Satellite Monitoring as a Legal Compliance Tool in the Environment Sector

Case Study Two: The Disposal of Waste on Land and Remote Sensing[1]

(Ref: AHRC Report 18).

1 Introduction

It is recognised that the increasing volume of waste generated by mankind and its disposal presents a problem for the global environment. Chapters 20 and 21 of the UN's Agenda 21 programme are devoted to promoting the reduction, management and recycling of hazardous and non-hazardous wastes. Despite this recognition, there is no major international instrument which addresses the production of waste and its disposal on land (although the Basel and Bamako Conventions do set standards for the sites at which transboundary movements of waste are ultimately to be dealt with). However, the European Union has been very active in introducing measures designed to prevent waste and, where it is created, to promote its recycling and/or its environmentally safe disposal. There are three key pieces of European legislation which variously address the management of all waste streams within the EC (Directive 2006/12/EC), the treatment of hazardous waste (Directive 91/698/EEC) and the control of sites at which waste may be lawfully disposed of (Directive 99/31/EC, 'the Landfill Directive'). There are also several Directives which address specific waste streams including waste oils, sewage sludge, batteries, end of life vehicles and waste electrical and electronic equipment. The requirements of these Directives are examined in the first part of this note.

[1] This note does not cover the dumping of waste at sea. Nor does it examine the laws concerned with the treatment and disposal of nuclear waste on land.

The use of space-borne remote sensing technology to support efforts to control waste disposal has been examined in a number of research initiatives. This research has focused on the use of satellite technology to monitor landfill sites. The identification of illegal waste disposal sites (or of unauthorised facilities for the treatment of end of life vehicles and WEEE) does not appear to have attracted as much interest, perhaps because the resolution of satellite imagery has, until recently, been inadequate to identify such sites. In view of this, the UCL AHRC-funded research into using satellites for environmental monitoring and compliance has explored the potential use of high-resolution satellite images from recently launched satellites for identifying illegal waste sites. These different research areas are examined in the second part of this note.

2. European Law

Directive 2006/12/EC of 5 April 2006 on waste

Directive 2006/12/EC, the successor to Directive 75/442/EEC, creates a framework for the management of all waste streams within the European Community. The broad categories of 'waste' which it covers are described in Annex I of the Directive and the disposal and recovery operations which are subject to its controls are set out in Annexes II(A) and II(B). It requires Member States to implement measures which control the recovery and disposal of waste, and to restrict the persons who may become involved in waste-related activities. It also requests Member States to draw up and adopt plans for the management of waste. The core provisions of the Directive direct the Member States to:

- Take the necessary measures to ensure that waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment;[2]

[2] Article 4(1) Directive 2006/12/EC

- Take the necessary measures to prohibit the abandonment, dumping or uncontrolled disposal of waste;[3]

- Cooperate in the establishment of ‘an integrated and adequate network of disposal installations’;[4]

- Draw up waste management plans relating, inter alia, to the type, quantity and origin of waste to be recovered or disposed of, general technical requirements, special arrangements for particular wastes, and suitable disposal sites or installations;[5]

- Ensure that holders of waste have it handled by private or public waste collectors or by undertakings which carry out recovery or disposal operations or recover or dispose of it themselves in accordance with the Directive;[6]

- Require establishments or undertakings which carry out the disposal operations in Annex II(A) to obtain a permit from the competent authorities.[7] Persons involved in recovery operations listed in Annex IIB are also required to obtain a permit;[8]

- Require establishments or undertakings which collect or transport waste on a professional basis or which arrange for the disposal or recovery of waste on behalf of others to be registered with the competent authorities where not already subject to authorisation; and

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[3] Article 4(2) Directive 2006/12/EC
[4] Article 5(1) Directive 2006/12/EC
[5] Article 7(1) Directive 2006/12/EC
[6] Article 8 Directive 2006/12/EC
[7] Article 9 Directive 2006/12/EC
[8] Article 10 Directive 2006/12/EC

- Subject bodies carrying out waste operations under a permit or which must be registered to periodic inspection.[9]

Directive 91/689/EEC of 12 December 1991 on hazardous waste

The hazardous waste Directive is subject to the general requirements of Directive 2006/12/EC, but lays down additional specific requirements for the treatment of hazardous non-domestic waste (the most recent list of waste types regarded as hazardous is set out in Decision 2000/532/EC[10]). The additional requirements direct Member States to take necessary measures for the treatment of hazardous waste including the following:

- Requiring that on every site where the tipping of or discharge of hazardous waste takes place, this is recorded and identified[11];

- Requiring that establishments and undertakings involved with disposing of, recovering, collecting or transporting hazardous waste do not mix different categories of hazardous waste or mix hazardous and non-hazardous waste save where this is permitted;[12]

- Requiring that hazardous waste be separated from other waste types with which it is already mixed where this is technically and economically feasible.[13]

Directive 1999/31/EC of 26 April 1999 on the landfill of waste

The Landfill Directive is concerned with reducing, as far as possible, the negative effects on the environment which might result from the disposal of waste in landfill sites including from the contamination of soil and of water supplies in the vicinity and the emission of greenhouse gases (particularly methane). The Directive (which applies to all

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[9] Article 13 Directive 2006/12/EC
[10] http://eur-lex.europa.eu/LexUriServ/site/en/oj/2000/l_226/l_22620000906en00030024.pdf
[11] Article 2(1) Directive 91/689/EEC
[12] Article 2(3) Directive 91/689/EEC
[13] Article 2(4) Directive 91/689/EEC

landfill sites whether used for hazardous, non-hazardous or inert waste) places obligations on Member States with a view to minimising the effect of such sites on the European environment. The key obligations which Member States must implement through national legislation are as follows:

- The waste types specified in Article 5(3) should not be accepted in a landfill. These are (a) liquid waste (b) waste which is explosive, corrosive, oxidising, highly flammable or flammable in landfill conditions (c) infectious hospital and clinical wastes from medical or veterinary establishments (d) whole used tyres and shredded used tyres (with limited exceptions) (e) any other type of waste which does not fulfil the acceptance criteria for waste in Annex II of the Directive. Levels of biodegradable municipal waste which are regarded as acceptable for landfill must be gradually reduced to 35% of such waste levels in 1995;

- Waste should not be accepted without prior treatment save where this is not technically feasible or would not contribute either to reducing the quantity of waste disposed of or hazards to health/the environment presented by the waste;[14]

- Landfill sites should only accept waste according to their classification with sites being reserved for hazardous waste or inert waste only and with non-hazardous sites being limited to accepting municipal waste, non-hazardous waste of other origins and stable non-reactive hazardous waste;[15]

- Permits for landfill should not be issued unless the competent authority is satisfied that a proposal fulfils certain conditions including that the landfill project complies with the general requirements for all classes of landfill set out in Annex I to the Directive as regards:

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[14] Article 6)(a) Directive 1999/31/EC
[15] Article 6(c) Directive 1999/31/EC

- Location (with a view to ensuring that the landfill does not pose a serious environmental risk);

- Controls on water entering the landfill body and the waste therein as well as provision for the collection of contaminated water and leachate and their treatment;

- The presence of a geological barrier (real or artificial) and leachate collection and sealing systems as directed in paragraph 3 to prevent pollution of the soil, groundwater or surface water and to ensure the efficient collection of leachate; and

- Controls on the accumulation and migration of landfill gases.

- Waste acceptance procedures should be adopted including the maintenance of a register of the quantities and characteristics of the waste deposited (recording the date of delivery, the identity of the producer/collector, and, for hazardous waste, its precise location in the site);[16]

- Landfill sites should be controlled and monitored during their operational phase including by the use of techniques specified in Annex III. These include techniques for the monitoring of leachate and surface water volume and composition and of gas emissions (CH_4, CO_2, O_2, H_2S etc.) and atmospheric pressure.

Directives Covering Specific Waste Streams

As mentioned in the introduction to this paper, several Directives have been introduced which restrict the means by which specified waste streams may be disposed of (all of

[16] Article 11 Directive 1999/31/EC

them operate within the framework established by Directive 2006/12/EC). The waste streams concerned are as follows:

Waste Oil: The discharge of waste oil into internal surface waters, ground water, and coastal water and drainage systems is prohibited as is any deposit or discharge of waste oil which is harmful to the soil and any uncontrolled discharge of residues resulting from the processing of waste oils. Undertakings which dispose of waste oil must obtain a permit.[17]

Sewage Sludge: The use of sewage sludge (which is to be restricted according to its source in any event) is prohibited on (a) grassland or forage crops if the grassland is to be grazed or the forage crops to be harvested before a certain period has elapsed (b) soil in which fruit and vegetable crops are growing with the exception of fruit trees (c) ground intended for the cultivation of fruit and vegetable crops which are normally in direct contact with the soil or eaten raw for a period of 10 months preceding the harvest of crops and during harvesting.[18]

Batteries: Waste industrial and automotive batteries and accumulators may not be disposed of in landfill.[19]

End-of Life Vehicles: Directive 2000/53/EC promotes the prevention of waste from end of life vehicles by requiring that increasing percentages of the material from such vehicles be recycled. The disposal of material for end-of life vehicles is not prohibited, but vehicles must first have been treated with a view to removing parts which are recyclable or which, because of their chemical composition, should not be deposited in landfill sites.

The treatment of end-of life vehicles is to be strictly regulated with only authorised facilities being allowed to treat them. A certificate of destruction which is required for

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[17] Directive 75/439/EEC, most recently amended by Directive 2000/76/EC
[18] Directive 86/278/EEC
[19] Directive 96/59/EC

vehicle de-registration should be issued to the last holder and/or owner only when a vehicle is transferred to an authorised treatment facility. The treatment facilities must have obtained a permit from or be registered with the competent authorities and are subject to strict requirements for the storage and stripping of vehicles.

3. Remote Sensing Technology and Waste Management

The use of air-borne and space-borne remote sensing technology to support waste management, particularly the controlled disposal of waste has been explored in many research projects over the last thirty years. A useful overview of these projects is provided by Ottavianelli et al. in their 2005 study *Assessment of Hyperspectral and SAR Remote Sensing for Solid Waste Landfill Management*[20]. The researchers identified potentially useful applications of remote sensing data in connection with waste disposal sites:

(1) The use of data for land-mapping to identify sites which may be appropriate for landfill and to provide basic data about their development over time. Brilis et al. note that the United States Environment Protection Agency (US EPA) use topographic mapping, (including the use of aerial photographs) to monitor the location, area and historical changes to hazardous waste sites and the translation of this data into digital format using geographic information systems (GIS)[21]. We have seen increasingly sophisticated mapping of wetland sites[22] and of remote habitats[23] using a combination of remote sensing data and GIS. These mapping techniques could also be applied to provide a more extensive data set for the analysis of landfill sites than has hitherto been possible.

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[20] http://earth.esa.int/workshops/chris_proba_05/papers/19_ottav.pdf

[21] Remote Sensing Tools Assist in Environmental Forensics. Part I: Traditional Methods, G.M.Brilis, C.L.Gerlach, R.J. van Waasbergen, Journal of Environmental Forensics (2000) 1. pp. 63-67

[22] Monitoring and Assessment of Wetlands using Earth Observation, K.Jones et al, presented at GlobWetland: Looking at Wetlands from Space, an ESA workshop, on19/20 October 2006 – http://www.globwetland.org/news_links/links/433855kj.pdf

[23] Gorilla Natural Habitat Monitoring Service (project completed in 2005 and final report issued) at http://dup.esrin.esa.it/projects/summaryp55.asp

(2) Remote sensing may be used to detect changes in land cover both in and around landfill sites and changes in site structure through visual interpretation of data and images. Applications of this use include the identification of unauthorised landfill sites and the assessment of the condition of sites and the surrounding areas. Molteni, in a study in 2000 under the EC APERTURE project, used air-borne data and visual interpretation of satellite images to study the textural and hydrological characteristics of soil in two illegal Italian landfill sites.[24] Illegal landfills were identified using air-borne and space-borne multi-spectral data based on their spectral signatures.[25] Gas emissions or leachate release was identified by detecting vegetation stress in closed and/or reclaimed sites[26].. As noted in Part 1, monitoring of gas migration and leachates is required under the Landfill Directive.

While Ottavianelli (et al) concluded that remote sensing has a role to play in the above applications, the authors note that the studies identify some difficulties with the technology:

(1) The ability to distinguish landfill from other development sites. Philipson et al, when studying the use of panchromatic and multispectral SPOT images for monitoring land cover change noted an interpretational ambiguity between landfills and areas undergoing development or which had been previously disturbed but not reclaimed[27].

(2) It is not proven to provide accurate quantitative analysis for leachate and gas monitoring, but can only support ground efforts. Ottavianelli (et al) refer to a 1994 study

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[24] Two 'virtual environmental case studies', in which mock prosecutions based on the identification of illegal Italian landfill sites were presented as part of the APERTURE project and reported in an article *Use of Earth Observation Data as Evidence in Judicial Proceedings Concerning Environmental Infractions: The Moot Court Test* by F. Molteni in Droit et Ville (publication details unknown).

[25] Ibid. at 30-31

[26] Ibid at 34-36

[27] Land-cover monitoring with SPOT for Landfill Investigations, W.R.Philipson, E.M.Barnaba, A.Ingram & V.L.Williams, Photogrammetric Engineering and Remote Sensing, Vol.54, No.2, pp.223-228. For more information on SPOT Image see http://www.spotimage.fr/web/en/167-satellite-image-spot-formosat-2-kompsat-2-radar.php?countryCode=GB&languageCode=en

which concluded that it was very difficult to establish and demonstrate a relationship between landfill gas dynamics, plant health and soil characteristics[28]. They also note that the 30m ground resolution of images referred to in many of the research papers is insufficient for studying small scale variations in contamination that may occur in a landfill site.

(3) Space-borne sensors are less useful than airborne sensors for providing information about methane from landfill sites[29].

It is noteworthy that the Ottavianelli et al. based their study on research papers produced many years before the development of the recent generation of satellites which are capable of capturing high resolution images. It does not explore whether data from new generation satellites has overcome the limitations listed above. These technological developments may make it possible to use remotely sensed data in support of the following activities possible, where this was not previously the case:

1. Accurate mapping of landfill sites to facilitate on-going monitoring and assessment of these sites using a combination of remotely sensed data and GIS.

2. Identification of illegal landfill sites, not just from analysis of images to identify land use change but directly from satellite images.

3. Accurate identification of contamination resulting from landfills.[30]

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[28] Remote Sensing to Assess Landfill Gas Migration, H.K.Jones and J.Elgy, 1994, Waste Management and Research, Vol.12, pp.327-337.

[29] Ottavianelli et al. report that the Cranfield research team proposed to conduct research which would evaluate the use of hyperspectral and radar images for landfill monitoring and management (using data from the Compact High Resolution Spectrometer on board ESA's Probe micro-satellite) with a view to identifying practical ways in which earth observation data could support landfill management and monitoring. Material communication the results of this research is not yet available.

[30] Note that past research has found that 30m resolution is not accurate enough to pick up smaller incidents of contamination

4. Identification of smaller waste operations, for example illegal end-of-life vehicle sites or small instances of illegal dumping which would not have been identified at lower resolutions.

UCL, in its AHRC funded research into the use of satellites for environmental monitoring and compliance has explored the increased potential for waste-crime detection using high resolution imagery from recently launched satellites.

4. Background to remote sensing of landfills

Landfill gas emitted from landfills contaminates soil thus inducing vegetation stress. The traditional means of monitoring contamination from landfills is through ground surveys by measuring gas concentrations. Remote sensing is not an alternative to ground surveys for monitoring contamination but may be used to identify vegetation stress as a symptom of soil contamination.[31] Silvestri and Omri [32]noted that soil contamination could be identified using remote sensing by identifying indicators of contamination such as vegetation stress or high soil temperature. These techniques can be employed to identify potential landfill sites on a case-by-case basis, but they highlighted the fact that that no universal method has been developed. They also noted that while vegetation stress may be an indicator of a landfill site, there are other factors which may induce vegetation stress, for example trampling of vegetation, such as at building sites, deposit areas or sport fields. To identify areas of vegetation stress specifically linked to potential landfill sites, in situ data and geographical coordinates of known landfill sites are used as 'training' sites. The training sites are used to determine the specific vegetation stress levels of known landfills. Unknown landfill sites can then be located by identifying where the vegetation stress levels are most similar to those at known landfill sites.

Silvestri and Omri[33] used IKONOS high-resolution remote sensing imagery to map potential landfills for a study area of 1969 km2 in Northeast Italy. The IKONOS imagery was multi-spectral pan-sharpened at 1m pixel resolution. They used seven known illegal landfill sites to calibrate vegetation stress. This information was then used to create four vegetation stress classes (Figure 2.1a). Then, 45 known illegal sites were used to validate the calibrated vegetation stress levels. Figure 2.1 (a) shows the spatial extent of the validated landfill sites. Figure 2.1b shows the procedure for mapping the spatial extent of validated landfill sites. To identify potentially unknown illegal landfill sites for the entire study area, the same procedure was applied to the entire 1969 km2 study area in

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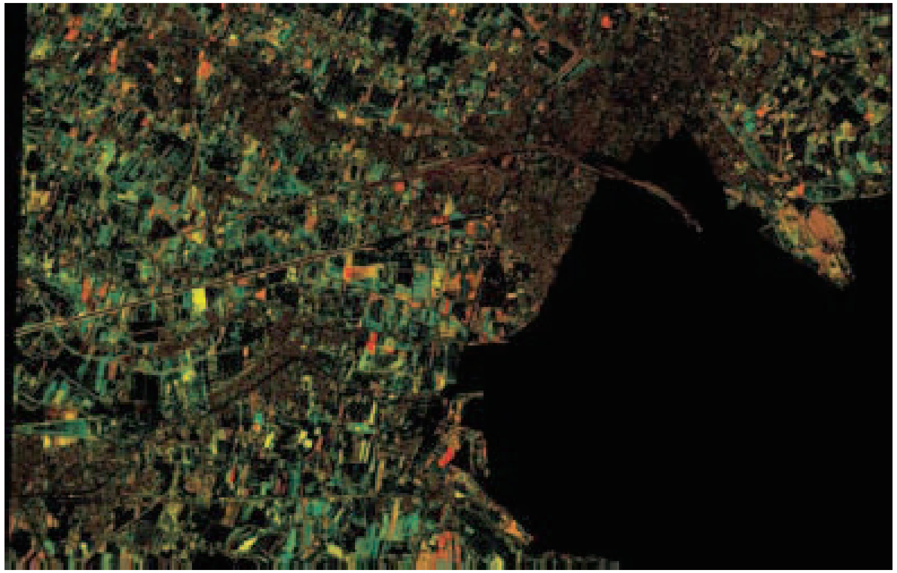
[31]Remote Sensing to Assess Landfill Gas Migration, H.K.Jones and J.Elgy, 1994, Waste Management and Research, Vol.12, pp.327-337; S. Silvestri and M. Omri, A method for the remote sensing identification of uncontrolled landfills: formulation and validation 2008 29 (4) International Journal of Remote Sensing, 975-989

[32] S. Silvestri and M. Omri, A method for the remote sensing identification of uncontrolled landfills: formulation and validation 2008 29 (4) International Journal of Remote Sensing, 975-989

[33] S. Silvestri and M. Omri, A method for the remote sensing identification of uncontrolled landfills: formulation and validation 2008 29 (4) International Journal of Remote Sensing, 975-989

Northeast Italy. Silvestri and Omri (2008) found 2944 possible contaminated sites in the study area. This authoritative study illustrates clearly the utility of satellite technology in the detection of illegal landfill sites.

a) 

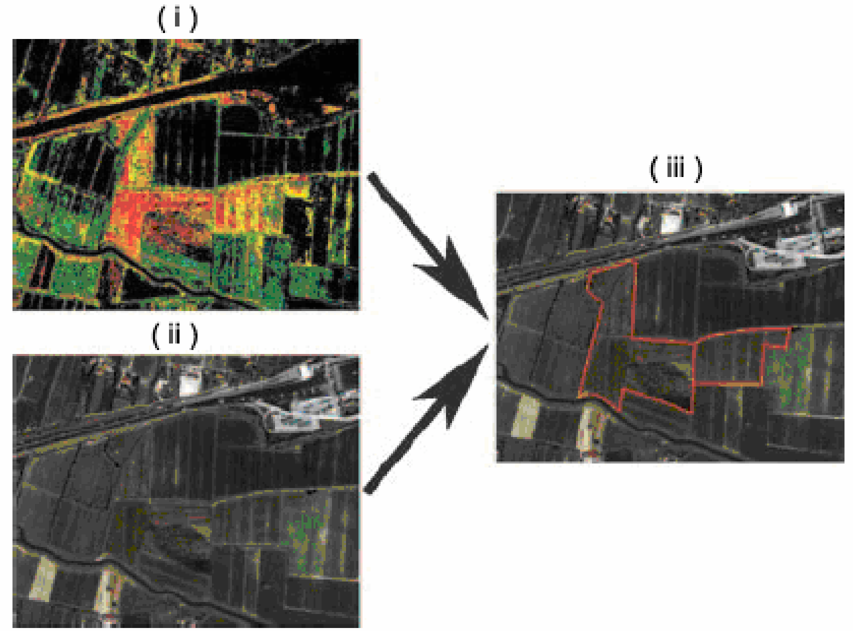
b) 

Figure 2.1 (a) Classification results on the training area: red = Class 1 (very stressed brown– yellow vegetation); yellow = Class 2 (non-uniformly stressed vegetation cover); brown = Class 3 (bare soil with very rare vegetation presence); green = Class 4 (lightly stressed vegetation); black = unclassified areas.

Figure 2.1 (b) Procedure followed for the digitization of sites recognized through the classification: (i) the classification result from training sites; (ii) the IKONOS Red/Green/Blue image used for comparison; (iii) the digitization result of the illegal landfill. (Source: Silvestri and Omri, 2008)

The Landfill Directive sets out criteria to aid the identification of suitable locations for landfills[34] Landfill sites can only be authorised if the characteristics of the site indicate that the landfill does not pose a serious environmental risk, having regard to these criteria:

(a) the distances from the boundary of the site to residential and recreation areas, waterways, water bodies and other agricultural or urban sites;

(b) the existence of groundwater, coastal water or nature protection zones in the area;

(c) the geological and hydrogeological conditions in the area;

(d) the risk of flooding, subsidence, landslides or avalanches on the site;

(e) the protection of the nature or cultural patrimony in the area.

Remote sensing (with GIS) could be used to identify some of these criteria

As noted above, the Landfill Directive obliges Member States to take appropriate measures to secure water control and leachate management. Remote sensing may be used to aid in the monitoring of the meteorological conditions identified in this section. It may be used to determine if there is a system in place to control water from precipitations entering the landfill body. It may also be used to map contaminated water and leachate by identification of vegetation stress as described above. High resolution imagery would only be useful for monitoring landfill areas if contamination is serious and can be seen in the limited spectral wavelengths available with high resolution passive sensors. The Directive does not lay out any frequency for monitoring vegetation, nor is there any wording in the directive that specifically links monitoring vegetation change to landfill contamination. The specific contamination that the Directive is concerned with is below ground soil and hydrologic contamination.

[34] Annex 1 Section 1.1

The Landfill Directive sets out minimum procedures for control and monitoring of landfills during its operation and the after-care phase.[35] In accordance with their reporting obligations under Article 15, Member States must supply data regarding the collection method for meteorological data. It us up to Member States to decide how the data should be collected, whether in situ, national meteorological network or other methods or sources are used.[36].Table 1 shows the specific meteorological conditions that must be monitored and the specific time requirements for each meteorological variable. Remote sensing derived products could be used for monitoring daily precipitation and temperature, especially when other meteorological data in unavailable. However, data regarding precipitation using remote sensing is not available in volume measurements, and temperature estimates are of daily surface temperate, not min and max temperatures. For this reason, if remote sensing were to be used to monitor the meteorological characteristics of landfills, the legislation would have to be rewritten to reflect the nature of the measurements derived from the technology.

The Directive also requires data on the topography of the landfill site. Digital elevation models derived from remote sensing could be used to refine the topographic data available for specific landfill sites.

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[35] Annex III
[36] Annex III (2)

Table 1. Meteorological requirements for landfill monitoring during operation and after-care phases as found in Section 2 of Annex 3 of Council Directive 1999/31/EC.

	Operation phase	After-care phase
1.1 Volume of precipitation	daily	daily, added to monthly values
1.2 Temperature (min., max., 14.00 h CET)	daily	monthly average
1.3 Direction and force of prevailing wind	daily	not required
1.4 Evaporation (lysimeter) (1)	daily	daily, added to monthly values
1.5 Atmospheric humidity (14.00 h CET)	daily	monthly average
(1) Or through suitable methods		

Limitations which remain even with new technology:

- The current position for monitoring methane, carbon dioxide, hydrogen sulphide etc. with remote sensing is that emissions of these gases over landfill sites can not be monitored with higher resolution imagery.

- Remote sensing does not identify waste contents in landfills. Landfills are monitored by the link between gas emitted from land fills and the affect this has on vegetation.

Specific waste streams:

- **Waste Oil**: The discharge of waste oil into internal surface waters, ground water, and drainage systems can only be monitored if it occurs on a large scale. Satellites can only be used to monitor the affects of waste oil in these categories and will prove difficult to catch the responsible party. Please see Case Study 5 with regard to monitoring surface oil in coastal waters.

- **Sewage Sludge**: The use remote sensing to monitor sewage sludge in three distinct agricultural categories cannot be completed unless the sludge alters vegetation in a unique way (i.e. in a different way to other forms of soil contamination).

- **End of Life Vehicles**: Remote sensing cannot be used to monitor the chemical composition or treatment of recyclable material in or on end of life vehicles. However, satellites potentially can be used to monitor for the legal or illegal storage of vehicles.

2.6 Waste Management Case Study

The following case studies involve criminal activity related to illicit waste management and storage in the UK. Both case studies were successfully prosecuted. The waste management cases studies are specifically linked to Section 33 of the Environmental Protection

Act of 1990 and the Waste Management Licensing Regulations which prohibit the disposal of waste unless it is in accordance with a waste management licence.[37]

Case Study 1

The real names and locations in this case study are not revealed to address legal sensititives. Land owner Mr. "X" was fined a total of £37,500 for running an illegal waste site at "Y" Farm in Chelmsford. He was also ordered to pay £7,500 towards Environment Agency costs. Mr. "X" was charging people to dump their rubbish on land at "Y" Farm, where it was burned, sorted or stored. He was operating without a waste management licence in contravention of Section s.33 of the Environmental Protection Act of 1990. It was calculated between May 2005 and January 2006 the illegal business would have produced a turnover of £40,000.[38] Smoke from a constantly smouldering open fire caused a nuisance to local residents. The resulting mound of ash was three metres thick and measured 260 metres in circumference.

Mr. "X" l pleaded guilty to five charges including permitting the deposit, storage, treatment and deposit of waste and hazardous waste on his premises. All illicit offences at "Y" Farm took place between May 2005 and January 2006. Two Quickbird pan-sharpened images at 0.6m x 0.6m were obtained from Digital Globe.[39] The first image was taken over "Y" Farm in October 2005 (Figure 2.2(a)-(d). "Y" farm is depicted by the blue box in Figure 2.2(a). The yellow circle in Figures 2.2(b) is of the area where the illicit burning of waste took place. Figure 2.2(d) and 2.2e are from June 2004. The red circle in Figure 2.2d depicts a burned area. This image evidences that the burning activities began at least a year prior to the period in which authorities prosecuted the case (they believed the

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[37] Bell & McGillivray, Environmental Law, 6th Edition, Oxford University Press, (2006)
[38] According to Hugh Rowland, prosecuting for the Environment Agency.
[39] http://www.digitalglobe.com/

burning only began in September 2005). This highlights the practical function of the archive of high resolution remote sensing for prosecuting authorities, i.e. to identify the start date of offences. This is particularly useful where the fine increases according to the amount of time the illegal site was in operation.

Figure 2.2 Quickbird images over "Y" Farm. The blue box in Figure a) is the total extent of "Y" Farm in October 2005. The yellow circle in Figures b) is where the illegal burning of waste occurred in October 2005. Figure c) is a zoomed in image of the burned area in October 2005. The red circle in Figure d) is where waste was burned at "Y" Farm as early as November 2004. Figure e) is a zoomed image of the burned area in November 2004

Case Study 2

Mr. "A" was owner of a scrap yard in Sheffield, who pleaded guilty to two charges of keeping scrap vehicles without a waste management licence. He was fined £15,000 for the offence. The unlicensed scrap yard was in operation between June 2004 and September 2005. Three Quickbird images were obtained over Sheffield at 0.6 by 0.6 meter resolution. Figure **2.3** is of car parks in Sheffield:

Image **2.3(a)** shows how vehicles are organized and aligned in straight lines in normal car parks.

Image **2.3(b)** points to clear distances between parked vehicles, so that vehicles can maneuver in and out of parked spaces.

Image **2.3(c)** is another example of a normal car park in Sheffield

These images illustrate the organization and alignment of cars in normal car parks.

Image **2.3(d)** is of a scrap yard in Sheffield. Notice the difference between the normal car park and the scrap yard. The vehicles in the scrap yard are tightly packed into the available space, with no organization or alignment, and there is no room for the vehicles to maneuver in and out of the scrap yard. These differences related to alignment and organization may be used to identify illegal scrap yards with high resolution imagery.

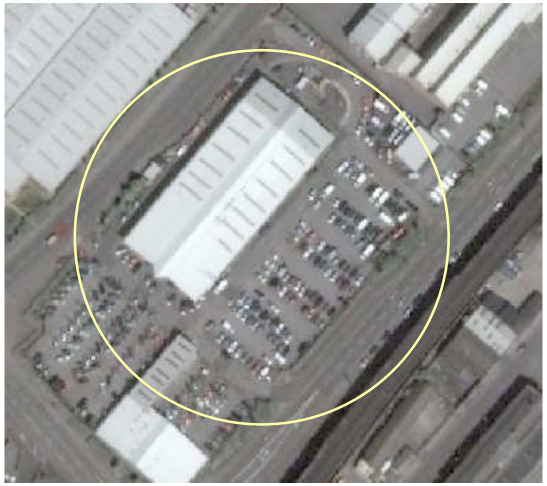
Figure 2.4 consists of three Quickbird images taken over Mr. "A's" illegal scrap yard at three different dates. Images 2.4(a) and 2.4(b) were taken in May and June 2005, respectively, during the period when the illegal scrap yard was in operation.

Image 2.4(c) was taken in February 2006, after Mr. “A” was prosecuted. This shows that the site was still being used for scrap vehicles after the prosecution. However, after a successful prosecution of an illegal waste management site, offenders are given a period of time, normally up to a year, in which to comply with the prosecution and remove the illegal vehicles. In terms of the “Mr. A” case study, compliance would mean removal of scrap vehicles from the site. As of February 2006, Mr. “A’s”scrap yard still had not taken steps for compliance with the court. High resolution remote imagery could therefore be used by authorities after a successful prosecution to monitor for compliance of illegal scrap yard sites and whether or not scrap vehicles were removed from the successfully prosecuted site.

a)

b)

c)



d)

Figure 2.3 Quickbird images of car parks over Sheffield. Image a) points to how vehicles in normal car parks are organized and aligned; Image b) points to the space between parked vehicles so that vehicles can maneuver in and out of normal car parks; the yellow circle in Image c) shows another example of normal car parks and the red circle in Image d) shows vehicles in a scrap yard. out of normal car parks.

2.7

These case studies prove that there is a role for remote sensing in the enforcement and prosecution of illegal waste management operators. Remote sensing technology can be used not only to prove the existence of such operations but to create a timeline of when the illegal operations began by studying images taken over time. The only problem is that there is less archived data available for earlier years and higher resolution imagery is only widely available since the year 2000. However, with the improvements to remote sensing technology in recent years, the archive if this high resolution imagery is expanding all the time and no doubt the use of this resource as a tool of environmental compliance and enforcement will increase accordingly.