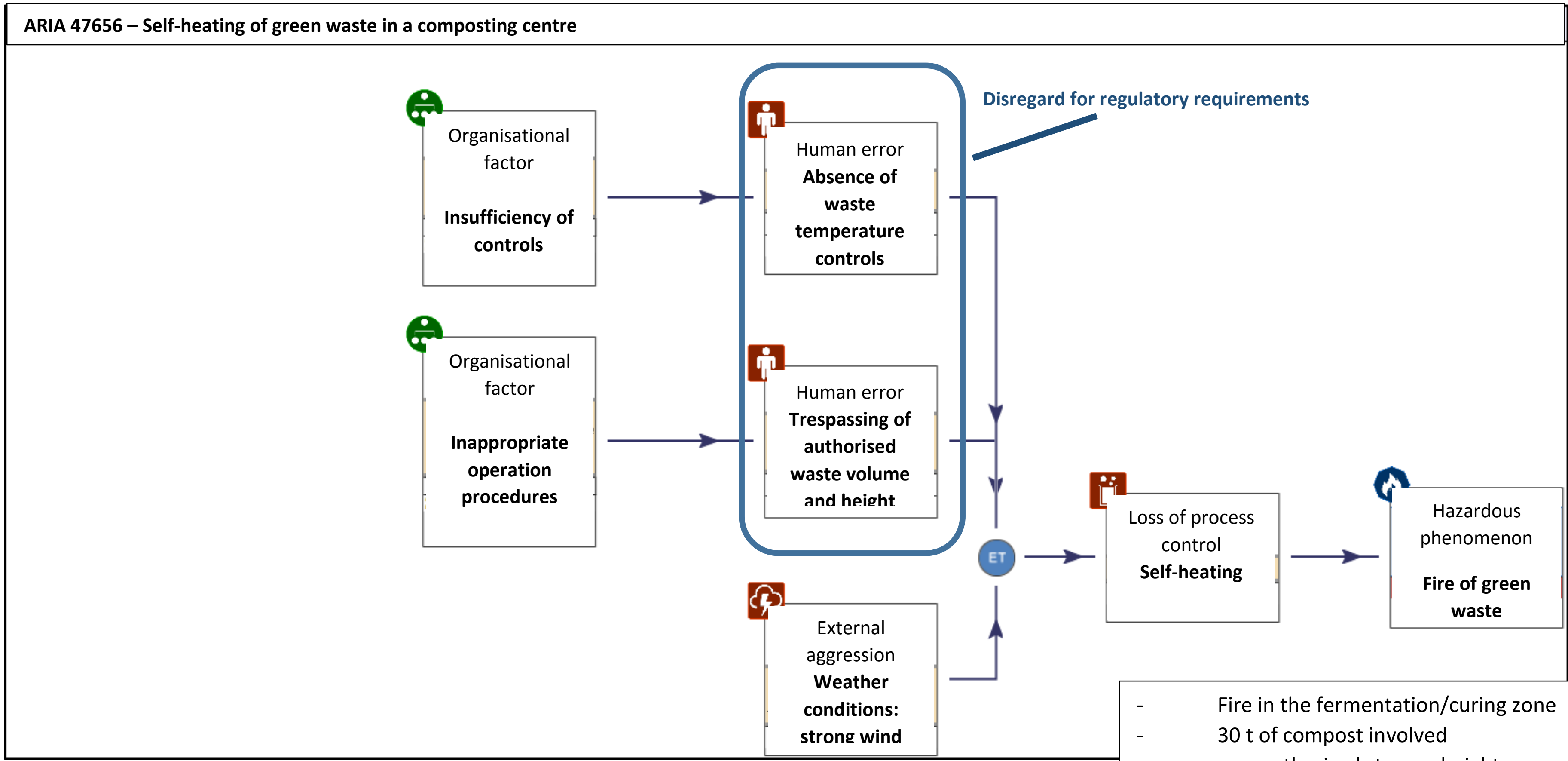
- “External aggressions”, involved in more than a third of the cases, correspond mostly (95% of the cases) to attacks of natural origin (high heat, strong wind, lightning, spread of a vegetation fire, etc.). Examples: ARIA 49940, 50321, 43269, 46799… The other cases correspond to external aggressions of anthropic origin (e.g. domino effect from a neighbouring industrial installation: ARIA 50321).

- “Malicious acts” correspond to arson. Whether proven or suspected, malicious acts are involved in nearly 40% of the accidents, which is particularly noteworthy.
  Examples: ARIA 45879, 45940, 49628, 44943, 38556, 39042, 41008.

- “Human interventions” correspond to human errors, such as poorly controlled hot work (welding, grinding), outbreaks of fire linked to cigarettes, and the disregard for watering procedures, etc. These occur in a little less than 10% of the cases.
  Examples: ARIA 47920, 47656, 49614.

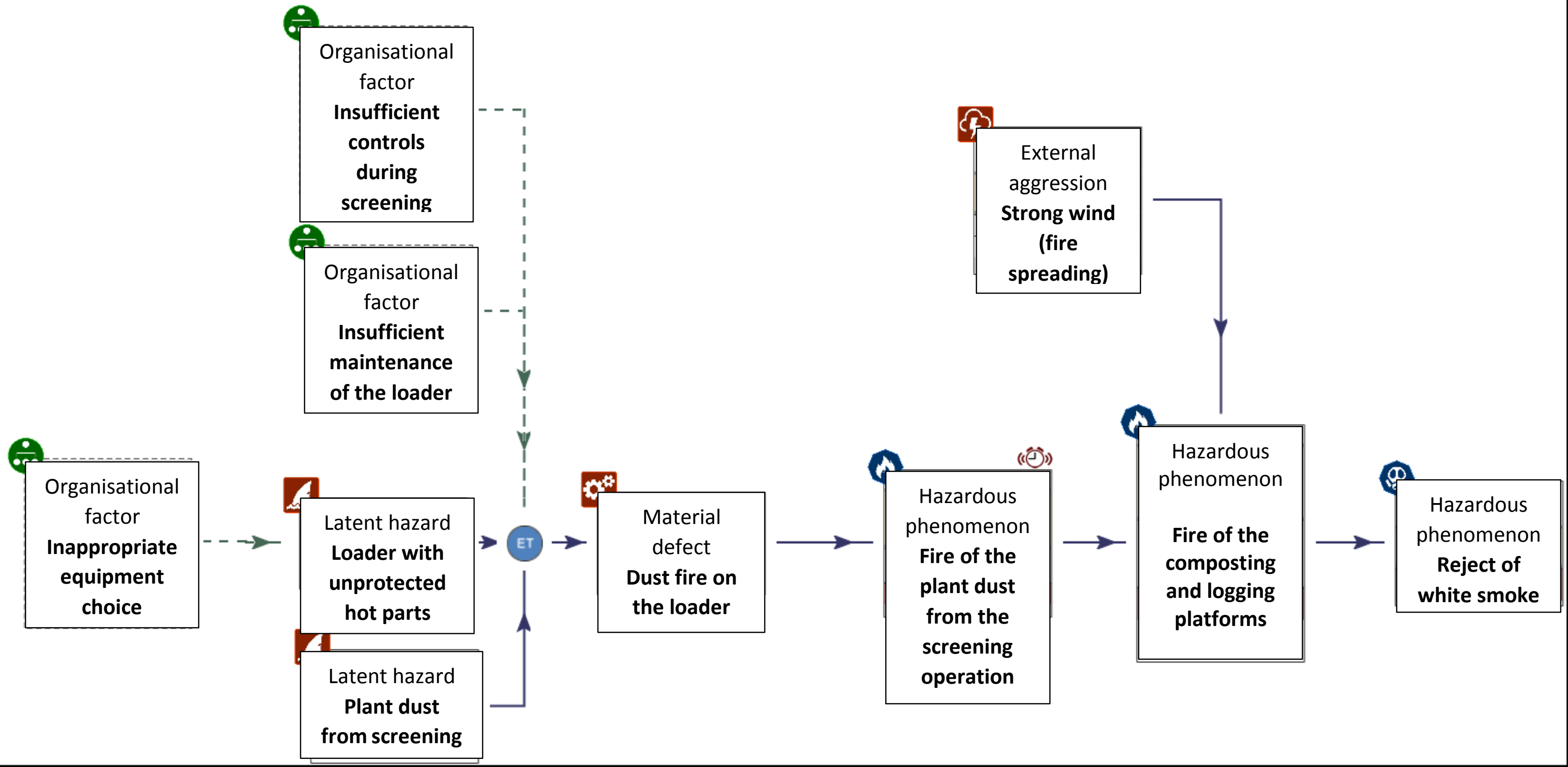
2.4. Illustrations

Below are two representative examples of the causal analysis of an accident, conducted using the BARPI's graphical modelling tool. The first example concerns a fire following self-combustion (ARIA 47656) while the second example concerns a fire following accidental ignition of plant dust (ARIA 50309).



- Fire in the fermentation/curing zone
- 30 t of compost involved
  - authorised storage heights exceeded: 8 m as opposed to 2.5 m
  - all compost amassed into a single heap prior to shipment
- Intervention by 25 firefighters
- Removal of waste with construction equipment + watering (insufficient water resources available on site)

ARIA 50390 – Fire after a screening operation in a composting centre



- Fire on a loader during screening operation
- Failed attempts to extinguish the fire by the employees → emergency call
- Despite windrows of limited size and separated by firebreak traffic areas, the strong wind (70-80 kph) spread the fire to products stored on the logging platform (600 t), then to the composting windrows (1500 t)
- Release of white smoke requiring evacuation of a nearby Roma and Travellers camp
- Mobilisation of all the site's water resources:
  - Fire pond (240 m^3), water collection basin (850 m^3), bladder tank for fire protection (400 m^3), fire hydrant.
  - Pumping in the lagoons of the municipal wastewater treatment plant (36 h) and the industrial wastewater treatment plant (12 h).
  - Water containment valves on the platform, closed to create two large water reserves used for extinguishing burning wood and plants.

3. Some elements on extinguishing operations[1] and the consequences of fires

3.1. Extinguishing operations

Extinguishing operations differ, and are more or less complex, depending on the nature of the fire. While surface fires leave little time to react, self-combustion is a slower burning phenomenon that offers longer reaction times. However, rapid action is essential to prevent the onset of self-heating to spread an entire row, or even its spread to adjacent heaps. Moreover, deep-seated fires can be difficult to put out completely, as evidenced by cases of repeated fires, lasting several days to several months after an initial intervention (ARIA 50580, 50880).

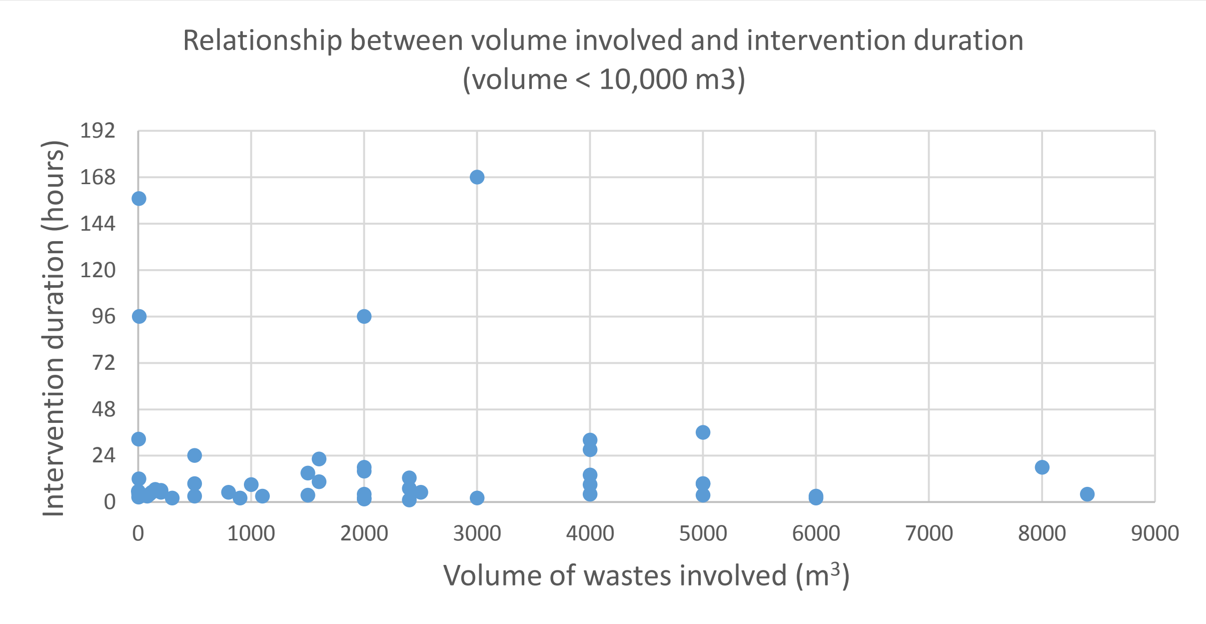
Source: DREAL Auvergne Rhône-Alpes

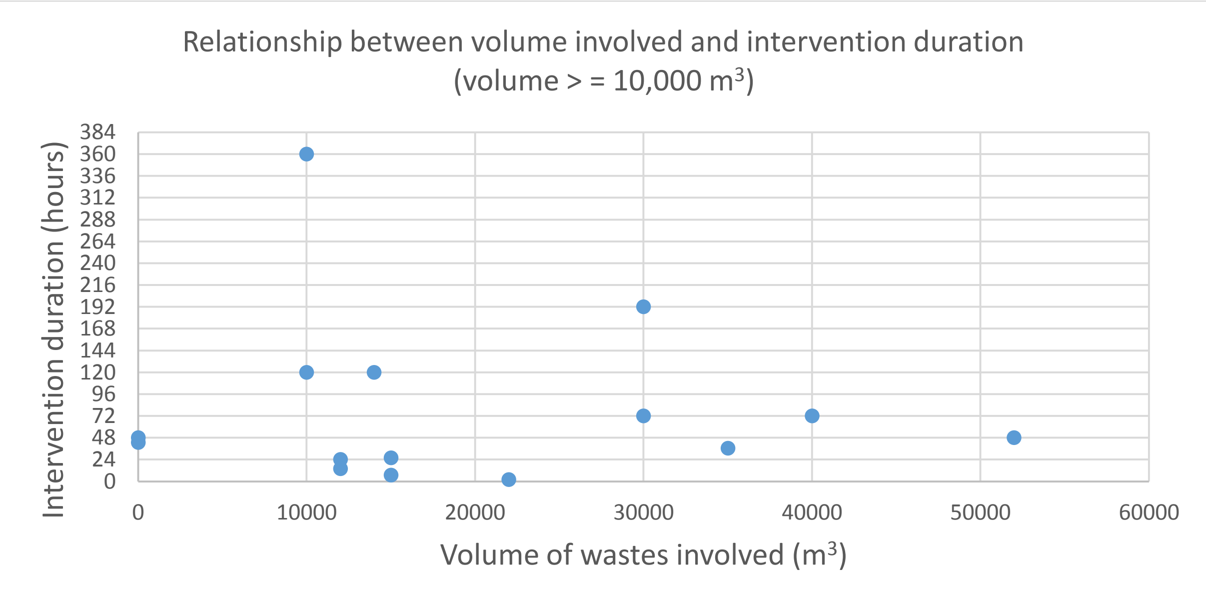
The extinguishing operations in composting centres require significant water resources (ARIA 50887: intervention by water-bombing helicopters, ARIA 50309: an example of an extinction strategy using various means). The use of private means (construction machinery) is also frequent. The importance of rapid mobilisation of equipment and drivers should also be noted (ARIA 43269).

Interventions are time consuming, especially when large volumes and heights of waste are involved. Based on available information, it appears that the intervention generally lasts less than one day when the volume involved is less than 10,000 m^3. On the other hand, the operation frequently lasts several days for volumes exceeding 10,000 m^3. However, there does not seem to be an obvious correlation between the volume of waste involved and the amount of emergency resources deployed (number of firefighters, equipment, etc.). Even if the intervention is certainly complicated when very large volumes are involved (sometimes resulting in the absence of available space for spread out material and

[1] It should be noted that the quality of the information relating to the intervention varies greatly depending on the accident (times communicated corresponding to the time when the fire was brought under control or when the emergency services left the site; data on the volumes corresponding to the waste actually on fire or to the volume of all waste present at the site…). For this reason, the conclusions of this section should be taken with caution.

watering down in good conditions: ARIA 50873), it is clear that the **complexity of the configuration (including the risk of spreading, the presence of adverse weather conditions, proximity of vulnerable third parties, etc.) also has an impact on the course of the disaster and the strategy to be put in place to deal with it.**





In this context of long-term interventions involving the deployment of significant resources, the problem of water resources logically arises. The resources planned for by the operator are sometimes rapidly exhausted and requires that alternatives be found (ARIA 22780, 43269, 49835, 32498, 42148, 43169, 47744, 48406, 49591). The recovery of the extinguishing water in ponds used for irrigation purposes (closed circuit) is an interesting solution (ARIA 50309, 42504, 45879, 49892).

Finally, the large volumes of extinguishing water generated by the intervention must then be properly managed: treatment in an on-site (ARIA 49591) or external (ARIA 50580) wastewater treatment plant, treatment in the lixiviates line (ARIA 47358), integration into the spreading plan with compliance verification (ARIA 35796)…

Source: SDIS 34

3.2.Consequences of fires

The human consequences of fires remain low. No deaths or serious injuries were reported. Smoke released during fires may require the residents be evacuated or confined (ARIA 50309, 38235, 45940, 40102).

The environmental consequences correspond mainly to smoke-related air pollution.
Water and soil are also impacted in some cases, often related to a lack of waterproofing of the surfaces involved or a breach/overflow of the pond used to contain the extinguishing waters (ARIA 35211, 41304, 50605, 35796, 38556, 49628, 50873).

The physical consequences of fires are particularly extensive in cases where composting takes place below buildings, and where the latter is severely damaged, or where equipment is involved. Some examples of significant accidents in terms of the scale of economic losses (between 0.4 and 1 M€): ARIA 43269, 43922, 45940, 48406.

3.3. Illustrations

Below are two examples of accidents in which the emphasis is placed on the means of intervention and the consequences.

ARIA 40102 - 12-04-2011 - 13 - ISTRES

- Fire starting in a 500 m³ compost heap.
- Strong wind fanning the flames → threatening the 20,000 m³ sorting building and the area surrounding the site (school, NATURA 2000 area, etc.).
- Black smoke visible from several tens of kilometres away → confinement + evacuation of residents.
- Reaction force: 92 firemen, 17 pump trucks, reinforcement provided by teams from the nearby military airbase.
- After the fire was put out, monitoring with rounds every 4 h for 5 days.
- One employee and a fireman were slightly injured during the intervention.
- More than 100,000 m³ of waste burned and 2 ha of brush and pine forests destroyed.
- Presumed origin: a backhoe loader had struck a marine distress flare that had mistakenly been abandoned in the green waste.

Source: SDIS 13

ARIA 49892 – 01-06-2017 - 39 - BREVANS

- Outbreak of fire on a stock of shredded green waste (30 m x 20 m over a height of 3.5 to 4 m), in a composting centre.
- Displacement of compost heaps by the personnel using a loader.
- Firefighters connected to the site's fire hydrant.
    - Spreading of the fire to the stock of fibreboard panels was avoided.
    - A bungalow and 3 bins of rubble were damaged by the flames.
- Strategy adopted by the firefighters: allow the green waste to burn.
    - Creation of a 3-metre high compost bund around the burning heap,
    - Use of compost to smother the fires,
    - Use of extinguishing water (retention basin) to water down the wood ash residues and compost bunds after mixing with a loader,
    - Monitoring of the combustion,
    - Five days later, the fire was sprayed down again with water from the retention basin + turning of the compost and waste with the loader.
- 7th day: the fire was put out. 300 m³ of water used.
- Intervention feedback: questions were raised regarding the efficiency of the bund which limited the spread of the fire to the other heaps, but participated in the combustion and the generation of smoke -> consideration of a lower bund height
- Suspected origin of the fire: self-combustion or a malicious act.

Source: DR

4. Recommendations drawn from the feedback

Behind the root causes of the accidents (loss of control over the composting process, physical defects, inappropriate human intervention, etc.) lie the underlying causes of a technical and organisational nature (inappropriate choice of equipment or operating methods, inadequate organisation of checks and activity monitoring, etc.). These root causes are generally the responsibility of the industrial site's operator. By working on these root causes, recommendations (preventive and/or protective measures) can be identified so as to prevent new accidents from occurring.
Concrete examples of the measures taken by operators following accidents are proposed.

- **General information**

  - Reinforce incoming inspections to detect the presence of prohibited elements (distress flares, etc.)

  - To avoid the spread of fire or external aggressions: ensure that the site is located outside forest fire risk zones, strip around the areas at risk, clear brush along the edge of the site, set up a system to prevent material from blowing away.

  - Reinforce monitoring of the site
    - ARIA 50993: following an outbreak of fire over the weekend, while no employees were present, a human presence on the platform was organised at least once per day, including over the weekend.
    - ARIA 50334: following a fire that broke out at night, after operations had ended, a systematic patrol was set up at the end of the day.

  - Installed devices to combat malicious acts (fences in good condition, cameras, etc.)
    - ARIA 45879: following an arson attack, a video-surveillance system was set up).

- **Combating self-heating**

  ➢ **Configuration of the compost processing installations**

  - Respect the authorised volumes and storage heights.
    - ARIA 47656: following a fire in a context where the permitted storage heights are exceeded (8 m as opposed to 2.5 m), the operator ensures strict compliance with this parameter.
    - ARIA 47358: following self-combustion with rapid spreading of the fire to several heaps, the operator is working to reduce green waste stocks and refuse and toward faster shipping of finished compost.

  - Ensure the safety distances between the various storage zones (distance between the heaps) or install constructed devices (firewalls).
    - ARIA 47459: following a fire on a large stock of green waste, stocks of green waste awaiting composting were separated into small batches (with physical separation between batches).
    - ARIA 47656: following a fire on a massive compost heap (all of the ripe compost had been grouped together into a single heap for shipment), the operator shall ensure

compliance with the regulatory requirements regarding the management of the compost based on production batches: separation of batches manufactured using uniform production parameters, temperature measurements carried out based on batches.

- Reduce the static storage duration (there is a critical static size/duration pair not to be exceeded to avoid reaching the temperature that favours self-combustion, i.e. 150/200 °C). Attention should be paid to downgraded situations which could lead to prolonged storage (equipment breakdown periods, supply/demand problems within the sector…) and accumulations of waste.
  - ARIA 41238: following self-combustion of compost, modification of operating procedures: limitation of the maximum fermentation time to 1 month, before screening, then curing for a maximum of 1 month as well.
  - ARIA 49892: development of refuse recovery sectors, including those outside winter periods involving the use of boilers.
  - ARIA 49591: reduced waiting time between green waste shredding and screening phases.
  - ARIA 50993: following self-combustion, increase in the frequency of screening operations: at least twice a year, instead of once a year as before.

- Increase the frequency of row handling/turning, to ensure that aerobic conditions are maintained.
  - ARIA 49020: following a shift in the heating at the core of a windrow containing particularly dry waste, the operator improves the mixing of the waste during turning to obtain better homogeneity of the product and to avoid the drier areas.
  - ARIA 49614: following a fire due to a heterogeneous distribution of green waste in the windrow, the operator reminded the employees to ensure homogeneous distribution of waste when forming the windrows. Controls to ensure homogeneity were set up.

- Following rainfall, readjust the humidity uniformly by mixing/turning the heaps to avoid overheating.
  - ARIA 50993: following self-combustion in windrows a few days after a rainy episode, the operator ensured more regular handling of the composted products.
  - ARIA 49853: following self-combustion in a windrow containing very dry portions, the operator mixed dry windrows with wet windrows.

- Implement operating practices adapted to the nature of the waste, the latter needing to be well-characterised.
  - ARIA 41238: following self-combustion, the operator changed co-products and normalise its compost to obtain less dry compost.
  - ARIA 49878: following self-combustion due to contact within a row between very dry malt wastes, screening refuse and sludge, the operator abandoned the composting of malt waste. The operator is searching for another outlet for this waste.
  - ARIA 49591: following the uncontrolled fermentation of the fine fraction of green waste in composted heaps, the operator has begun screening shredded green wastes on site to extract the fine fraction before composting.
  - ARIA 46021: following self-combustion of sludge, the self-heating power of which was unknown to the operator, an operating procedure for sludge was set up with specific rules for transfer, mixing and storage. The sludge must be stored in windrows less than 1 metre high and quickly incorporated into the windrows upon arriving at the site

  - ARIA 45879: following a fire that spread to multiple heaps, the operator reduced the quantity of non-shredded wastes entering the site, which are more easily flammable and generate an increased risk for the spread of fire.
  - ARIA 45722: following a self-combustion due to the addition of new shredded materials on an existing row (which has had a "layering" effect), the operator prohibits stacking additional shredded materials on a row already being composted.

- Train the operators to detect smouldering fires: vigilance with white fumaroles, combustion odours, use of temperature probes (to be inserted deeply into the heaps)

- During the phases of the process taking place in a building, monitor the vapour space of the premises (CO_2)

- Think about innovative monitoring systems, e.g. site inspection by automated UAV (3D volume calculation and thermal analysis; alert in the case of detection of a hot spot on the surface of a row)

➢ **Monitoring of temperature/watering**

- Reinforce row temperature monitoring: it is recommended to go beyond the minimum temperature reading intervals established by the regulations (Ministerial Orders of 22/04/2008 and 20/04/2012). The frequency of temperature measurements must be increased during periods of risk (high heat, after heavy rainfall, etc.).
  - ARIA 45868: following temperature readings that did not detect a shift in the fermentation, the operator modified the configuration of the windrows (triangles measuring 4 m wide and 3.5 m high, instead of a previously wider tubular shape) and their spacing (1 m between each windrow) to facilitate temperature control in the centre of the heaps.
  - ARIA 41238: following self-combustion of compost, continuous temperature monitoring was set up in curing heaps (2 temperature probes per cell with alarm reporting).
  - ARIA 41238: following a compost self-combustion incident, a thermal camera system (at a cost of approx. 35,000 €) was set implemented and weekly screening was performed by an operator.
  - ARIA 45722: following runaway fermentation resulting from the penetration of precipitation into the heart of the windrows (i.e. the addition of dissolved oxygen), the operator increased the frequency of the temperature measurements in the composting waste after heavy rains.

- Take weather warnings into account (rainfall, temperatures, etc.) when defining watering volumes and frequencies.
  - ARIA 50935: following an outbreak of fire in windrows of shredded green waste during a period of strong winds, a watering network was installed with which operates when weather warnings are announced.
  - ARIA 47920: following an outbreak of fire as a result of insufficient watering during periods of low rainfall, the operator revised his watering procedure: pluviometry was taken into account in the definition of watering frequency and volumes.
  - ARIA 49020: following heating at the heart of a windrow containing particularly dry waste, a more intensive watering programme was established during periods of drought.

- If the heating starts to shift (high temperature > 80 °C, fumaroles), the heap is opened up, watered down and monitored for several days.

- **Combating surface fires**

  - Smoking is prohibited, with appropriate signage and a reminder to personnel.
    - ARIA 50334: following a fire, potentially triggered by a cigarette butt thrown by a delivery driver, the operator reminded all players that smoking is prohibited in high-risk areas.

  - A fire permit is required before any hot work.

  - Be particularly vigilant regarding "sensitive" equipment, i.e. equipment that generates heat. Avoid the accumulation of dry dust.
    - Shredders: remove metal elements (removal of iron/metal, sorting by magnet), ventilate and dust/clean, provide fire detection above the shredding chamber
    - Lighting: installation of protected and hermetic lamps (in the curing and fermentation tunnel)
    - Loader type handling equipment: monitoring of maintenance, installation of circuit breakers, regular cleaning
    - Ventilation ducts: if plastic, install non-combustible sections at building penetrations
    - Conveyors: flame-retardant strips

  - Select dust-tight shredding/screening equipment.

  - Do not shred/screen during excessively dry weather (otherwise, spray with water).

  - Store screen refuse, particularly flammable elements, away from other activities and storage facilities.

- **Safety and emergency response procedures (fire detection and firefighting equipment, behaviour in an emergency situation)**

  - Efficient surveillance is the key to early detection and, if necessary, early intervention.
    - Install smoke detectors in the composting activity (ARIA 49614),
    - Set up a video-surveillance system.

  - Ensure proper dimensioning of fire detection and extinguishing systems:
    - make small fire-prevention equipment available for internal response teams (extinguishers),
    - hose reels located near equipment having a significant risk such as trommels screens..., but far away from places where loaders or other equipment is operated to avoid mechanical impacts,
    - Installation of specific fire detection (optical detection) and fire protection equipment (deluge system) on sensitive equipment/areas: trommel screens, conveyors, etc.

  - Regular inspection of the proper operation of the fire-fighting equipment (ARIA 47920),

- Ensure the water requirements and retention capacities (dimensioning according to prefectoral detected and SDIS requirements).
    - ARIA 47656: following intervention difficulties, a 500 m^3 bladder tank was installed to guarantee sufficient water reserves in the event of a fire.

- Provide for the recovery of extinguishing water for reuse (basin designed to filter recovered water: decantation, screening, etc.),

- Set up an instruction on what to do in the case of fire (ARIA 41238),

- Train the personnel in on-call and emergency procedures (ARIA 47920, 47358),

- Anticipate the availability of private resources (backhoe loaders) and their drivers,

- Conduct fire drills with firefighters: work on the accessibility to storage areas, firefighting equipment, water supplies… (ARIA 47656),

- Facilitate emergency response: reception at the site, accessibility (provide access for fire brigade, layout of roads for manoeuvring emergency equipment)
    - ARIA 50993: after experiencing certain intervention difficulties (difficult access to burning heaps), the operator has envisaged a configuration/layout of the windrows that would provide rapid access to the silage mass with a loader in order to be able to, if necessary, separate the hot products and remove them from the windrow to spread them out or water them down,
    - ARIA 45868: following intervention problems, the signalling of the fire reserve was reinforced.

Conclusion

Fire is the main risk facing waste composting facilities. These accidents can have serious consequences, not only within the site involved but also for the entire waste management chain. What are the alternatives in the event of a major disaster destroying the facilities or leading to the suspension of activity?

In order to effectively prevent such disasters, the preliminary step is to fully understand the process of transforming and breaking down plant matter through the use of microorganisms, which, to a certain extent, involves **life sciences**, and which are the various parameters that govern and influence these processes. This knowledge allows us to understand how the various types of fire occur in composting facilities (deep-seated fires vs. surface fires) and what management and prevention measures should be put into place, more particularly in terms of **presence and follow-up**.
As illustrated by the numerous cases of accidents at site with non-conformities, **compliance with the regulatory requirements set out by the ministerial and prefectoral orders alone would have made it possible to avoid a large number of these accidents** (especially cases of deep-seated fires caused by a loss of process control): this particularly relates to measures concerning storage volumes and heights, the fragmentation of heaps, very regular monitoring of the temperature in the heart of the heaps, etc.
As far as fires caused by events external to the process, special attention should be given to malicious acts, for which the waste processing sector is a regular target (malicious acts are involved in 27% of fires in composting centres, and in nearly 40% when the highly suspicious cases are considered…).

Feedback analysis is very useful in risk reduction. However, as mentioned in section 2.3, **the technical and organisational causes of the accidental events are unfortunately too rarely studied in order to be elucidated**. Composting site operators should make progress in this area. If inquiries/diagnostics are conducted and lead to the origin of the fires, or at least allow assumptions to emerge, these elements should be sent to the BARPI. The same applies to information relating to the intervention conditions. To allow further progress to be made in the use of feedback and to make analyses more reliable, it is particularly useful to provide the BARPI with data on: the volumes exposed to fire, the volumes actually burnt, the duration of the firefighters' intervention, the human and equipment resources used, the volume of water used, and the retention volume available/used, etc.
It is this **participative approach that will allow feedback to play a full roll in prevention, for the benefit of all players in the waste processing sector.**

Source: SDIS 47

The list of the 115 accidents analysed in this summary is available in the appendix hereto. The accident summaries can also be found using our website's search engine using their ARIA https://www.aria.developpement-durable.gouv.fr/?s=

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- Part of the information in this document comes from the presentations made during a technical day devoted to the "fire risk on composting platforms", organised by the interprofessional network for organic by-products or RISPO (Réseau interprofessionnel des sous-produits organiques https://rispo.org/) on 8 February 2018.

TECHNOLOGICAL ACCIDENTS ONLINE

Safety and transparency are two legitimate demands being imposed by our society.
As such, since June 2001, the website, www.aria.developpement-durable.gouv.fr, hosted by the Ministry for an Ecological and Solidary Transition, has been proposing to both professionals and the general public many lessons drawn from analyses of technological accidents.
The main headings of this site are presented in both French and English.
Under the general headings, site visitors have the opportunity to: consult a plethora of information, e.g. on governmental action, obtain large extracts from the ARIA database; and discover the presentation of the European scale of industrial accidents; learn about the index relative to hazardous substances released in order to complement “on-the-spot reporting” in the event of an accident or incident.
The description of accidents, as the raw material of any feedback-driven approach, makes up a significant portion of the site's resources: event sequencing, consequences, origins, circumstances, identified or assumed causes, actions taken and lessons learnt.
Some 100 detailed and illustrated technical datasheets present the accidents selected to benefit from their lessons. Many analyses by theme or industrial sector are also available. The heading dedicated technical recommendations is broken down by various topics, e.g.: fine chemistry, pyrotechnics, surface treatment, silos, tyre warehouses, fire permits, waste processing, and material handling.
A multicriteria search pulls up information on accidents that occurred in France or abroad.

The site www.aria.developpement-urable.gouv.fr is continually being expanded. For now, some 50,000 accident entries appear online, while new thematic analyses are regularly uploaded.

The summaries of all events presented are available on the following website:
www.aria.developpement-durable.gouv.fr

To submit a comment or suggestion, to notify of an accident or to obtain permission to use this data for publication purposes:
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