Material change for a better environment

Environment Agency

Waste Protocols Project

Paper sludge ash

A technical report on the production and use of paper sludge ash

Contents

Executive summary

Background

The Waste Protocols Project is a joint Environment Agency and WRAP (Waste & Resources Action Programme) initiative in collaboration with industry, funded by the Department for Environment, Food and Rural Affairs (Defra) as a business resource efficiency activity.

The aim of the Waste Protocols Project is to provide guidance to business on a number of waste streams that will:

- define the point of full recovery from waste back into a product or material that can be either reused by the business or industry or sold into other markets; or
- confirm to the business community what legal obligations remain to control the reuse of the treated waste material.

Paper sludge ash (PSA) was chosen as one of the waste streams to be addressed by the Waste Protocols Project. A Technical Advisory Group (TAG) was set up to bring together representatives from the Environment Agency, WRAP and industry. The Project Board asked the TAG to consider if a Quality Protocol could be produced so that the point of recovery of PSA could be moved closer to the point of production.

Methodology

The TAG set out to:

- identify and quantify the major markets and appropriate end uses for PSA;
- identify the current legislative framework;
- seek analytical data on the composition of material produced;
- review available standards and specifications;
- assess relative risks to human health and the environment from using PSA, and any necessary mitigation methods; and
- suggest a way forward for each of the major markets such as that certain end uses may be regarded as fully recovered where strictly defined conditions are met.

Findings

The TAG found there is significant evidence that PSA can be fully recovered and therefore recommended the production of a Quality Protocol. The TAG's findings are summarised below:

- There is a viable market for PSA with approximately 88,000 tonnes being sold in 2006. The composition and properties of PSA vary between mills due to the different input materials and operational practices. All PSA is marketable, and depending on its properties it can be suitable for different markets. For example, where paper sludge is the only input material, the resulting PSA has a higher lime content (>10 per cent) and is more valuable for agricultural use as a liming agent. The introduction of the Quality Protocol is expected to result in an increased demand for PSA and has the potential to open up new markets.
- The TAG identified existing British Standards for PSA use in block making and cement manufacture. However, these standards do not consider potential impacts on human health or the environment from the use of PSA for these purposes. Similarly, PSA is commonly used as a liming agent in agriculture and as a desiccant in animal bedding and, although there are recognised properties it must have, there are no recognised standards which it must achieve.
- Without a standard, the point at which PSA ceases to be waste cannot be defined. The TAG consider that an environmental standard could be set (based upon the maximum chemical values within the risk assessment) which would ensure minimal risk to the environment. This has been set out in Section 8 of this report.
- The risk assessment concluded that overall the application of PSA poses a low risk to human health and the environment where a number of simple control measures are followed. This standard good practice is listed in Section 7 of this technical report.
- Risks of the identified hazards from the use of PSA materials are considered to be low in the following applications:
  - PSA applied to agricultural land as a liming agent;
  - PSA used as a desiccant in animal bedding;
  - PSA used for sewage sludge stabilisation;
  - PSA used in block making; and
  - PSA used in cement manufacture.

Recommendations

The TAG made the following recommendations:

- based on the findings of this technical report, a Quality Protocol should be developed for the production and use of PSA;
- PSA from each mill should be analysed regularly to ensure its composition/leachability is below the maximum values in Section 7;
- PSA used in the block making and cement manufacture must also adhere to the relevant engineering standards;
- if the process and/or inputs change, full compositional and leachability analysis should be carried out to ensure that the overall composition and availability of the metals present in the PSA is not affected;
- if the values in Section 7 are exceeded, the material should be considered to be waste, and should not be covered by the Quality Protocol;
- the frequency of testing should be every six months, in line with Environmental Permit requirements;
- the recommendations from the risk assessment regarding standard good practice in all applications should be listed in the Quality Protocol and adhered to by users of PSA;
- there is no need for independent certification and verification provided compositional and leachability limits are set to represent the chemicals of concern in the risk assessment. These are detailed in Section 8 and have been set at a level which will safeguard against harm to human health and the environment where PSA is used in accordance with standard good practice; and
- good practice guidance should be written for use by producers of PSA that pulls together the identified good practice detailed in this report. This will help reduce the risk of any confusion over how the material should be handled and used. It will also serve as a central reference document.

1. Introduction

1.1 The Waste Protocols Project is a joint Environment Agency and WRAP (Waste & Resources Action Programme) initiative in collaboration with industry, funded by the Department for Environment, Food and Rural Affairs (Defra) as a business resource efficiency activity.[1]

1.2 Uncertainty over the point at which waste has been fully recovered and ceases to be waste within the meaning of Article 1(1)(a) of the EU Waste Framework Directive 2006/12/EC [1] has inhibited the development and marketing of materials produced from waste which could be used beneficially without damaging human health and the environment. In some cases, this uncertainty has also inhibited the recovery and recycling of waste and its diversion from landfill.

1.3 Interpretation of EU legislation is ultimately a matter for the European Court of Justice and there is now a substantial body of case law on the interpretation of the definition of waste in Article 1(1)(a) of the Waste Framework Directive. Drawing on the principles established in this case law, it is possible to identify the point at which certain wastes cease to be waste and thus when the Waste Framework Directive's waste management controls no longer apply. This identification is the purpose of the Waste Protocols Project.

1.4 More specifically, depending on the circumstances of the sector concerned, the project aims to achieve one of the following outcomes:

- to produce a Quality Protocol defining the point at which waste, having been the subject of a complete recovery operation, may become a non-waste product or material that can be either reused by business or industry, or supplied into other markets, enabling such fully recovered products to be used without the need for waste management controls; or
- to produce a position statement that confirms to the business community what legal obligations they must comply with to use the treated waste material.

1.5 Boiler ash from the thermal treatment and energy recovery of paper sludge was one of the waste streams selected to be addressed during the second year of the Waste Protocols Project. A Technical Advisory Group (TAG) was set up to bring together representatives from the Environment Agency, WRAP and industry. Appendix A contains a list of TAG members and Appendix B gives its terms of reference.

1.6 The TAG agreed to refer to boiler ash from the thermal treatment of paper sludge as paper sludge ash (PSA).

1.7 As agreed by the TAG, this technical report does not consider bottom ash or bed material from the combustion of paper sludge. This accounts for 5 per cent of ash output and is processed separately to recover metals, sand, stones, etc.

1.8 Paper sludge is a combination of short cellulose fibres, water, ink, soap and other minerals (e.g. kaolins, carbonates and talcs) separated from the recovered paper feedstock. It arises from the recycling of newspaper-related products at the recovered paper de-inking plant and from the mill's effluent treatment plant.

1.9 PSA is a residue from the incineration of paper sludge. Such sludge arises from the manufacture of paper and board. The increasing costs of landfill and other forms of waste management, together with increasing costs of gas and electricity, are driving the thermal treatment and energy recovery from incineration of paper sludge as a recovery option.

1.10 For PSA to be considered as having ceased to be waste, it is necessary to demonstrate that the material has been fully recovered and that there is no further need for waste management controls.

1 The Waste Protocols Project was formerly funded by Defra's BREW (Business Resource Efficiency and Waste) Programme.

1.11 To investigate this, the TAG considered in particular whether the waste has been made into a distinct product:

- having a market and certainty of use;
- meeting an appropriate publicly available standard (e.g. an identified specification) requiring no further processing before being used; and
- capable of being used without undermining the aims of the Waste Framework Directive [1] and Water Framework Directive [2] of protecting human health and the environment.

1.12 The TAG set out to:

- identify the major markets and end uses for PSA;
- identify the current legislative framework that governs the production, handling, storage, transportation and use of PSA;
- source analytical data on the composition of material produced;
- review available standards and specifications;
- assess relative risks to human health and the environment from using PSA, and any necessary mitigation methods; and
- propose ways forward for each of the major markets so that PSA may be regarded as fully recovered where clearly defined conditions are met.

1.13 The objectives of this report are to:

- describe the TAG's progress on this topic;
- set out the TAG's findings; and
- provide recommendations to the Project Board and the Environment Agency on what steps are needed to meet the project aims as stated in point 1.4.

2. Production process

2.1 PSA is a residue from the incineration of paper sludge and other input materials from the recycling of newspaper-related products.

2.2 The input proportions of different materials vary for separate mills. This has an effect on the composition of PSA. Details on the composition of PSA are given in Section 3.

2.3 In most cases paper sludge is co-incinerated with other input materials. These arise from the process of papermaking and are included for economic or operational reasons, e.g. sustaining combustion.

2.4 The TAG considered the following input materials:

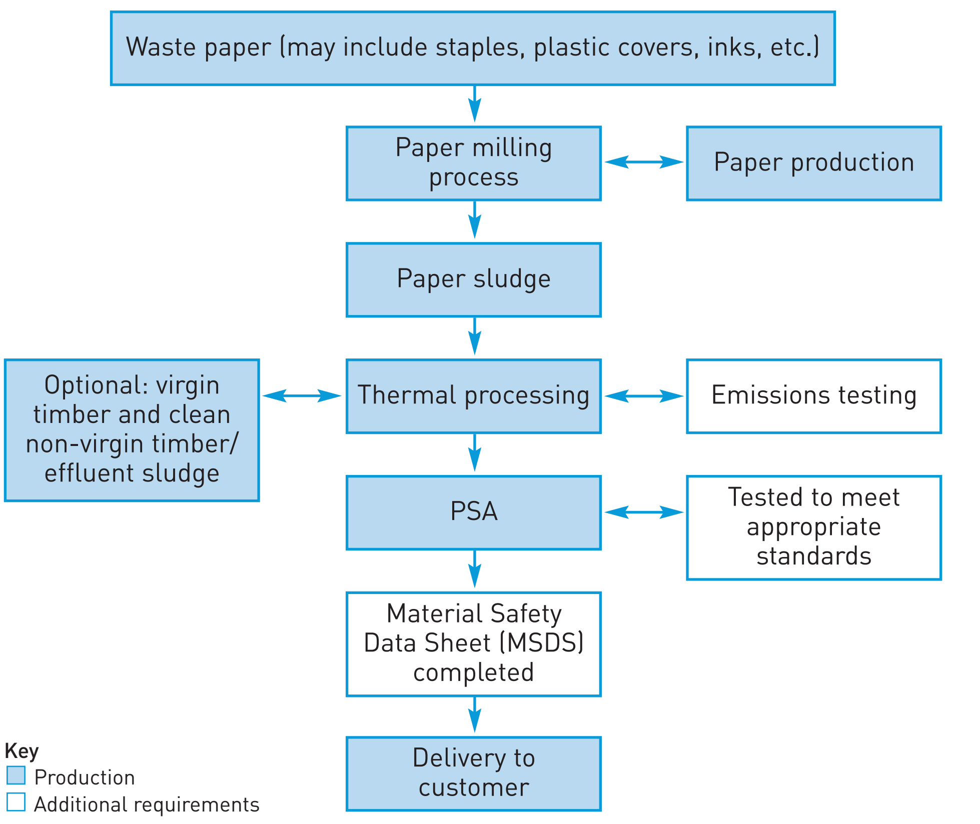
- de-inking paper sludge;
- virgin timber and clean non-virgin timber;
- effluent sludge; and
- plastic arising from inputs to the paper recovery and manufacturing process (e.g. magazine wrappings and plastic strapping).

2.5 The most suitable technology for the management of paper sludge is thermal processing with energy recovery, typically either in a fluidised bed or a grate-fired combustion process. The operation of the thermal process is covered by the Waste Incineration Directive 2000/76/EC [3] (WID) and is regulated, in England and Wales, by the Environmental Permitting (England and Wales) Regulations 2007 [4]. As such, each thermal process requires an environmental permit in order to operate.

2.6 The TAG reviewed the PSA production processes and quality control measures at two mills with similar operations.

2.7 Figure 2.1 shows a typical PSA production process. However, the actual processes used and their configuration can vary from mill to mill due to the different thermal combustion processes used and the nature of the paper sludge being combusted. Emission monitoring requirements can also vary from mill to mill depending on the requirements of the environmental permit for a given mill.

Figure 2.1: Typical PSA production process



2.8 To ensure the quality of the PSA is controlled, each mill should have its own quality control procedures. Table 2.1 lists the elements of a generalised quality control process.

Table 2.1: Example quality controls for mills producing PSA

Key element	Summary description
Raw material receipt	Keep contracts of supply for auditing purposes. Test raw materials regularly to determine their calorific value. Keep detailed records of input materials.
Raw material storage	Ensure compliance with waste management controls including the site's environmental permit.
Process control	Operate a process control system supported by accurate record-keeping and document control procedures throughout the PSA production process. This may include details of input and output flow rate, temperature, residence time and airflow. PSA producers have a clearly defined quality policy. PSA producers have clearly defined Standard Operating Procedures (SOPs) covering quality management aspects of the PSA production process.
PSA product output	Undertake sampling and analysis in accordance with the standard appropriate to the designated market sector to which the PSA will be supplied. Report product quality testing results annually. Keep detailed records of sampling.
PSA product storage	Make provision for final product storage including storage location and conditions.
PSA product sale	Keep supply documentation for auditing purposes.

2.9 The thermal processing of PSA generates hot gases which are used to heat boilers in order to generate steam. This steam is normally used in the papermaking process for heating and drying purposes. In an increasing number of cases the steam is being used to generate electric power by means of a steam turbine.

2.10 Nevertheless, when the boiler is small and its main purpose is to process paper sludge with a minimum amount of fuel, it is only economically viable for the boiler to produce low-pressure steam for heating and drying purposes in the papermaking process. As such, the decision as to whether the steam is used for the production of electricity or not is an economic one.

2.11 In terms of calorific value, mechanically dewatered paper sludges have a low heat value (typically 2.5–6.0 MJ/kg) due to their moisture and ash content. However, the calorific value of dry paper can be as high as 20 MJ/kg.

2.12 Both conventional grate-fired boilers and fluidised bed boilers can be used in the thermal processing of paper sludge. However, fluidised bed technology has the following advantages:

- it is more versatile in its operation;
- it is easier to operate;
- it has a higher efficiency; and
- it has lower emissions.

2.13 In addition, fluidised bed boilers are better at meeting the stringent emission demands required by the Waste Incineration Directive [3]. For example, a fluidised bed system can provide in-situ sulphur dioxide (SO_2) and nitrogen oxide (NO_X) emission control.

2.14 In terms of SO_2 control, the calcium content of the PSA helps to bind the sulphur present in the fuel (i.e. paper sludge). A high calcium surplus provides up to 80–95 per cent sulphur removal from the PSA (it can be greater with circulating fluidised bed combustion, CFBC). Consequently, some mills find it necessary to inject lime into the boiler to provide additional SO_2 reduction. However, the downside to using additional lime is that it increases the amount of ash produced by the combustion process.

2.15 Optimum sulphur capture (binding) occurs when the operating temperature of the combustion process is approximately 850ºC. Operating at 850ºC also ensures that dioxins and furans are kept at trace levels.

2.16 Following thermal processing, the PSA is transferred to silos from which it can be discharged in a closed operation to tankers.

2.17 A delivery note is raised for each load. The PSA is delivered by tanker:

- directly to the final customer;
- to an intermediary who sells the PSA forward to the final customer on behalf of the PSA producer; or
- to a third party storage or bagging facility.

2.18 When PSA is delivered to a bagging facility, it is likely to accept the PSA into silos or hoppers which discharge the material into various sizes of bags. Bagging PSA allows small volumes to be stored more safely at the final customer's premises prior to consumption and applied in a more controlled way. The TAG agreed that for the purposes of a Quality Protocol, such a facility should:

- be made aware of good practice guidance for handling PSA; and
- use a closed system to prevent dust.

3. Material composition

3.1 As discussed in Section 2, the composition of PSA can vary between mills according to the input materials used. For example, mills burning only paper sludge produce ash with a high calcium oxide content (>10 per cent) while those burning plastics with paper sludge can produce PSA with a relatively high chlorine content making it unsuitable for cement manufacture.

3.2 For the purposes of this technical report and the risk assessment (see Section 6), samples of PSA were taken from a number of mills and analysed. Tables 3.1 and 3.2 show the typical range of elements identified.

Table 3.1: Example quality controls for mills producing PSA

Determinand	Units	Statistical parameter					
		Min	Mean	95%ile	Max	RSD%	n
Sulphur trioxide (SO_3)	mg/kg	2,800	5,317	6,808	15,100	3	140
Sulphur (S)	mg/kg	90	1,443	4,850	4,850	116	12
Aluminium (Al)	mg/kg	57,368	68,899	76,117	86,952	12	155
Arsenic (As)	mg/kg	1.93	3.34	4.82	5.02	38	6
Barium (Ba)	mg/kg	71	140	182	1549	119	158
Calcium (Ca)	mg/kg	102,375	330,641	369,103	376,000	16	159
Cadmium (Cd)	mg/kg	0.340	1.06	2.45	3.21	89	16
Chromium (Cr)	mg/kg	21	41.34	52.7	59	24	16
Cobalt (Co)	mg/kg	6.42	11.1	15.16	15.6	41	3
Copper (Cu)	mg/kg	98	280	403	562	20	168
Fluorine (F)	mg/kg	705	767	867.5	885	13.37	3
Iron (Fe)	mg/kg	1,748	4,335	4,966	5,106	31	155
Mercury (Hg)	mg/kg	0.020	0.118	0.35	0.860	175	16
Potassium (K)	mg/kg	1,826	3,156	4,428	15,800	56	168
Lithium (Li)	mg/kg	7.57	23.7	34.2	1,626	513	155
Magnesium (Mg)	mg/kg	121	23,992	28,821	31,119	22	167
Manganese (Mn)	mg/kg	0.01	177	229	1781	121	157
Molybdenum (Mo)	mg/kg	1	6.852	13.675	14.8	81	5
Sodium (Na)	mg/kg	1,187	2,162	2,893	2,8487	104	155
Nickel (Ni)	mg/kg	9	27.87	37.725	38.4	33	16
Phosphorus (P)	mg/kg	652	1,076	1,593	3,650	25	155
Lead (Pb)	mg/kg	21	62.04	117	125	48	16
Antimony (Sb)	mg/kg	8	12	15.97	17	34	3
Selenium (Se)	mg/kg	0.11	0.66	1	1.0	68	5
Silicon (Si)	mg/kg	103,423	117,924	135,053	139,799	22	155
Strontium (Sr)	mg/kg	280	694	778	7,001	134	155
Titanium (Ti)	mg/kg	0.210	1,323	1,828	1,918	24	155
Thalium (Tl)	mg/kg	48.7	49.6	50	50	2	3
Vanadium (V)	mg/kg	12	16	18.97	19	22	3
Zinc (Zn)	mg/kg	68	205	405.5	449	57	16
Dioxin ITEQ	ng/kg	0.29	0.51	0.665	0.70	–	8

Source: Waste Protocols Project: Risk assessment for applications of paper sludge ash [5]
ITEQ = International Toxic Equivalents; RSD = relative standard deviation

Table 3.2: Other relevant typical compositional data for PSA

Determinand	Statistical parameter					
	Min	Mean	95%ile	Max	RSD%	n
Moisture (%)	0.04	0.20	0.54	7	173	8
pH	12.4	12.62	12.82	13	2	18
Fraction organic carbon (%)	0.05	0.58	2.39	3.3	87	17
Free lime as calcium oxide (%)	5.1	6.72	20.75	25.7	304	101

Source: Waste Protocols Project: Risk assessment for applications of paper sludge ash [5]

3.3 PSA is a highly alkaline (pH 12–13) and dry powder (<0.1 per cent moisture); 40 per cent of the particles are <0.063 mm. Test reports indicate that bulk density and particle density in kerosene for a typical PSA are 0.5 mg/m^3 and 2.49 mg/m^3 respectively.

3.4 Organic carbon levels are low – typically 0.6 per cent, maximum 3.3 per cent w/w[2] as total organic carbon (TOC).

3.5 The principle oxide chemistry is dominated by calcium oxide (CaO), silica, alumina and magnesium oxide. Calcium levels can range from 5–55 per cent w/w in fresh PSA using appropriate techniques such as XRF (X-ray fluorescence) analysis.

3.6 Table 3.3 shows typical leachability data for PSA at a liquid to solid (L/S) ratio of 10.

Table 3.3: Typical leachability of PSA at L/S 10 (mg/kg)

Determinand	Statistical parameter					
	Min	Average	95%ile	Max	RSD%	n
Silver (Ag)	<0.01	<0.01	<0.01	<0.01	–	7
Aluminium (Al)	8.91	30.6	36.0	36.0	29	8
Arsenic (As)	0.02	0.07	0.25	<0.25	147	10
Barium (Ba)	10.05	35.27	67.82	77.20	66	15
Beryllium (Be)	<0.005	<0.005	<0.005	<0.005	–	7
Cadmium (Cd)	<0.005	0.008	0.01	<0.01	34	15
Cobalt (Co)	<0.01	0.042	0.1	<0.1	96	10
Chromium (Cr)	0.004	0.058	0.1	<0.1	79	15
Copper (Cu)	<0.01	<0.06	<0.10	<0.10	80	15
Mercury (Hg)	0.0002	0.0031	0.0051	0.0054	75	15
Molybdenum (Mo)	0.014	0.134	0.381	0.570	117	15
Manganese (Mn)	<0.05	0.08	0.10	<0.1	34	5
Nickel (Ni)	<0.01	0.06	0.10	<0.1	80	15
Lead (Pb)	0.042	0.238	0.673	0.960	113	15
Antimony (Sb)	<0.02	0.02	0.04	0.05	45	8
Selenium (Se)	<0.01	0.02	0.02	<0.02	28	15
Tin (Sn)	<0.01	<0.01	<0.01	<0.01	–	7
Thalium (Tl)	0.014	0.165	0.500	0.500	140	10
Vanadium (V)	<0.01	0.04	0.10	<0.1	117	10
Zinc (Zn)	<0.01	0.08	0.24	<0.3	114	14

continued

2 w/w is an abbreviation for 'by weight'.

Table 3.3: Typical leachability of PSA at L/S 10 (mg/kg) continued

Determinand	Statistical parameter					
	Min	Average	95%ile	Max	RSD%	n
Fluorine (F)	0.80	2.26	6.26	8.34	111	8
Chlorine (Cl)	2.60	2,553	9,603	11,500	146	15
Sulphate (SO_4)	0.60	131	464	547	144	15
TDS	3.23	2,041	3,923	3,950	89	12
Phenols	<0.03	<0.03	<0.03	<0.03	–	7
Ammonia	0.01	0.03	0.05	0.05	47	7
Phosphorus (P)	0.10	0.15	0.24	0.25	38	7

Source: Waste Protocols Project: Risk assessment for applications of paper sludge ash [5]
TDS = total suspended solids

3.7 The composition and leachability showed major differences in values, which could be attributed to different plant operations or feedstock. The use of maximum concentrations from the overall dataset incorporates all between-plant variability and provides a worst case parameter for the risk assessments. Relative standard deviation (RSD) and 95 percentile values have also been calculated.

3.8 Calcium carbonate from chalk and limestone is a primary component of some papers; for example, high-gloss paper can contain over 50 per cent calcium carbonate. Paper sludge is made up of refractory paper additive minerals – kaolinite,[3] calcite[4] and talc.[5] Unlike the sludges, PSA from paper mills is mainly inorganic and consists primarily of Fe, Al, Mn, Si, Ca and Mg with an array of other chemical elements in lesser quantities. However, a small amount of organic residue may remain as a result of incomplete combustion. PSA content and chemical composition also vary according to the tree species used to produce the paper; they also depend on the soil type and climate where the trees were grown.

3.9 A sludge combustor burning plastic and paper sludge together generates less PSA per tonne input than an incinerator burning sludge with virgin timber and clean non-virgin timber. This is because virgin and clean non-virgin timber generates a greater quantity of ash than plastics.

3.10 The composition of the PSA varies even in waste classification as currently some PSA may be classified as hazardous waste if it possesses any of the hazardous properties H1–H14. For more information on assessing the hazardous properties of waste, refer to Technical Guidance WM2 published by the Environment Agency [6].

3.11 Operators of paper sludge combustion plants represented on the TAG were approached for information on plant operations, PSA quality and leachability data on a commercial-in-confidence basis. In response to this request:

- Aylesford Newsprint, E-ON and UPM-Kymmene released data from their energy-from-waste (EfW) plants at Aylesford, Kemsley and Shotton respectively; and
- end-users ENVAR and Tarmac released additional data and specifications with the permission of the suppliers.

3.12 The composition of PSA is dealt with collectively in this report. However, where appropriate, the outputs of individual mills are considered separately.

3.13 In summary, the composition of PSA varies depending on:

- the input material;
- operational procedures; and
- the technology used for the combustion process.

3 Kaolinite is a clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$.
4 Calcite is a carbonate mineral made up of chemical or biochemical calcium carbonate corresponding to the formula $CaCO_3$.
5 Talc is a mineral composed of hydrated magnesium silicate with the chemical formula $H_2Mg_3(SiO_3)_4$ or $Mg_3Si_4O_{10}(OH)_2$.

4. Key markets for PSA

4.1 UK paper recycling mills generate nearly one million tonnes of wet paper sludge annually [7]. Table 1 shows the amount of paper sludge, biomass and plastics incinerated in England and Wales in 2006 [8]. According to the Confederation of Paper Industries, this generated 125,000 tonnes of PSA, of which 88,000 tonnes (70 per cent) were sold to end uses and 37,000 tonnes (30 per cent) were landfilled [8][9].

Table 4.1: Combustion of paper sludge in England and Wales, 2006 [8]

Material fed to incinerator	Amount (tonnes/year)*
Paper sludge	275,000
Biomass (virgin and clean non-virgin timber)	120,000
Plastics	17,000

* Approximate tonnages for the major paper sector combustors (all figures on a dry basis).

4.2 The size of the UK paper market is growing, with some expansion planned at existing mills and two additional mills expected to start combusting paper sludge in England in 2009 and 2010 respectively. Production of ash is therefore expected to increase over time [8].

4.3 Current and potential markets for PSA depend on its composition and, in particular, its lime concentration. PSA may be used in the following applications:

- PSA applied to agricultural land as a liming agent;
- PSA used as a desiccant for animal bedding;
- PSA used to stabilise sewage sludge;
- PSA used in block manufacture;
- PSA used in cement manufacture; and
- PSA used as a binder in steel slag manufacture.

4.4 A higher concentration of calcium oxide (commonly referred to as lime in the context of these uses) in PSA leads to greater value. This is due to the better substitution ratio of virgin lime products and ultimately better binding properties in the applications.

4.5 The main variables currently affecting the inputs to incineration are the wastes produced at the paper mill in question and the material required for co-firing the sludge, rather than the required product composition and the market value of PSA with a higher lime concentration. Section 2 describes the production process and input materials in more detail.

4.6 The minimum potential market for PSA is estimated at 300,000 tonnes/year, though this is expected to be a conservative figure [8]. The current amount supplied to end markets is taken to be 88,000 tonnes/year; with the introduction of the Quality Protocol, the volume of PSA recovered could in theory increase by the amount currently being landfilled [9]. However, as with all products the PSA needs to be of the right specification and within an economically feasible distance of end users to access the relevant markets. It is also expected that the new paper mills will recycle at least 50 per cent of their PSA to end markets from 2009/10 onwards [8].

4.7 The potential for PSA to maintain or increase its market share and open up new markets will depend upon the specification, price and consumer confidence in PSA as a product.

4.8 Gauging the levels of confidence in PSA was not within the scope of this work, but if a Quality Protocol is produced it is expected to increase consumer confidence in markets where there are issues around the consistency of the lime concentration. As the market price of PSA depends on its lime content, market prices could increase and new end markets possibly arise if the Quality Protocol allows an increased concentration.

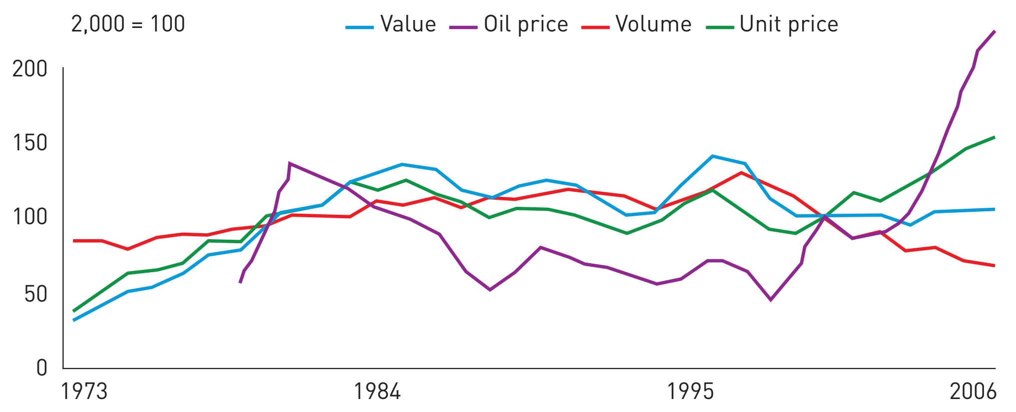
4.9 The main markets for PSA are discussed in more detail below.

4.10 Agricultural liming agent

4.10.1 PSA contains a range of calcium compounds which give liming properties, such as calcium oxide. This means that it meets the definition of an agricultural liming agent, that is a material whose calcium and magnesium compounds are capable of neutralising soil acidity[6]. These materials include limestone and chalk, quicklime, hydrated lime, marl and shells.

4.10.2 There is a huge demand for lime within the UK agricultural industry which could be partly substituted by PSA. Farmers have always limed their fields, but depressed farm incomes have let to reducing liming over the years. Fertiliser application rates have been falling since the mid-1980s (Figure 4.1), with usage now at the levels see in the late 1970s [10]. With today's low field pH values, there is potentially a significant environmental benefit from direct landspreading of lime and liming agents.

Figure 4.1: UK consumption of fertilisers, 1973–2006 [11]



4.10.3 Economic and policy influences on the structure of livestock farming and more efficient utilisation of nutrients in animal manures are likely to have played a role in the trends seen in Figure 4.1. Environmental legislation such as the Water Framework Directive is likely to have a significant impact on future fertiliser use in agriculture as there is pressure for farmers to reduce diffuse pollution resulting from fertiliser application.

4.10.4 Classifying PSA as a product rather than a waste is expected to further open up this market. PSA could be used as a direct replacement for purchased lime and is potentially suitable for purpose on leaving the paper mill. Soil samples from the fields would be needed to calculate appropriate application rates and confirm, if and how much, lime was required. Use of qualified agronomic advice for this task would ensure safe and sensible application – as is currently carried out with virgin lime [8].

4.11 Animal bedding desiccant

4.11.1 PSA has been proven to be useful in animal bedding. The PSA is used in the dairy industry as a direct replacement for purchased lime as a high pH biocide to dust down cubicle beds and straw yards in an attempt to reduce the levels of pathogens. PSA is a very effective desiccant when used in association with materials such as straw; it increases absorbency, improves bedding conditions and the longevity of bedding materials and reduces levels of mastitis. The material is normally supplied with a product data sheet to advise the farmer when using the product.

6 Correct liming practice is important in order to maintain optimum pH levels in the topsoil in all parts of the field. Insufficient use of lime on acid soils can cause large yield losses, but excessive use is wasteful and can aggravate trace element deficiencies. Optimum soil pH levels vary depending on soil type and cropping [28].

4.12 Sewage sludge stabilisation

4.12.1 The treatment of sewage sludge (biosolids) by lime stabilisation can be achieved by applying a controlled dose of hydrated lime or quicklime to the sludge. This is considered the simplest and most efficient method of treatment to produce a valuable end product [12]. PSA can be used as a replacement for hydrated lime or quicklime.

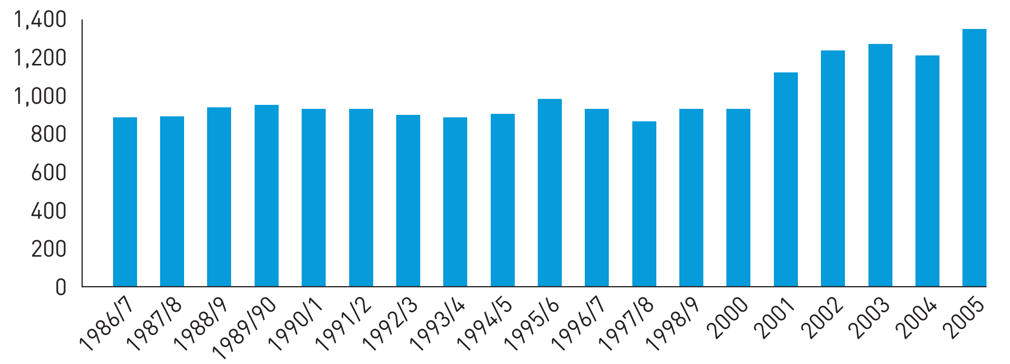
4.12.2 The treated sewage sludge can then be applied to land in accordance with the *Code of Practice for the Agricultural Use of Sewage Sludge* [13].

4.12.3 As shown in Figure 4.2, sewage sludge arisings increased slightly between 1986 and 2000, with larger increases between 2000 and 2004 [14].

4.12.4 Sewage sludge is governed by various legislation, but chiefly the Urban Waste Water Treatment Directive 91/271/EEC [15]. The Directive's objective is to 'protect the environment from the adverse effects of urban waste water discharges and concerns the collection, treatment and discharge'[7] of that water.

4.12.5 Guidelines (*Safe Sludge Matrix*) agreed between ADAS, Water UK and the Retail Consortium banned the use of untreated sewage sludge on land after 31 December 1999 [16]. Under these guidelines, advanced treatment of sludge will be required for most agricultural applications and therefore could represent a large potential market for PSA [8].

Figure 4.2: Estimated sewage sludge arisings in England and Wales, 1986–2004 (thousand tonnes) [14]



4.13 Block manufacture (cement products)

4.13.1 Lime has distinct advantages in the manufacture of both cement and sand mortars as it makes them cohesive, adhesive and workable. In addition, lime makes mortars more pliable and less prone to water penetration.

4.13.2 Between 2001 and 2005, production of bricks in the UK remained stable at around 2,700 million bricks [17]. From 2000 to 2005, the price of pre-cast concrete products (e.g. blocks and bricks) increased by 21.8 per cent according to Department of Trade and Industry price indices for 2006.

4.13.3 The main factors affecting the potential for PSA to maintain or increase its market share of brick and block manufacture, and its share of the cement market, are the price and consumer confidence in PSA as a product. A higher lime concentration in the PSA product would be conducive to the use of PSA in this industry. All lime or lime containing substances, such as PSA, used in construction must conform to the necessary standards.

7 http://ec.europa.eu/environment/water/water-urbanwaste/index_en.html

4.14 Steel slag manufacture

4.14.1 The potential use of PSA in the manufacture of steel slag was examined by the TAG but, as PSA is not currently used in this market, this use is not considered in detail in this technical report.

4.14.2 UK demand for steel mill products fell from 19 million tonnes in 1970 to 14.3 million tonnes in 2007, yet exports more than doubled from 3.3 to 7.7 million tonnes [18].

4.14.3 Steel slags are created when iron and scrap are converted into steel in the presence of lime and dolomite fluxes. These fluxes form the basis of steel slag which, in turn, absorbs the oxidised impurities from the molten iron.

4.14.4 The quality of liquid steel and slag are closely inter-related and slag chemistry must be carefully controlled during steelmaking as an alkaline slag is required for optimum steel quality. The alkalinity of steel slag is known as the V ratio where:

$$V = CaO\ \% / (SiO_2 + P_2O_5)$$

4.14.5 Lime additions are regulated during steelmaking in order to achieve the desired V ratio. PSA tends to have a high lime content and therefore could possibly be used as a fluxing agent in steel manufacture. But depending on its composition, the PSA may affect the absorption of the oxidised impurities. This potential end use would therefore require further investigation.

4.15 Exports and Imports

4.15.1 PSA is not currently imported or exported because:

- it is classed as a hazardous waste; or
- it is a waste that requires an environmental permit or exemption in order to be handled, transported, stored and disposed of.

4.15.2 As PSA is a partial substitute for lime, the import and export activities of lime are relevant as it could be used as a proxy for the potential to import/export PSA[8]. In 2003, the UK was a net exporter of lime and had a net supply of 637,400 tonnes available for sale [11].

4.16 Conclusion

4.16.1 Currently, PSA as a waste requires an exemption in order to be used in these applications whereas primary materials can be used without any controls. For example, PSA needs an exemption to be used to treat sewage sludge whereas the non-waste alternative, lime, can be used without any controls. If PSA can be demonstrated to be fully recovered and can be used without waste management controls, then it can be used as a direct competitor to primary materials.

4.16.2 In light of the above market analysis, the TAG agreed that the technical report should relate to PSA use in following five market sectors exclusively:

- PSA applied to agricultural land as a liming agent;
- PSA used as a desiccant for animal bedding;
- PSA used for sewage sludge stabilisation;
- PSA used in block manufacture; and
- PSA used in cement manufacture.

8 Please note that If producers intend to export PSA they should be aware that, although the material may cease to be waste in England and Wales, the importing country may take a different view. It is prudent for producers to check with the competent authority what the position is before exporting their product. A list of the competent authorities can be found at: http://ec.europa.eu/environment/waste/shipments/pdf/list_competent_authorities.pdf?lang=_e

5. Current legislative position

5.1 PSA is currently classed as a waste and is regulated under the Environmental Permitting (England and Wales) Regulations 2007 [4] to the point where it is incorporated into another product.

5.2 The EU Landfill Directive 1999/31/EC [19] bans the landfill of corrosive waste and the co-disposal of hazardous and non-hazardous waste. This change resulted in the number of landfill sites accepting hazardous waste decreasing significantly after July 2005. PSA is corrosive because of its lime concentration and could be classified as hazardous waste if it possesses any of the hazardous properties H1–H14.[9] If deemed hazardous, producers in England and Wales need to register the site of production with the Environment Agency and use a consignment note to move or dispose of hazardous waste. Like any other waste, the receiving site must hold the appropriate authorisation to accept it.

5.3 Table 5.1 summarises current legislative controls governing the combustion of paper sludge, the storage of PSA and the delivery/receipt of the final product once it has left the processing site. Table 5.2 gives examples of activities exempt under the Environmental Permitting (England and Wales) Regulations 2007 [4].

Table 5.1: Summary of legislative controls

Activity	Current legislative control	Current approach
Combustion of paper sludge	An environmental permit required under the Environmental Permitting (England and Wales) Regulations 2007 [4] for combustion of paper sludge. Combustor must meet the requirements of the Waste Incineration Directive [3].	Normal regulatory controls apply
Storage of PSA	The storage requires an environmental permit under the Environmental Permitting (England and Wales) Regulations 2007 [4] unless it is exempt under those regulations.	Normal regulatory controls apply
Delivery of PSA to end user (consumer)	PSA is currently viewed as waste and must be handled according to the Environmental Protection (Duty of Care) Regulations 1991 [20]. The materials must be transported by a person who is registered as a waste carrier.	Normal regulatory controls apply
Use of PSA by the consumer	PSA is currently viewed as a waste and its use requires an environmental permit under the Environmental Permitting (England and Wales) Regulations 2007 [4] unless it is exempt under those regulations.	Normal regulatory controls apply

Table 5.2: Examples of activities exempt under the Environmental Permitting (England and Wales) Regulations 2007

Activity	Exemption
Use of PSA in manufacture of blocks	Paragraph 13 would normally apply.
Use of PSA as a liming agent in sewage sludge stabilisation	Paragraph 15 would normally apply.
Use of PSA as a desiccant in animal bedding	Paragraph 15 would normally apply.

9 For information on assessing the hazardous properties of waste, see Environment Agency Technical Guidance WM2: *Hazardous Waste: interpretation of the definition and classification of hazardous waste* [6].

6. Risk assessment

6.1 The aim of the risk assessment was to determine whether the application of bound or unbound PSA would present a risk to human health or the environment. This was done through a combination of appropriate exposure scenarios, quantitative and qualitative assessment for each of the end uses of PSA identified in this report. The assessment required:

- collation of characterisation data for the PSA;
- identification of gaps in the data sets; and
- provision of recommendations for mitigation measures (if appropriate).

6.1.2 External consultants were commissioned to do this work on behalf of the TAG. The following is taken from the risk assessment report [5].

6.2 Methodology

6.2.1 The risk assessment looked at a number of realistic scenarios in which PSA would be used. The scenarios are as follows:

- PSA applied to agricultural land as a liming agent;
- PSA used as a desiccant in animal bedding;
- PSA used as a sewage sludge stabilisation agent; and
- PSA used in block making for commercial/industrial and residential uses.

6.2.2 For each scenario, the principal pathways and receptors were identified and the following approaches used to determine risks to principal receptors, i.e. workforce, general population, animal, soil, surface water and groundwater:

6.2.3 **Soil quality impact from agricultural applications.** Soil metal loading calculations determined the number of applications and quality of PSA that could be applied in order to maintain compliance with the limit values in the Code of Practice for Agricultural Use of Sewage Sludge [13].

6.2.4 **Surface water.** A tiered approach was used to assess potential risks to surface water, including a tier 1 screening assessment followed by a tier 2 assessment for determinands failing the screening level. In line with other river quality models, a simple mass balance approach was used in the second tier of the assessment. A spreadsheet tool was developed to calculate the risk of failure of river Environmental Quality Standard (EQSs) [21] by each parameter and the likely acceptable dilution to ensure compliance with EQS.

6.2.5 **Groundwater.** A similar tiered approach was used to assess the potential impact on groundwater. As none of the determinands failed the screening level, the second tier of the assessment was not undertaken.

6.2.6 **Human health.** This assessment considered two main scenarios as follows:

- *Short-term exposure by the workforce and general population to dust arising from the application of PSA.*
  - Occupational exposure. Compositional data were used to calculate the concentration of each contaminant in 10mg dust/m^3. These were compared with the eight-hour Workplace Exposure Levels (WELs) set by the Health and Safety Executive (HSE) [22] to protect the workforce from exposure to chemicals in the workplace.
  - General population. Contaminant concentrations in 10mg dust/m^3 were compared with short-term Environmental Assessment Levels (EALs) calculated under the Integrated Pollution Prevention and Control Directive (as amended) [23].[10] The EAL takes into consideration exposure longer than the working day and is therefore more conservative than the approach to occupational exposure.

10 See http://ec.europa.eu/environment/air/pollutants/stationary/ippc/legis.htm for more information about the amendment of the IPPC Directive.

- *Long-term exposure by the general population to PSA after application.* The Environment Agency's CLEA model (Contaminated Land Exposure Assessment model) [24] was used to evaluate the potential risk to human health via the medium of soil. Compositional data for PSA were used as a substitute for contaminated soil concentrations and two scenarios were considered:
  - commercial/industrial use with an adult female as a receptor; and
  - residential (typical house) with a six-year-old female as a receptor

6.2.7 Animal health. The risk of exposure through ingestion was assessed by comparing maximum levels of contaminants that could be ingested with maximum limits in animal feed. Risk of inhalation was also considered qualitatively.

6.2.8 At the time the risk assessment was commissioned, the issue of the use of PSA in cement manufacture had not been raised. The TAG therefore undertook a qualitative risk assessment of this application. Its findings are as follows:

- cement manufacture is regulated under the Environmental Permitting (England and Wales) Regulations 2007 [4] and thus human health and the environment will be adequately protected;
- the total amount of PSA present in a final cement mix will be 15 per cent. This equates to a final percentage of the ash in precast concrete of 1.35 per cent. The risk assessment demonstrated that up to 20 per cent PSA in block manufacture poses no risk to human health or the environment; and
- assuming the PSA fraction is ≤20 per cent, the risks and appropriate mitigation measures for the use of PSA in cement manufacture will be the same as for PSA used in block manufacture.

6.2.9 Two data sets were used for the assessment models as follows:

- composition (e.g. total metals); and
- leachability at a liquid to solid ratio of 10 based on, for example, BS EN 12457-2 [25] or BS EN 12457-3 [26] (European test for granular wastes) or the National Rivers Authority (NRA) leaching test.

6.2.10 Data on the composition and leachability of PSA were obtained from operators of three paper sludge combustion plants and two end users. These data were considered representative of all PSA produced in the UK.

6.3 Results

6.3.1 Overall the risk assessment found that the risks to human health and the environment associated with the use of PSA in the scenarios considered were acceptable where specific restrictions are complied with. These restrictions are detailed below.

6.3.2 Soil loading

- PSA contains similar or lower levels of arsenic, lead, manganese, mercury and vanadium to those found in urban soils in the UK. Mean concentrations of cadmium, copper, chromium, titanium and zinc exceed those of mean rural and urban soils.
- When PSA is applied directly to land as a liming agent, the risk assessment found that application rates are limited by the levels of copper and molybdenum in the PSA. At an application of 10 tonnes/ha, the number of applications of PSA must not exceed 13 in any 10-year period on the basis of maximum concentrations, and 27 in any 10-year period for typical concentrations to prevent any detrimental effect on the soil from the perspective of metal loading.
- On the basis of a neutralising value of 37 per cent, for the worst case example (peaty soils with a pH of 5.0), the risk assessment found that no more than 6.3 applications at 22.7 tonnes/ha should be made in a 10-year period (based on maximum molybdenum concentrations) to prevent any detrimental effect on the soil from the perspective of metal loading.

6.3.3 Surface water

- PSA has the potential to cause breaches of EQS for a number of determinands if accidentally released in large quantities to small volumes of surface water. This is particularly the case for soft waters (<50 mg/l $CaCO_3$) where EQS values are most stringent. Good operational practice should therefore be adopted when handling and managing PSA as 100 per cent of maximum concentration show a potential excess of 10 per cent EQS.
- The incorporation of PSA in lightweight construction blocks as a liming agent at up to 10 per cent of the overall dry ingredients would not pose a significant risk to surface water quality.
- The use of PSA as a liming agent on agricultural land at application rates of 7.5 and 10 tonnes/ha with incorporation into the top 5cm and 25cm of soil in grassland and arable would not pose an identifiable threat to surface water quality.

6.3.4 Groundwater

- PSA has the potential to cause breach of groundwater benchmarks for a number of determinands. A risk management plan is required for the storage and use of PSA product. PSA should not be released to drains or groundwater and the product should be stored under cover and protected from flooding.
- The use of 10 per cent PSA as a liming agent in lightweight construction blocks poses no risk to groundwater bodies below the area of placement when the standard recommendations provided in Section 7 are applied.
- There is no significant risk to groundwater when the standard recommendations provided in Section 7 are applied.

6.3.5 Human health

The risk assessment for human health uses a number of assumptions in order to assess a worst case scenario. The assumed composition of PSA is the maximum levels reported. Unbound, uncovered material is considered.

- Simple occupational exposure during use of 100 per cent PSA: assessment of concentrations in 10mg dust/m^3 against available WELs suggests there is no risk to the health of workers from exposure to the dust. However, Material Safety Data Sheets for PSA recommend use of appropriate personal protective equipment (PPE) due to the irritant nature of the powder. The exposure of the workforce to dust arising from PSA would be similar to that from exposure to dust arising from lime from other sources.
- Comparison of metal concentrations in 10mg dust/m^3 exposure of general population during use of 100 per cent PSA against available EALs suggests that dust arisings pose no risk to the health of the nearby general population.
- A worst case assessment of exposure to 100 per cent PSA used as uncovered soil substitute shows that only manganese in the commercial/industrial setting and aluminium in the residential setting warrant further investigation. Any risk would only be present while the PSA was uncovered. However, PSA would not be used in this way as it is a lightweight ash and would disperse into the air and environment. Therefore this would be deemed a disposal activity.
- At 10 per cent substitution, the assessment showed that there was no risk to human health in either residential or commercial/industrial settings, even when uncovered.

6.3.6 Animal health

- Even with a very conservative approach of comparing the ingestion of the PSA with maximum limits in animal feed, there was some concern about the mean level of lead, manganese and mercury at maximum concentrations. However, this scenario is very unlikely as the PSA is unpleasant to eat [27] and so consumption would be minimal. If it was considered that only a maximum of 10 per cent of the PSA was likely to be consumed, a more realistic but still precautionary scenario, there would be only a low risk to animal health from the use of PSA as an animal bedding additive.
- This conclusion is supported by data that suggest that the levels of metals present in cow's milk are not significantly different when PSA is used as a bedding additive than when either straw or recycled plasterboard are used.
- The one exposure scenario where consumption, and therefore the risk to animal health, may be higher is during calving where licking may lead to some ingestion of PSA. The suppliers of PSA to cattle farmers strongly advise that PSA is not used during calving.
- The Food Standards Agency and Animal Health and Welfare (Defra) were asked to comment on the Animal Health section of the risk assessment. The Food Standards Agency stated that 'the approach looks reasonable' and they agreed with the conclusions. Animal Health and Welfare (Defra) raised no issues on the risk assessment.

7. Risk management

7.1 The risk assessment concluded that, if good practice guidance is followed, the risk to human health and the environment from the use of PSA is low in the following applications:

- PSA applied to agricultural land as a liming agent;
- PSA used as a desiccant in animal bedding;
- PSA used for sewage sludge stabilisation;
- PSA used in block making; and
- PSA used in cement manufacture.

7.2 However, the risk assessment was based on data provided by the TAG. As PSA composition and leachability may vary due to differences in feedstock and the operation of both the paper mill and combustion plant, the TAG recognised that the data may not encompass the full range of values that might be attributable to PSA.

7.3 In the absence of data that covers every eventuality, the TAG agreed that a precautionary approach was merited and that all PSA should be regularly tested to ensure its composition and leachability meets the maximum values used in the risk assessment. This would provide assurance that the potential risk of harm to human health and the environment continues to be low.

7.4 Because some determinands may not cause a problem for human health and the environment and to avoid unnecessary analysis, it was agreed that, if possible, a maximum values table should represent only those parameters of concern that can be used as indicators. If these indicators are exceeded, a full suite of testing may be needed.

7.5 The Waste Protocols Project commissioned RPS group plc, to use the risk assessment data and results to understand the chemical constituents that should be tested on a routine basis in order that the risk assessment mitigation measures stand across all PSA.

7.6 The RPS report containing the full results of this work is detailed in Appendix D. The key elements of the report are extracted below. It is recommended that producers of PSA should routinely test for the chemicals listed in the following tables:

Table 7.1: Chemicals that should be tested for in all applications

Determinand	Leachability data (mg/l)	Solid analytical data (mg/kg)	Determinand	Leachability data (mg/l)	Solid analytical data (mg/kg)
Silver (Ag)	<0.001	n/a	Molybdenum (Mo)	0.057	14.8
Aluminium (Al)	3.6	n/a	Nickel (Ni)	<0.01	38.4
Arsenic (As)	<0.025	5.02	Lead (Pb)	0.096	125
Barium (Ba)	7.72	n/a	Antimony (Sb)	0.005	n/a
Cadmium (Cd)	<0.001	3.21	Selenium (Se)	<0.002	1.0
Cobalt (Co)	<0.01	n/a	Zinc (Zn)	<0.03	449
Chromium (Cr)	<0.01	59	Fluorine (F)	0.834	885
Copper (Cu)	<0.01	562	Chlorine (Cl)	1150	n/a
Mercury (Hg)	0.0005	0.860	Sulphate (SO_4)	54.7	n/a
Manganese (Mn)	n/a	1781			

Table 7.2: Chemicals that should be tested for when used as an animal bedding desiccant

Determinand	Leachability data (mg/l)	Solid analytical data (mg/kg)	Determinand	Leachability data (mg/l)	Solid analytical data (mg/kg)
Silver (Ag)	<0.001	n/a	Nickel (Ni)	<0.01	38.4
Aluminium (Al)	3.6	n/a	Lead (Pb)	0.096	125
Arsenic (As)	<0.025	5.02	Antimony (Sb)	0.005	n/a
Barium (Ba)	7.72	n/a	Selenium (Se)	<0.002	1.0
Cadmium (Cd)	<0.001	3.21	Zinc (Zn)	<0.03	449
Cobalt (Co)	<0.01	n/a	Fluorine (F)	0.834	885
Chromium (Cr)	<0.01	59	Chlorine (Cl)	1150	n/a
Copper (Cu)	<0.01	562	Sulphate (SO_4)	54.7	n/a
Mercury (Hg)	0.0005	0.860			Solid analytical data (ng/kg) Test method: HRGCMS
Manganese (Mn)	n/a	1781			
Molybdenum (Mo)	0.057	14.8			
			Dioxin	n/a	0.70

7.7 Dioxins are only a critical determinand for the use of PSA as an animal bedding desiccant. As the test for dioxin analysis is expensive, it was decided to include two tables in order that producers will only need to test for dioxins if using the PSA in that end use.

7.8 The chemicals highlighted in Table 7.1 and 7.2 (Al, Ag and Co) may be additional to those that need to be tested for under producer's permit requirements.

7.9 It was suggested that solid analysis can not always be used as an indicator of leachability. Therefore the tables above include both the solid and leachability analysis that is necessary. It is proposed that:

- solid phase analysis should be performed using X-ray fluorescence (XRF) techniques as the majority of data in the risk assessment was derived using this method;
- dioxin analysis should be performed using High Resolution Gas Chromatography/Mass Spectrometry (GC/MS). High resolution mass spectrometers can distinguish between ions with very small mass to charge ratios; and
- leachability analysis should use the test method detailed in BS EN 12457-3 [26].

7.10 It was proposed by RPS that the tests could be performed on a six-monthly basis, to tie in with the tests necessary for producers to comply with their permit requirements.

7.11 If the PSA exceeds these maximum values, the material will normally be classified as waste unless additional risk assessment demonstrates it is acceptable to use.

7.12 The TAG recommend that the wider industry be asked if they agree with the proposed environmental standard, test methods and frequency of testing at the consultation stage.

7.13 Results of testing should be provided to customers/users in the form of a Material Safety Data Sheet (MSDS) or similar document.

7.14 If the process and/or inputs change, full compositional and leachability analysis should be carried out to ensure that the overall composition and availability of the metals present in the PSA is not affected.

7.15 In addition to the requirement to test the material composition and leachability, a number of standard good practice measures should be followed depending on the application. These are detailed on page 23.

7.16 Use of PSA as an agricultural liming agent

7.16.1 The use of PSA as an agricultural liming agent will require a pH assessment of the fields before spreading. Application rates should be based on guidelines given in *Fertiliser Recommendations for Agricultural and Horticultural Crops* (RB209) [28] and any subsequent guidance.

7.16.2 Based on metal concentrations, the risk assessment concluded that no more than 6.3 applications should be made in any 10-year period. However, it is unlikely that a field in regular agricultural production will require an application of lime to correct pH any more frequently than three applications in five years. For example, data from the Representative Soil Sampling Scheme (RSSS) [29] for 1995–1999 showed that 68 per cent of fields had either not received any lime or had not been limed within a five-year period.

7.16.3 Therefore, the TAG felt the maintenance of the soil alkalinity appropriate to supporting crops is the limiting factor and not the metal concentration.

7.16.4 Should liming be required more frequently, a soil assessment for Potentially Toxic Elements (PTE) should be undertaken before application to check that background soil levels do not exceed those set out in the *Code of Practice for the Agricultural Use of Sewage Sludge* [13].

7.16.5 The Environment Agency considers there is potential for metal accumulation from the addition of other products to soil. The *Safe Sludge Matrix* [16] should be followed to ensure this does not occur.

7.16.6 The requirements set out in the *Code of Good Agricultural Practice* (CoGAP) [30] should also be adhered to in line with standard good practice for applying products to land. If necessary, advice should be taken from an advisor qualified under the Fertiliser Advisers Certification and Training Scheme (FACTS).[11]

7.17 PSA as a desiccant in animal bedding

7.17.1 The risk assessment concluded that the risk to animal health is low from the use of PSA as an additive for desiccation and biocidal activity. Anecdotal evidence from the farmers who use PSA regularly in this way suggests considerable benefits to the health of cattle. However, the following recommendations are made regarding its use to minimise potential risks to animal health:

- to avoid inhalation of the dust, cattle should not be present in the area when the PSA is laid;
- to avoid risk of irritation and ingestion of PSA by licking, do not allow cattle to calve on bedding underlain by PSA; and
- comply with relevant codes of practice and regulations such as CoGAP [30].

7.17.2 This is standard good practice that would be applied to any powder material being used in this end use.

11 For more information on FACTS, see http://www.factsinfo.org.uk/facts/ or phone 01335 343945.

7.18 Standard good practice for all applications

7.18.1 In all end uses, PSA users should adopt the following good practice measures, which are followed when handling virgin lime:

- wear appropriate PPE;
- use dust suppression measures, including bagging PSA in a closed system;
- store PSA and products containing PSA under cover with protection from flooding to guard against accidental release to drains or surface water;
- do not use PSA within 10 metres[12] of surface water as stated in Pollution Prevention Guidance 5 (PPG5) [31];
- control run-off from stockpiles of any PSA or products containing PSA;
- do not use PSA within 50 metres of a potable abstraction borehole. This is in accordance with published Groundwater Source Protection methodology [32][13];
- operate good practice with respect to areas prone to poor drainage or at high risk from flooding;
- take care when handling and transporting PSA; and
- operate current good practice with respect to record-keeping, storage, use and disposal of PSA products and waste.

7.18.2 This is standard good practice that would be applied to any material being used in these end uses.

7.19 Conclusion

7.19.1 Based on the findings of the risk assessment and TAG discussions, the TAG concluded that PSA has no worse environmental effects than virgin material in the applications specified in 7.1. The TAG considers PSA as being capable of being used for these applications without undermining the aims of the Waste Framework Directive [1] and Water Framework Directive [2] of protecting human health and the environment provided:

- PSA is tested to ensure its composition and leachability falls below the maximum values used to develop the risk assessment; and
- the standard good practice detailed above is followed.

7.19.2 The TAG therefore considers that PSA can be fully recovered and that a Quality Protocol should be developed covering these applications.

12 There may be local variations in this distance, so check with the Environment Agency during the planning stage of a project.

13 Zone 1 or the Inner Protection Zone must be protected by a minimum of a 50-metre protection radius of a potable groundwater borehole. Identifying small abstraction boreholes may require liaison with neighbouring land owners.

8. Standards and specifications

8.1 For PSA to be fully recovered, it is necessary to demonstrate that it is in a form that meets a standard and therefore requires no further processing.

8.2 The range of markets means that a single unified specification for PSA materials would not be suitable for, or applicable to, existing or potential future end uses. The market end use predominantly defines the specification that the material will be required to be processed to. For example, in agricultural applications such as animal bedding or sewage sludge stabilisation, the PSA applied will depend on individual requirements and soil conditions respectively. Thus defining a standard may not be practical nor provide sufficient flexibility. The following paragraphs consider each application of PSA in turn.

8.3 Liming agent for direct application in agriculture

8.3.1 There are no existing publicly available standards for the specification of PSA as a liming agent to be used for agricultural benefit. It is recognised that a number of materials contain lime which gives it these properties. PSA is one of these materials. All potential liming agents must meet the requirements of *Fertiliser Recommendations for Agricultural and Horticultural Crops* (RB209) [28] in order that they can be demonstrated to be beneficial.

8.4 Animal bedding desiccant

8.4.1 No publicly available standard or specification currently exists for lime used in animal bedding desiccant. It is possible that customers may produce a specification as the market becomes more established.

8.5 Sewage sludge stabilisation

8.5.1 There is no publicly available standard or specification for the specification of lime to be used for sewage sludge stabilisation.

8.6 Block making and cement manufacture

8.6.1 The TAG reviewed 'standards' in the broad sense including publicly available national and international standards, codes, industry and company specifications and acceptance criteria. Comparable British and European standards are listed in Table 8.1.

8.6.2 Although these standards cover the engineering properties of the material, no environmental elements are considered.

Table 8.1: Comparable British and European standards for concrete and block manufacture

Standard	Title
BS EN 196-2: 2005	Methods of testing cement. Chemical analysis of cement.
BS EN 934-3: 2003	Admixtures for concrete, mortar and grout. Admixtures for masonry mortar. Definitions, requirements, conformity, marking and labelling.
BS EN 12620: 2002	Aggregates for concrete.
BS EN 13055-1: 2002	Lightweight aggregates. Lightweight aggregates for concrete, mortar and grout.
BS EN 459-1: 2001	Building lime. Definitions, specifications and conformity criteria.
BS EN 197-2: 2000	Cement. Conformity evaluation.

Source: BSI online catalogue (http://www.bsi-global.com/en/Standards-and-Publications/)

8.7 All applications

8.7.1 As there are either no publicly available standards, or those which do exist do not adequately consider environmental impacts, the TAG agreed that regular testing to the environmental standard, detailed in Section 7, would ensure low risk of harm to human health and the environment. The 'environmental standard' resulting from this work, is detailed in Appendix D.

8.7.2 The environmental standard should be met by all PSA, regardless of end use, in addition to the other standards identified in the Sections 8.3 to 8.6.

8.8 Record-keeping by PSA producers

8.8.1 The production of PSA will continue to be controlled by the site's environmental permit. This requires detailed record-keeping including the data on the PSA being produced. Detailed compositional data are also required where the material is currently being landfilled. The TAG confirmed that, if a Quality Protocol is produced, this level of sampling and record-keeping should continue.

8.8.2 In addition, producers will need to provide their customers with supply documentation including:

- date;
- quantity by weight/volume and sale;
- name and address of receiving business/establishment;
- nature of receiving business/establishment (classified according to designated market sector);
- date of last test to appropriate standard (if applicable);
- copy of a materials safety data sheet (MSDS); and
- copy of the Quality Statement.

8.8.3 The Quality Statement should contain the following information:

- a statement that the PSA was provided/produced according to the Quality Protocol; and
- the date on which it was provided/produced.

8.8.4 Producers should retain records of:

- sampling and analysis of compositional and leachability data to show that the PSA does not exceed the environmental standard limits; and
- testing results to show that PSA meets a standard (in the case of cement manufacture or block making).

8.9 The need for certification

8.9.2 The need for certification was discussed with the TAG as PSA has a potential for variable output quality if the production process and inputs are not stringently controlled and monitored. Also, where used as an agricultural liming agent, there is a potential for elevated PTEs to build up in the soil over time.

8.9.3 Some TAG members thought that, to ensure good practice guidance was followed, there may be a need for independent testing, certification and verification of PSA materials.

8.9.4 Other TAG members suggested that it would be in the best interest of users of the PSA material to follow the good practice guidance.

8.9.5 The TAG discussed the following reasons for not requiring certification:

- if the good practice for PSA applications to land is not followed, farmers may not be able to grow crops for many years due to soil pH issues;
- sewage stabilisation is controlled by the Environmental Permitting Regulations (England and Wales) 2007 [4] and the process is subject to HACCP (Hazard Analysis and Critical Control Point) control;
- the industry is made up of a few key players and so there is less risk of confusion over requirements; and
- customers are likely to challenge companies if the material does not meet the necessary standard or specification.

8.9.6 No specific regime regarding the certification of material quality has yet been established at an industry-wide level, although some larger manufacturers do test and publish specification sheets confirming the quality of their materials. Those tests that are conducted are typically made against a number of specifications (required by the consumer as important characteristics of the PSA materials).

8.9.7 The TAG concluded that the appointment of an independent, certified body to perform material verification and to certify it had been produced to a publicly available standard is not required.

8.9.8 The TAG recommended that good practice guidance is prepared that pulls together the identified good practice detailed in this report. Use of this guidance by PSA producers will help to reduce the risk of any confusion over how the material should be handled and used. The guidance would also act as a central reference document.

8.10 Conclusions

8.10.1 In order for PSA to be fully recovered and suitable for use, normally it must meet a publicly available standard. However, there are currently no publicly available standards for the following applications:

- PSA applied to agricultural land as a liming agent;
- PSA used as a desiccant in animal bedding; and
- PSA used for sewage sludge stabilisation.

8.10.2 In the absence of publicly available standards, the environmental standard, detailed in Section 7 should be met. This will ensure PSA can be used without risk of harm to human health and the environment.

8.10.3 There are a number of publicly available standards for the use of PSA in block making and cement manufacture. For PSA in these applications to be both safe to use for human health and the environment and suitable for use, the producer would need to meet both the environmental standard and the appropriate engineering standard.

8.10.4 The TAG recommends that certification is not necessary.

9. Findings

9.0 The purpose of this report is to identify the point at which PSA can be fully recovered and therefore be considered to cease to be waste and no longer be subject to waste management controls. To investigate this, the TAG considered the following criteria:

- PSA has a market and certainty of use;
- PSA meets a publicly available standard and requires no further processing; and
- PSA is capable of being used without undermining the aims of the Waste Framework Directive and Water Framework Directive of protecting human health and the environment.

9.1 PSA has a market and certainty of use

9.1.1 In terms of markets, PSA is currently being successfully sold to a number of end markets. According to the Confederation of Paper Industries, a total of 125,000 tonnes of PSA was produced by mills in 2006, of which 88,000 tonnes were sold to the UK market and 37,000 tonnes were landfilled [8]. The varying composition of PSA means that ash from different mills is often suitable for different applications.

9.1.2 Markets are currently limited by the status of PSA as a waste with users required to obtain either an environmental permit or exemption. The removal of this requirement and thus the stigma of using a 'waste' product are expected to open up new markets. The PSA will directly substitute virgin materials such as quicklime and limestone and requires no further treatment or processing before it can be used.

9.2 PSA meets a publicly available standard and requires no further processing

9.2.1 No publicly available standards or specifications exist for use of PSA as a liming agent, an animal bedding desiccant or a sewage sludge stabiliser. In these cases, an environmental standard should be met, based upon the maximum values used in the risk assessment.

9.2.2 There are a number of existing publicly available standards that could be applied to PSA destined for use in block making and cement manufacture. The standards give the required engineering specification of the material but do not address any potential environmental issues associated with its use.

9.2.3 To ensure minimal risk to the environment, all applications should reach the environmental standard.

9.3 PSA can be used without undermining the aims of the Waste Framework Directive and Water Framework Directive

9.3.1 The findings of the risk assessment are based on PSA samples whose composition showed a range of values. The variety is due to different operational practices at different mills and particularly the range of input materials.

9.3.2 The risk assessment concluded that, overall, the application of PSA poses a low risk to human health and the environment provided a number of simple control measures are followed.

9.3.3 For the findings of this risk assessment to be valid and the proposed mitigation measures appropriate, mills must ensure the PSA they produce continues to be below the maximum values used in the risk assessment (the environmental standard). If analysis shows these values are exceeded, the PSA will be considered to be waste and subject to waste management controls. If the process and/or inputs change, the TAG recommends that a full compositional and leachability analysis is carried out to ensure that the overall composition and the availability of the metals present is not affected.

9.3.4 In addition to this testing, the following standard good practice measures should be adhered to:

- wear appropriate PPE;
- use dust suppression measures, including bagging PSA in a closed system;
- store PSA and products containing PSA under cover with protection from flooding to guard against accidental release to drains or surface water;
- do not use PSA within 10 metres of surface water;
- control run-off from stockpiles of any PSA or products containing PSA;
- do not use PSA within 50 metres of a potable abstraction borehole;
- operate good practice with respect to areas prone to poor drainage or at high risk from flooding;
- take care when handling and transporting PSA; and
- operate current good practice with respect to record-keeping, storage, use and disposal of PSA products and waste.

9.3.5 In addition, the application of PSA to land as a liming agent will be controlled by existing guidelines on the use of fertiliser and application of sludge to land. These will prevent any contamination through over-application. These existing guidelines are:

- *Code of Practice for the Agricultural Use of Sewage Sludge* [13];
- *Code of Good Agricultural Practice* (CoGAP) [30] or subsequent guidance; and
- *Fertiliser Recommendations for Agricultural and Horticultural Crops* (RB209) [28] and any subsequent guidance.

9.3.6 When PSA is used as an animal bedding desiccant, the following guidance should be followed:

- to avoid inhalation of the dust, cattle should not present in the area when the PSA is laid; and
- to avoid risk of irritation and ingestion of PSA by licking, do not allow cattle to calve on bedding underlain by PSA.

9.4 Conclusion

9.4.1 It is clear that PSA currently has a market and that this would be further stimulated if its classification as a waste was removed. It is also clear from the risk assessment that, used with the appropriate controls, the risk to human health and the environment from the application of PSA is low.

9.4.2 Producers must ensure that the composition and leachability of the PSA they intend to supply as a non-waste falls below the environmental standards maximum values. They must also ensure they provide customers with the appropriate information to handle and apply their product in safe manner.

9.4.3 Where PSA is being supplied as a filler aggregate from block making and cement manufacture, it should also meet the appropriate standards identified in this report. For its other uses, existing guidance and regulations will control its application to land and ensure that is used beneficially with low risk to the environment.

10. Recommendations

10.1 Based on the findings of this technical report, the TAG recommends that a Quality Protocol be developed for the production and use of PSA.

10.2 PSA from each mill should be analysed regularly to ensure its composition and leachability falls below the environmental standard values in Section 7.

10.3 PSA used in the block making and cement manufacture industries must adhere to the relevant engineering standards.

10.4 If the process and/or inputs change, full compositional and leachability analysis should be carried out to ensure that the overall composition and availability of the metals present in the PSA is not affected.

10.5 If the environmental standard values in Section 7 are exceeded, the material should be considered to be waste, and should not be covered by the Quality Protocol

10.6 The frequency of testing should be every six months, in line with Environmental Permit requirements.

10.7 The recommendations from the risk assessment for using standard good practice in all applications should be listed in the Quality Protocol and adhered to by users of PSA.

10.8 The TAG considered the need for independent certification and verification. It concluded that the environmental standard set in Section 7 for maximum compositional and leachability values are adequate to safeguard against risk of harm to the environment resulting from the use of PSA and that independent certification and verification are therefore unnecessary.

10.9 Good practice guidance should be written for use by producers of PSA that pulls together the identified good practice detailed in this report. This will help reduce risk of any confusion over how the material should be handled and used. It will also serve as a central reference document.

Appendix A Technical Advisory Group (TAG) membership

Organisation	Representative	Type of member
Aylesford Newsprint Ltd	Paul Richards	Attending
	Rachel Bain	Attending
	Anders Astrom	Corresponding
	Stuart Chandler	Corresponding
Confederation of Paper Industries	David Morgan	Attending
Envar	Steve Hadden	Attending
	Joanne Milne	Attending
	Steve Dudman	Attending
Environment Agency	Jon Gulson	Attending
	Victoria Sturt	Attending
	Clare McCallan	Corresponding
	Kathryn Harriss	Corresponding
	Jess Hicken	Corresponding
Environment Agency Wales	Becky Favager	Corresponding
Kemsley CHP	Andy Llewellyn	Attending
M-Real New Thames	Kate Cathie	Corresponding
Northern Ireland Environment Agency	Peter Parsons	Corresponding
RPS	Claudia Amos	Attending
	Dr Ahlim Hashm	Attending
	Simone Aplin	Attending
SCA Hygiene Products	Stew Begg	Corresponding
	Jim Smith	Corresponding
SEPA	Mark Heggie	Corresponding
St Regis Paper Company Ltd	Kevan Harris	Corresponding
Tarmac Topblock	Dr Trevor Grounds	Attending
UPM-Kymmene UK Ltd	Andrew Bronnert	Attending
WRAP (Waste & Resources Action Programme)	John Barritt	Attending
	Mike Burgess	Attending
Waste Protocols Project Team	Suzanne Laidlaw (Chair)	Attending
	Sarah Clayton	Attending
	Michelle Steer	Attending
	Oliver Barrett	Attending
	Laura Holloway	Attending
	Nick Boase	Attending

Appendix B Terms of reference[14]

1. Mission statement

1.1 To produce a technical report, recognised by (and produced with the support of) industry. The technical report will contain sufficient information to determine when boiler ash from the thermal treatment with energy recovery of paper sludge (otherwise referred to as paper sludge ash (PSA)) has been processed to such a level that it can be considered to be fully recovered and no longer subject to the requirements of the regulatory waste regime.

1.2 If this is unachievable, the technical report will contain sufficient information to enable the Environment Agency to:
- determine whether PSA is recovered to a state where its use is acceptable in accordance with the Environment Agency's low risk regulatory principles; or
- confirm to the business community what legal obligations remain to control the reuse of the treated waste material.

2. Desired outcomes/outputs

2.1 The Technical Advisory Group (TAG) will produce a technical report that will identify and establish the point where:
- contaminants present by virtue of the nature of the waste have been eliminated or reduced so much that their presence is immaterial;
- the waste will be fully suitable as a substitute for a non-waste and can be considered a 'recovered product';
- there is a market for the recovered product and it is certain to be used; or
- the use of the recovered product will not result in harm to human health or the environment.

2.2 To do this the TAG will consider:
- PSA output from different mills (i.e. incineration of different proportions of inputs such as paper sludge, virgin and clean non-virgin wood and plastic) separately;
- current or future markets for PSA;
- whether there are any existing industry standards and specifications which PSA can meet;
- existing standards and specifications. If these do not exist, the TAG will identify alternatives and/or scope out projects for producing a new standard or specification;
- the potential human health and environmental impacts associated with the use of the recovered products, identifying any necessary mitigation methods;
- augmenting/developing existing standards (if required); and
- the requirement for certification and auditing/monitoring.

2.3 With the aid of the project economist, the TAG will provide input into a Financial Impact Assessment (FIA) which will determine the costs and benefits of a change in the point that waste ceases to be waste.

2.4 The TAG will also contribute to the delivery of a communications plan.

3. Limitations

3.1 Knowledge from the industry is vital in the production of the technical report and financial impact assessment. By being a member of the TAG, it is expected that participants will willingly share information from their sector and be prepared to participate in writing and reviewing elements of the report. If this help is not forthcoming, it may not be possible to fully develop a technical report in the timescale available.

3.2 The technical report will provide sufficient evidence to the Environment Agency to support moving the point at which waste ceases to be waste. However, it is ultimately the Environment Agency that will decide this point.

14 These terms of reference were adopted by the TAG at the start of the project on 21 August 2007.

Appendix C Definitions

Term	Description
Agricultural liming agent	An agricultural liming agent is a calcium or magnesium based compound used to increase the pH of soil to benefit soil fertility and agricultural productivity. Typically it would be calcium carbonate ($CaCO_3$) but could also be magnesium carbonate ($MgCO_3$), calcium hydroxide [$Ca(OH)_2$], calcium oxide (CaO) or a wide range of other more complex calcareous materials such as basic slag (from the steel industry), sugar beet factory waste, and lime-treated sewage sludge. For a more complete list of agricultural liming materials and their relative neutralising values, see page six and Appendix 7 of *Fertiliser Recommendations for Agricultural and Horticultural Crops* (RB209). (http://www.defra.gov.uk/farm/environment/land-manage/nutrient/fert/rb209/index.htm)
Controlled waste	Controlled waste is household, commercial and industrial waste. Controlled waste is defined in section 30 of the Control of Pollution Act 1974, section 75 of the Environmental Protection Act 1990 and the Controlled Waste Regulations 1992 (as amended). Paragraph 9(2) of Schedule 4 to the Waste Management Licensing Regulations 1994 provides that any reference to 'waste' in Part II of the 1990 Act includes a reference to Directive waste.
Desiccant	A desiccant is a hygroscopic substance that induces or sustains a state of dryness (desiccation) in its local vicinity. The PSA is used in the dairy industry as a direct replacement for purchased lime to dust down cubicle beds and straw yards in an attempt to reduce the levels of pathogens, increase absorbency and reduce levels of mastitis. The material is supplied with a Material Safety Data Sheet (MSDS) to advise the farmer when using the product.
Duty of Care	The Duty of Care is set out in section 34 of the Environmental Protection Act 1990 and associated regulations. It applies to anyone who is the holder of controlled waste. Persons concerned with controlled waste must ensure that the waste: ■ is managed properly; ■ is recovered or disposed of safely; ■ does not cause harm to human health or pollution of the environment; and ■ is transferred only to someone who is authorised to receive it. The duty applies to any person who produces, imports, carries, keeps, treats or disposes of controlled waste or, as a broker, has control of such waste.
Environment Agency	The Environment Agency is the leading public body for protecting and improving the environment in England and Wales. Its job is to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

continued

Term	Description
Environmental permit	Environmental permits or exemptions issued under the Environmental Permitting (England and Wales) Regulations 2007, which came into force on 6 April 2008, or low risk waste activities in accordance with Environment Agency guidance. From 6 April 2008, the following automatically became environmental permits: ■ PPC permits issued under the Pollution Prevention and Control (England and Wales) Regulations 2000 (as amended); and ■ Waste Management Licence (WMLs) issued under the Environmental Protection Act 1990 (as amended). Exemptions from the need for a Waste Management Licence, registered under Regulation 18 and Schedule 3 of the Waste Management Licensing Regulations 1994 (as amended) now come under Schedule 3 of the Environmental Permitting (England and Wales) Regulations 2007.
Input materials	Materials incinerated alongside paper sludge for economic, environmental or practical reasons. Accepted input materials include plastic covers, staples, virgin timber and clean non-virgin timber, de-inking sludge and effluent.
Lime	When this report refers to lime, it means calcium oxide (CaO), also known as burnt lime.
MSDS	A Material Safely Data Sheet is a document containing health and safety information on a hazardous product. It includes the chemical and common names of all ingredients that have been determined to be health hazards if they constitute 1 per cent or more of the product's composition (0.1 per cent for carcinogens). An MSDS also includes precautionary guidelines and emergency procedures for handling the product.
Mitigation measures	Measures put in place to reduce all potentially significant effects.
Paper sludge	Paper sludge is a combination of water, ink, soap, short cellulose fibres and other minerals (e.g. kaolins, carbonates and talcs) separated from the recovered paper feedstock. It can also include sludge from effluent treatment.
Paper sludge ash	Boiler ash arising from the incineration of paper sludge with or without input materials such as virgin and clean non-virgin wood, and plastics. This technical report does not consider bottom ash or bed material from the combustion of paper sludge.
Potentially Toxic Element (PTE)	Chemical element with the potential to cause toxicity to humans, flora and/or fauna. The majority are also known as 'heavy metals' or 'transition metals' (e.g. lead, cadmium, mercury, copper, zinc, nickel).
Quality Protocol	A Quality Protocol sets out criteria for the production of a product from a specific waste type. Compliance with these criteria is considered sufficient to ensure that the recovered product may be used without risk to the environment or harm to human health, and therefore without the need for waste management controls. In addition, the Quality Protocol indicates how compliance may be demonstrated and points to good practice for the use of the recovered product.
	continued

Term	Description
Standard	A standard can be defined as a document, established by consensus and approved by a recognised body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at achieving the most order in a given context. Standards range from individual company standards to multi-national (international) standards.
TAG	Technical Advisory Group. The TAG is a group of representative experts from industry, trade bodies, publicly-funded and regulatory authorities. The role of TAG members is to contribute their expertise to discussions regarding the technical, economic and environmental feasibility of developing and implementing the Quality Protocol.
Waste	Waste is any substance or object that the holder discards, intends to discard, or is required to discard. There have been a number of judgements by the European Court of Justice (ECJ). A summary of these judgements, which are legally binding, is available on the Defra website (see http://www.defra.gov.uk/ENVIRONMENT/waste/topics/index.htm)
Waste carrier	A person who transports controlled waste, within the UK, including journeys into and out of the UK.
WRAP (Waste & Resources Action Programme)	WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

Appendix D Report on the production of a maximum chemical values table for the use of PSA

The production of a maximum chemical values table for the use of PSA

RPS Group plc

October 2008

1 Chemicals of no concern

1.1 The solid analysis (Compositional data)

The total concentrations in the solid were used in the following assessments:

- maximum soil loading from land application of PSA to agricultural land as a liming agent;
- animal health assessment in relation to the use of PSA as a desiccant in animal bedding;
- human health risk assessment assuming exposure by the general population to PSA after application; and
- occupational exposure and short-term public exposure to PSA dust during construction.

Determinands that were in the original table and are not included in any of the above applications include the following:

Moisture content, pH, fraction organic C, free lime, SO_3, S, Ba, Ca, K, Li, Mg, Na, P, Si, and Sr.

None of these determinands have soil loading limits according to the code of practice for the use of Sewage Sludge in agriculture or maximum limits in animal feed.

Occupational exposure limits and short-term Environmental Assessment levels are related to specific compounds rather than elements. For the above determinands, in the form they are likely to exist in the PSA, they either have no limits or their limits are similar to total inhalable dust and therefore require no risk assessment. Free lime is an exception in that it has occupational exposure limit of (2mg/m^3 for calcium oxides and 5mg/m^3 for calcium hydroxide). However the risk from this component is similar to that of natural lime and can be controlled by the use of appropriate protection measures.

The human health risk assessment is based on the CLEA HHRA model which was used to assess potential risk to human health if PSA was used as an uncovered soil substitute or in soft landscaping in residential or commercial areas. None of the above determinands are relevant to this type of the risk assessment.

Therefore the original composition of paper ash table presented in the Risk Assessment and Technical Report can be modified by removing these determinands as presented in Table D1 overleaf.

Furthermore, the human health risk assessment demonstrated potential health risk even with significant dilution (10% PSA as an uncovered soil substitute). Therefore the assessment concluded that PSA should never be used uncovered as a soil substitute or soft landscaping in commercial or residential area and that this risk is mitigated by covering. The assessment also concluded that this use is extremely unlikely to occur in practice and therefore risk from this exposure scenario was dismissed. Some of the above listed contaminants were only relevant to this assessment and may be removed. These include Co, Fe, Sb and Tl (highlighted in bold and blue in the Table).

Table D1: Solid analytical data

Determinand	Units	Max concentration	Number of samples
Aluminium (Al)	mg/kg	86,952	155
Arsenic (As)	mg/kg	5.02	6
Cadmium (Cd)	mg/kg	3.21	16
Chromium (Cr)	mg/kg	59	16
Cobalt (Co)	**mg/kg**	**15.6**	**3**
Copper (Cu)	mg/kg	562	168
Fluorine (F)#	mg/kg	885	3
Iron (Fe)	**mg/kg**	**5,106**	**155**
Mercury (Hg)	mg/kg	0.860	16
Manganese (Mn)	mg/kg	1,781	157
Molybdenum (Mo)	mg/kg	14.8	5
Nickel (Ni)	mg/kg	38.4	16
Lead (Pb)	mg/kg	125	16
Antimony (Sb)	**mg/kg**	**17**	**3**
Selenium (Se)	mg/kg	1.0	5
Titanium (Ti)	mg/kg	1,918	155
Thalium (Tl)	**mg/kg**	**50**	**3**
Vanadium (V)	mg/kg	19	3
Zinc (Zn)	mg/kg	449	16
Dioxin ITEQ (ng/kg)	ng/kg	0.70	8

Fluoride was used in the land application calculations but was not presented in the table.

1.2 Leachability analysis

The leachability analysis data was used in the surface water and groundwater assessments. Determinants that were not included in any of the above applications due to the absence of relevant benchmarks include the following:

Be, Tl and P.

Therefore the original Table (leachability of paper ash at L/S 10mg/l) was modified by removing these determinands as presented in Table D2 below.

Table D2: Leachability data

Determinand	Units	Max	Number of samples
Silver (Ag)	mg/l	<0.001	7
Aluminium (Al)	mg/l	3.6	8
Arsenic (As)	mg/l	<0.025	10
Barium (Ba)	mg/l	7.72	15
Cadmium (Cd)	mg/l	<0.001	15
Cobalt (Co)	mg/l	<0.01	10
Chromium (Cr)	mg/l	<0.01	15
Copper (Cu)	mg/l	<0.01	15
Mercury (Hg)	mg/l	0.0005	15
Molybdenum (Mo)	mg/l	0.057	15
Manganese (Mn)	mg/l	<0.01	5
Nickel (Ni)	mg/l	<0.01	15
Lead (Pb)	mg/l	0.096	15
Antimony (Sb)	mg/l	0.005	8
Selenium (Se)	mg/l	<0.002	15
Tin (Sn)	mg/l	<0.001	7
Vanadium (V)	mg/l	<0.01	10
Zinc (Zn)	mg/l	<0.03	14
Fluorine (F)	mg/l	0.834	8
Chlorine (Cl)	mg/l	1,150	15
Sulphate (SO_4)	mg/l	54.7	15
Phenols	mg/l	<0.003	7
Ammonia	mg/l	0.005	7

2 Key parameters of concern

2.1 The solid analysis (Compositional data)

The following were identified as key determinants in the above risk assessments:

Use in agricultural applications as a liming agent	Cu, Mo
Use in animal bedding as a desiccant-Animal health	Pb, Hg, Mn
Occupational and short term public exposure	None identified as a limiting factor*
Human Health	Manganese and aluminium**

* aluminium was identified as being potentially problematic. However that was based on two unrealistic assumptions. The first is that aluminium was present in the form of alkyl compounds and the second is that the public will be exposed to dust concentration of 10mg/m^3.

** the type of application was considered extremely unlikely and therefore of no relevance in relation to animal health.

Considering the significant variability in the concentrations of the above determinands (with the difference between the maximum and minimum being orders of magnitude for some) and the limited number of data points for others, it may not be possible to judge the likely environmental performance of the PSA from knowledge of one determinands concentration in relation to the other compounds. For instance, molybdenum, one of the limiting factors in land application as a liming agent, demonstrated apparent plant to plant variability in concentration and therefore copper was selected as the limiting factor.

To give an example, the number of land applications was determined to be 1.3 for copper and 3.3 for zinc based on their known maximum concentrations. If the concentration of zinc, for instance, was greater than 2.5 (the ratio of the zinc to the copper number of applications) its maximum concentration, the number of application will have to be reduced to below 1.3 applications or the soil loading limits will be exceeded. Considering that there is no direct correlation between the different contaminants it is not possible to guarantee a concentration of one by knowledge of another.

However from the results of the above discussed applications, the most critical determinands are found to be those related to the soil loading and the animal bedding limits. Occupational exposure, and short-term public exposure can be controlled by adopting standard control and mitigation measures required for any construction projects as the PSA is proven to be no worse than any dust or the natural lime it is replacing. Potential human health impact from application in residential gardens and landscaped area was considered as a very unlikely scenario.

The soil loading and animal bedding limits are determined by As, Cd, Cr, Cu, F, Pb, Hg, Ni, Mn, Mo, Se, Zn and dioxins. Therefore, as a minimum, data on these should be available to assess the suitability of PSA for most of its applications.

It should be noted that analysing a sample for one or a number of the above determinands does not make a difference to the cost of analysis as most of the cost is associated with the preparation of the sample. Dioxin analysis is one of the most expensive analysis and may not be required for land applications in the absence of limits on soil loading. However it is one of the critical determinands for the animal bedding applications and therefore need to be retained.

It is our understanding that producers of PSA are required to carry out analysis including all chemicals in the Environment Agency ash sampling protocol which we believe include all the above chemicals.

2.2 Leachability data

The following were identified as key determinants in the controlled waters risk assessments:

Surface water Ag, Cl, Co, Cr, Cu, Pb, Zn

Groundwater Al, As, Ba, Cl, Hg and Pb

Besides Be, Tl and P that have been identified above as chemicals with no environmental benchmarks in relation to both surface and groundwater, only phenol and Sn were found to be of no significance due to the absence of benchmarks for groundwater and being well below the EQS for surface water.

It is our understanding that producers of PSA are required to carry out leachability analysis using the BS EN 12457/s on regular basis (six monthly) to comply with their permit conditions. This test includes all the chemicals in Table 2 excluding Al, Ag, ammonia, Co, Mn, Sn and V. Ag, Al and Co are proven to be of high significance to surface and groundwater assessment and therefore need to be retained. The remainder (ammonia, Mn and V) may be removed from the suit of analysis if their addition is proven to add a burden to the operator in terms of the analysis cost as none of these are of high significance in terms of potential impact on either surface water or groundwater. It should be noted that some of the operators have a more comprehensive list of analysis required by their permit caused by site specific factors.

3 Neutralisation capacity

The risk assessment was based on typical rates of applications of 10t/ha for arable and 7.5t/ha for grassland with the number of applications limited to 1.3 application per year or 13 in any 10 year period.

However, based on the Defra guidance RB209 which provides recommended lime application rates to acidic soils in order to achieve optimum pH, the recommended application rate based on lime and PSA with neutralisation value of 50-55 per cent (compared with CaO) and 37 per cent, for the worst case example (peaty soils with pH of 5.0) should be increased to 22.7t/ha reducing the number of applications to 6.3 times in a 10-year period.

(Please note that neutralisation capacity cannot be calculated from pH of the material)

4 Recommended types of analysis

It was suggested that the solid analysis is used as an indicator for the leachability of the PSA, eliminating the need for leaching tests. The chemistry of PSA is very complex and the leachability of any substance is not wholly controlled by the total concentration as many other factors such as solubility, co-solubility, and pH can control the process. Therefore the total concentration is not a good indicator. Furthermore, some of the critical elements in the leachate, such as Ag and chloride, are not tested in the solid and therefore the solid analysis cannot be used as an indicator for the leaching of such compounds.

It is our knowledge that both the solid and leachability analysis are required to be provided by the operators to comply with their permit conditions. As such both will be available at no additional cost and can be provided by the producer for assessment of suitability of the PSA for the quality protocol applications.

5 Appropriate test methods

5.1 The solid analysis (Compositional data)

It is our understanding that the analytical results used in the risk assessment were based on the following test methods, and therefore it is recommended that the same methods are used:

- Heavy metal analyses are usually performed ICP-OES (Induced Couple Plasma-Optical Spectrometry) on hot aqua regia digests.
- The bulk oxides such as calcium oxide, silica, alumina and magnesium oxides were reported to have been measured using XRF and converted into elemental concentrations. However, none of these oxides are of significance to the risk assessment as discussed above. Therefore alternatives may be used as appropriate to meet the objective of the test.
- Dioxin analysis is performed using High Resolution Gas Chromatography/Mass Spectrometry (GC/MS). High resolution mass spectrometers can distinguish between ions with very small mass to charge ratios.

5.2 Leachability data

It is our understanding that the leachability data used in the risk assessment were based on the following test methods, and therefore it is recommended that the same methods are used, especially the first:

- BS EN 12457-2 or –3;
- NRA leaching test (NRA, 1994); and
- DIN 38414-S4.

6 Frequency of analysis

It is our knowledge that operators are required to carry out solid and leachability analysis six monthly to comply with their permit requirements. It is considered that these will be adequate for the purpose of the Protocol. However, alteration to the process or the feedstock will warrant the need for a comprehensive sampling and testing strategy to adequately characterise the material and investigate potential changes resulted from these alterations on the compositional or leaching properties of the produced PSA.

Based on the above, the final Tables are as follows:

Table D3 Solid analytical data

Determinand	Units	Max concentration
Arsenic (As)	mg/kg	5.02
Cadmium (Cd)	mg/kg	3.21
Chromium (Cr)	mg/kg	59
Copper (Cu)	mg/kg	562
Fluorine (F)#	mg/kg	885
Mercury (Hg)	mg/kg	0.860
Manganese (Mn)	mg/kg	1,781
Molybdenum (Mo)	mg/kg	14.8
Nickel (Ni)	mg/kg	38.4
Lead (Pb)	mg/kg	125
Selenium (Se)	mg/kg	1.0
Zinc (Zn)	mg/kg	449
Dioxin ITEQ (ng/kg)	ng/kg	0.70

Fluoride was used in the land application calculations in the RA but was not presented in the table.

Table D4 Leachability data

Determinand	Units	Maximum value
Silver (Ag)	mg/l	<0.001
Aluminium (Al)	mg/l	3.6
Arsenic (As)	mg/l	<0.025
Barium (Ba)	mg/l	7.72
Cadmium (Cd)	mg/l	<0.001
Cobalt (Co)	mg/l	<0.01
Chromium (Cr)	mg/l	<0.01
Copper (Cu)	mg/l	<0.01
Mercury (Hg)	mg/l	0.0005
Molybdenum (Mo)	mg/l	0.057
Nickel (Ni)	mg/l	<0.01
Lead (Pb)	mg/l	0.096
Antimony (Sb)	mg/l	0.005
Selenium (Se)	mg/l	<0.002
Zinc (Zn)	mg/l	<0.03
Fluorine (F)	mg/l	0.834
Chlorine (Cl)	mg/l	1,150
Sulphate (SO_4)	mg/l	54.7

Important Note

It should be noted that the maximum will usually apply to maybe only one of the determinands in each application, which sets the limits for all the remaining determinands in the ash. For instance copper was the element that limited the number of applications to 1.3 applications in any one-year and that exceeding the maximum concentration of copper which was used to determine the number of applications will result in breach of the limits.

However the number of applications on the basis of the zinc concentration was 3.3 applications in any one-year. Therefore if the zinc maximum concentration exceeded the value used in the assessment and the number of application is still 1.3 set by the copper limits, this increase should not cause a breach in the zinc limits unless it is more than 2.5 times the maximum concentration. So using the maximum concentration of zinc as a limit that cannot be exceeded is not entirely correct. The problem is the assessment has not determined the maximum concentration for each individual compound that will cause a breach due to the complexity and time requirement to take the assessment to this level of detail.

Appendix E References and information sources

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