COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

1. In December 2009 and February 2010 Members discussed two risk assessments carried out under the Waste And Resources Action Programme **(**WRAP) Confidence in Compost Programme (COT 2009/39; 2010/01). These were draft risk assessments on Use of Green Composts in the Scottish Livestock Sector and All composts in all agricultural sectors. In 2011 the Committee considered a further report on anaerobic digestates (COT 2011/25). The minutes of these discussions are at Annex 1. Following these discussions Members provided comments on the reports which the Secretariat communicated to WRAP. The Committee wished to see the final versions of the reports before agreeing its conclusions.

2. The Food Standards Agency (FSA) also sought advice on the microbiological aspects of WRAP's peer-reviewed risk assessments from the Advisory Committee on the Microbiological Safety of Food (ACMSF). The ACMSF comments on the compost reports were forwarded to WRAP in Autumn 2010 allowing revision of these reports.

3. The revision of the compost reports was delayed by WRAP's and the contractor's other priorities and commitments. The revised versions of the compost and digestate reports are now available together with reports of additional work to address some issues raised by ACMSF. The reports are listed below:

1. AHVLA catering waste compost risk assessment (revised).

2. Hutton Institute green waste compost risk assessment (revised). (entitled Risk Assessment of the Use of PAS100 Green Composts in Scottish Livestock Production)

3. Cranfield University PAS100 compost risk assessment (revised). (entitled Risk assessment for the use of source-segregated composts in UK agriculture)

4. Cranfield University PAS110 digestate risk assessment (revised). (entitled Risk-based guidance for the use of source-segregated anaerobic digestates in GB agriculture)

5. ADAS report on Clostridium botulinum in the environment (new).

6. FERA report on Clostridium botulinum in AD systems (new).

7. ADAS good practice guidance and biofertiliser matrix (new). (entitled Making best use of renewable fertilisers)

8. FERA report on the impacts of AD and pasteurisation (new).

4. The three reports which include consideration of chemical risks are the Hutton Institute and Cranfield reports (2, 3 and 4 in the list). These are appended at Annexes 2, 3 and 4 respectively. These reports also include consideration of microbiological risks which will be addressed by ACMSF. The new ADAS good practice guidance is also appended at Annex 5 as this provides useful context and background. The remaining reports are relevant to microbiological issues only and will be considered by ACMSF.

Background

5. WRAP is a not-for-profit private sector company established in 2000 and backed by substantial Government funding from Department for Environment, Food and Rural Affairs (DEFRA), Department of Trade and Industry (DTI) and the devolved administrations in Scotland, Wales and Northern Ireland. WRAP has a major UK programme established to promote sustainable waste management. WRAP works with local authorities, business and households to prevent waste, increase recycling and develop markets for recycled and sustainable products. WRAP works with partners to prevent waste, promote recycling and develop markets for valuable products. WRAP works with the public providing information and tools that support recycling and reduces food waste.

FSA involvement with WRAP and Consideration by Advisory Committees

6. The FSA's position has been that, based on the evidence currently available, the treatment and recovery of waste materials, including animal by-products (ABP) and catering waste, for application on agricultural land should not pose unacceptable risks to food safety providing such application and the composting or biogas treatment is carried out in accordance with regulatory requirements

7. The work commissioned by WRAP has provided an opportunity to re-assess composts and anaerobic digestates in light of the most up to date scientific evidence and FSA officials have provided technical and legislative input on relevant food safety matters. Stakeholders have highlighted a range of concerns relating to the potential risks to food safety and animal health associated with the use of composts and anaerobic digestates. While these concerns relate to the microbiological and chemical risks associated with both digested green and ABP-derived wastes, the application of food-derived wastes containing meat have caused particular concern. It was recognised that in addition to the peer reviews undertaken

for WRAP additional scrutiny by independent experts would provide greater reassurance for other stakeholders. During discussions with WRAP and other stakeholders, the FSA has again agreed to provide this additional scrutiny by consulting the ACMSF and the COT on the report.

Legislative and policy context

8. UK targets to recover value from municipal waste, coupled with the legal requirements of the EU Landfill Directive (1999/31/EC) have increased the importance of waste reduction and sustainable methods of waste management such as recycling and composting. The number of composting and anaerobic digestion plants is set to increase as the UK moves away from landfill, and with the costs of fertiliser continuing to rise, there will be benefits associated with the use of anaerobic digestates made from green and ABP-derived wastes in agriculture.

9. In the UK, the production of compost is controlled through the regulation of composting and anaerobic digestion plants (by the Environment Agency (EA) in England and Wales, the Scottish Environment Protection Agency (SEPA) in Scotland and the Northern Ireland Environment Agency (NIEA) in Northern Ireland), as well as a British Standards Institution Publicly Available Specification (BSI PAS 100:2005), which sets a standard for compost quality.

10. In addition, there are further legal controls in place for the composting of ABP and catering waste regulated through the EU Animal By-Products Regulation (EC) 1774/2002. This Regulation permits the treatment of low-risk (category 3) ABP in an approved composting or biogas plant according to the required standard (treatment at 70ºC for 1 hour, with a maximum particle size of 12mm).

11. Regulation (EC) 1774/2002 also allows Member States to set their own national treatment standards for composting plants treating only ABP derived from catering waste containing meat (but not other animal by-products, except for manure, digestive tract content, milk or colostrum), providing the same level of pathogen reduction can be achieved. In the UK, national standards were developed by DEFRA following an independent risk assessment commissioned in 2002, and a public consultation exercise. Based on the findings of this risk assessment, from 1 January 2007, the UK permitted the use of treatment standards that differed from the EU standard. These require minimum time/temperature and particle size standards for treating catering wastes that are based on the type of system used (e.g. closed reactor, biogas, windrow), with additional barriers for wastes that contain meat.

12. The DEFRA risk assessment underpinning the UK national standard was evaluated by the ACMSF in 2003. Overall, the Committee considered the approach adopted as robust in relation to the scenarios covered. However several issues

relating to food safety matters were considered not to have been adequately addressed and the Committee's recommendations were communicated to DEFRA.

Source segregated wastes

13. WRAP together with environmental regulators, trade associations and other partners developed the baseline PAS100 and PAS110 specifications to provide quality assurance for composts and digestate respectively. These cover input materials, minimum process parameters and minimum output quality so that, when used in line with good agricultural practice, the compost or digestate does not harm human health or the environment. Compliance with the specifications are part of the process together with the Quality Protocol for Anaerobic Digestate (ADQP), the Compost Quality Protocol (CQP) and the Biofertiliser Certification Scheme by which anaerobic digestates and composts can be classified as products (by the respective regulatory bodies) for which there is no need to apply for a waste exemption or permit to spread the biofertiliser. (Further details can be found in the ADAS guidance at Annex 5).

Previous COT discussions.

14. The Committee identified the following concerns during their discussions in 2009 and 2010 of the original All Composts in All Agricultural Sectors and Use of Green Composts in the Scottish Livestock Sector reports. Members recognised the ambitious scope and scale of the task and considered that the approach taken was transparent and objective but laborious. Whilst it might have been more efficient to have focussed the investigations more, this would have prevented the desired comprehensive approach. The aminopyralid example could have served as a positive control on the process. A major assumption underpinning all the assessments was that material was composted correctly in accordance with the PAS100 standard. Assessments were based on measured levels of chemicals in composts rather than feedstocks compared to reference values selected from earlier authoritative toxicological evaluations, using predefined priorities. However a number of issues were identified;

- priorities should have been identified if this major assumption were not met.
- uncertainty over levels in feedstocks themselves should be described.
- description of the risk assessment process employed was inaccurate, and some definitions of terms were incorrect
- the description of the methodology in the reports was unclear, risk characterisation was a critical element in the evaluation and the reference values, basis for their selection and sources should be clearly identified

- due to the limited toxicological database, less confidence existed in reference values derived for plant toxins

- initial selection of hazards was based on what had been identified in composts or could conceivably be added under the PAS 100 standard.

- the conclusions needed to be more circumspect as some complex exposure scenarios had not been considered. There was a lack of clarity in describing decisions and assumptions made when constructing exposure scenarios

- in addition to individual congeners, cumulative risks should be addressed for some hazards e.g. dioxins and PCBs.

- the simple binary decision of risk or no risk was too definite and an oversimplification

- the rationale for not completing the scenarios on allergens was not supportable as based on evidence from other areas, allergens could survive these conditions although exposures to them would be very low.

15. Since it was proposed that the majority of these points could be clarified by rewriting sections of the reports. The Committee wished to see the final versions of the reports before agreeing its conclusions.

16. The Committee commented in September 2011 on a further WRAP report on anaerobic digestates. Members agreed the following conclusions;

- the approaches employed were appropriate and sufficiently rigorous to assess fully the chemical risks associated with application of PAS 110-compliant anaerobic digestates to food-producing land.

- agreed with the conclusion of the report that risks from allergens in the food chain would be negligible, and also with its conclusions on chemical risks, although only for the range of chemicals considered in the report.

- possible risks to the food chain considered in this programme of work focussed on environmental contaminants and should take greater account of pesticides and natural toxins.

- agreed with the overall conclusion that any risks associated with the use of PAS 110-compliant anaerobic digestates in agriculture would be similar to those from other materials used for these purposes.

17. The Committee also highlighted the following issues in the report;

- the basis of the draft EU limits for chemicals used in the risk assessment from the draft Sewage Sludge working document (2000) and draft Biowaste Directive (EU 2001) should be checked.

- rationales for the choice of chemicals to be analysed was unclear and should be stated. Whilst it seemed unlikely that some of the chemicals selected for study would be present in food at significant levels, it was possible that these were stakeholders' greatest concerns.
- Information on what was being digested, and whether certain types of feedstock were associated with high levels of particular chemicals would aid future risk assessments

- assessment of a greater range of pesticides and herbicides would have been desirable, particularly as feedstock could include garden waste.

- The scope of some assessments appeared very limited in particular contaminating herbicides were considered only in the context of possible damage to crops and plant alkaloids were assessed only in the context of possible harm to livestock.

- Information on whether chemicals could be concentrated in the course of the digestion process would be desirable.

- The calculations were not always clearly set out – for example the conversion of kg/hectare to concentration in dry matter.

- The use of toxic equivalency factors (TEFs) was inconsistent as these were used for dioxin-like PCBs, but did not appear to have been used for the dioxins themselves.

- It was unclear whether digestate could be used on ready-to-eat crops.

- Exposure to allergens from the digestate was likely to be extremely low. The allergens present were expected to be high molecular weight proteins. Very little evidence was available on whether proteins could be taken up by plants, but based on their physico-chemical properties, it was unlikely that proteins would be taken up by passive processes.

The revised reports.

18. The compost reports have been extensively revised to address comments received from COT and ACMSF together with those from stakeholders. The anaerobic digestate report has incorporated some changes to reflect the comments received, however the more extensive revisions are in the sections dealing with pathogens.

Risk Assessment of the Use of PAS100 Green Composts in Scottish Livestock Production

19. This report had a more specific focus in response to concerns raised by specific groups of stakeholders. The intention was to produce a quantitative risk assessment that established the potential for harm to animal, human health or the environment, resulting from the application of PAS100:2011 source-segregated green waste (SSGW) compost products for certain agricultural uses; grazing land; land used to grow grain crops for animal consumption; land used to grow root crops for animal consumption and land used to grow leaf crops for animal consumption. One element of this assessment was consideration of potential risks from chemicals present in the source material.

20. The methodology used is described from pages 15 to 36 of the report. This now sets out the approach taken, assumptions made and remaining uncertainties more clearly.

21. Potentially hazardous agents were included in the list if either they had been identified or measured in SSGW compost or evidence was available that specific agents could enter the SSGW composting process assuming ‘typical practice’ (defined as PAS100 compliant and controlled or exempted from waste management licensing). Activities outside of this specification, including unauthorized contamination of feedstocks and illegal use of compost have not been considered

22. The agents to be considered were organized into the following major groupings; toxic compounds present in plants, organic pollutants, potentially toxic elements, animal pathogens and other organisms, invasive weeds and exotic (i.e., non-farmland) species, physical contaminants and other environmental hazards. A series of successive, defined, filters were then applied to each group of agents to identify those considered most likely to present a risk to animals, humans, or the environment. The full list of hazards considered can be found at Appendix B (Sift for principal agents) of the report (pages 108-219).

23. Filter 1 asked whether the agent under consideration has a potentially serious effect on animal or human health, or on the environment. Only those agents considered to have a potentially serious effect passed through Filter 1. Filter 2 considers if each agent is likely to be present in commercially-produced SSGW compost at a level or concentration likely to cause harm to animals, humans, or the environment. This filter does however highlight agents that could become an issue if good agricultural practice is not adhered to and receptors are exposed to pure SSGW compost. Filter 3 assesses only those agents that have remained after the first two filters have been applied. This filter is concerned with exposure once the product has been spread in accordance with current agricultural practice. The primary exposure of concern in this assessment was characterising risks posed to grazing animals and the assessment was weighted towards modelling this exposure. However, where potential risks to the environment or human health were highlighted, these were also investigated.

24. Although more sophisticated plant uptake models capable of simulating the dynamic behaviour of the soil-plant system exist, the chosen model for estimating the uptake of organic contaminants into crop plants is well-accepted, simple and relies on relatively few inputs and was appropriate for the purpose. The use of the steady-state solution is likely to over estimate the concentrations in the crops by

orders of magnitude, which is in line with the precautionary approach used throughout. In reality the source (concentrations in soil) is better described as a pulse injection. It should be noted that the plant uptake predictions are uncertain due to the large variations in both environmental and plant physiological conditions. Because of the limited data available, the calculations carried out were by necessity rather crude.

25. Exposure models were developed for the following scenarios utilising SSGW composts: (i) surface application to grazing land; (ii) incorporation into soil for growing grain crops for animal consumption; (iii) incorporation into soil for growing root crops for animal consumption; (iv) incorporation into soil for growing leaf crops for animal consumption. Scenarios ii to iv were combined into a single approach for estimating uptake of identified potentially toxic agents by various crop types. The exposure models developed simulated the 'realistic worst case scenario' given operational constraints.

26. Risk was defined as the modelled probability that after spreading composted green waste on agricultural land, an individual animal or environmental receptor would experience deleterious health effects or reduction in meat/milk quality from either direct ingestion or ingestion of fodder crops post-harvest. The approach of calculating risk on an individual basis was considered the most appropriate since the basis of the associated legislation, e.g. food safety, is individual meat/milk products, rather than on the market as a whole. Risk was calculated as the ratio of the exposure (Average Daily Dose, ADD, mg kg^{-1} d^{-1}) to the appropriate reference dose (RfD, mg kg^{-1} d^{-1}). If the ADD exceeds the RfD, deleterious effects on animal health, or on meat/milk quality might be expected. Due to the uncertainties associated with estimating these risks, a ratio greater than 1.0 indicates an issue that may require further investigation – but does not automatically imply a 'real' risk. A ratio less than or equal to 1.0 may be regarded as 'safe' (or negligible risk). The Reference dose (RfD, mg kg^{-1} d^{-1}) values used in this assessment and their source are tabulated in Appendix F (pages 232-233 of the report).

27. Dioxins and dioxin-like PCBs were assessed both on an individual basis, and collectively using Toxic Equivalency Factors (TEFs) and Toxic Equivalents (TEQs). Toxic Equivalency Factors (TEFs) are toxicity potency factors that are used by the World Health Organization (WHO) and regulators as a consistent method to evaluate the toxicities of highly variable mixtures of dioxin compounds. While TEQs are the standard approach, it was considered appropriate for this study to also assess each congener separately because: (i) published data on the levels of all congeners in SSGW compost were not available; (ii) there are differences in the extent to which different congeners move through the environment.

28. The results of the risk assessment carried out for SSGW compost were compared, where appropriate, to risks associated with comparator materials (dairy cattle slurry, pig slurry, cattle and pig farmyard manures, laying hen manure, and broiler litter). Published concentrations of potentially toxic agents in the above comparator materials were used in the exposure models described taking into account different management practices. Details of the comparative risk assessment data identified are summarised in Appendix E (pages 230-231 of the report).

29. A summary of all assumptions made in the risk assessment is now included at Appendix G (pages 234-239 of the report).

30. A sensitivity analysis was carried out for a scenario in which SSGW was applied to the surface of grazing land. The calculated risks are most sensitive to the concentration in compost, animal body weight, ingestion rate, percent soil ingestion rate and the RfD.

Results

Plant Toxins

31. 89 agents were identified as potentially harmful toxic compounds present in plants. Agents included alkaloids, glycosides, volatile oils, phyto-dynamic substances, and carcinogens. Of these, 34 were considered to have serious effects. As there is a paucity of peer-reviewed measurements of plant toxins in SSGW compost (or measurements made in any other form of compost), and few data describing the degradation of these products, a precautionary approach was adopted. Where information was not available, it was assumed no degradation of the compound occurred during the composting process, after application to the surface of pasture, or when incorporated into the soil. A total of nine toxic compounds/groups of compounds initially passed through Filter 2.

Common Name	**Scientific Name**	**Principal Toxins (Aniszewski, 2007)**
Ragwort	Senecio spp.	Pyrrolizidine alkaloids
Rhododendron	Rhododendron ponticum	Gryanotoxins
Bracken	Pteridium aquilinum	Ptaquiloside
Privet	Ligustrum spp.	Ligustrin
Foxglove	Digitalis purpurea	Digitoxin
Laburnum	Laburnum spp.	Cytisine
Hemlock	Conium maculatum	Coniine
Yew	Taxus spp.	Taxine, Taxol
Monkshood	Aconitum spp.	Aconitine

32. However, during the lifetime of this project, new studies investigating the degradation of some of these compounds during composting were undertaken. This reduced the list to two sources (privet and foxglove) eventually passing through Filter 2 and going forward to the exposure assessment. This was based on the assumption that no degradation of ligustrin or digitoxin had occurred during the composting process.

33. Two scenarios on the proportion of each of the plants in SSGW feedstock representing the extremes were considered: compost that contained 1 % toxic plant material; and compost made entirely from the toxic plant in question. The proportion of each plant in SSGW feedstock giving a risk ratio (RR > 1.0) required to initiate

further investigation was also calculated. The two toxins were entered into the exposure models for surface application on pasture followed by immediate grazing and incorporation into soil and subsequent cultivation of fodder crops. Two application rates (25 and 50 t ha^{-1}) and two soil ingestion rates (realistic and extreme worse case, 1 % and 100 %) were used in this analysis. Incorporation of SSGW compost into soil by ploughing has a large dilution effect reducing concentrations of plant-derived toxins in surface soils comparative to surface spreading. For example, at an application rate of 50 t ha^{-1}, the concentration of all plant-derived toxins in surface soil would be diluted 83-fold. There are no data available to estimate the uptake of these chemicals by crop plants. However, due to the chemical nature of these compounds, they would be expected to remain strongly sorbed to the compost itself. This would result in insignificant uptake by crop plants. Where risk ratios were estimated at >1, these were for composts derived from more than 35% foxglove inputs, and where no degradation of digitoxin was modelled to occur during or after composting. Both of these are considered extremely unlikely. For plant toxins, PAS100 compliant green compost presents a negligible risk to grazing animals. This conclusion is based on the assumption that the feedstock contains roughly 1 % fresh material. For a number of the plants, this is likely to be an over-estimation. There were no data describing the composition, in terms of plant species, of green waste feedstock material to improve the accuracy of this assumption.

Organic pollutants

34. The assessment focussed on organic pollutants that have been recorded as being measured in SSGW compost feedstock or output materials.

35. Data were included in the assessment if they were: (i) derived from SSGW feedstock material; and/or (ii) derived from SSGW output material that had undergone windrow or in-vessel composting; (iii) derived from samples obtained from commercial composting operations; and (iv) reported concentrations of single compounds on a dry weight basis.

36. Data were excluded if they were: (i) derived from feedstock or output material from non-SSGW sources such as mixed-waste composts or MSW composts; (ii) derived from samples from pilot-scale, experimental, or laboratory investigations; (iii) reported organic pollutants as classes or groupings of chemicals, rather than on an individual compound basis.

37. Many organic pollutants are ubiquitous in our environment. This is reflected in the long list of compounds that have been measured in compost and other similar derived materials. The initial hazard screening identified a total of 253 organic pollutants that had been measured in SSGW compost products. These were grouped into polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzo– dioxins and furans (PCDD/Fs), linear alkylbenzene sulphonates (LASs), chlorinated paraffins, brominated flame retardants (BFRs), phthalates, perfluorinated alkylated substances (PFASs), nonylphenols (NPs),

pesticides, and other chlorinated hydrocarbons (Appendix B.2). Numerous peer reviewed articles were assessed and a thorough internet search undertaken to identify grey literature.

38. Although a wide range of organic contaminants have been measured in SSGW compost, the majority of these are present at levels that pose a negligible risk to animals, humans, or the environment. A few contaminants may be present in SSGW product at concentrations that exceed the reference doses under the modelled parameters. Only 1,2,3,4,6,7,8-HpCDD may require further investigation, although the same dioxin has also been shown to present a theoretical risk for a range of other materials, including cattle farmyard manures, pig slurry and chicken manures. In the context of these other materials, the risks from SSGW compost may be viewed as manageable, but as this dioxin is associated with the industrial bleaching of paper, it might be that reducing paper and card levels in compost feedstocks could reduce concentrations of this dioxin still further.

39. The potential for risks associated with animal ingestion of soil adhering to fodder crops was not considered, since such adhesion rates are likely to be much lower than those modelled for direct ingestion during grazing.

Pesticides and herbicides

40. Four compounds were evaluated in the exposure assessment: clopyralid, fenoxycarb, imazalil, and pentachlorophenol. After exposure assessment only clopyralid was considered to have the potential to present an exposure of concern post-spreading. The concern relates to the potential impact on the environment (potential risk to sensitive broad-leaved plants and aquatic insects), since it is of low toxicity to animals and wildlife, but high toxicity to certain plants (e.g. tomato). Clopyralid levels are highly dependent on feedstock and can be managed.

41. Some studies report that concentrations of the compound drop to below threshold levels within a few weeks post application. Codes of Practice should be followed to ensure that compost is not applied within recommended distances from water courses. It may be difficult to manage levels of clopyralid entering SSGW in contaminated feedstock. However, PAS100 compliant compost requires a tomato seed germination and growth bioassay that should protect against negative effects associated with clopyralid residues. Concern about the use of clopyralid in agriculture has resulted in labelling changes and product withdrawals, so that levels of clopyralid in compost products are likely to decline in the future

Potentially Toxic Elements (PTEs)

42. Composts and other soil treatments contain heavy metals and other potentially toxic elements in varying amounts. Animal exposure is through ingestion of treated soil and consumption of herbage grown on treated soils. Human health could also be affected if sufficient quantities of these elements are taken up by crops, by grazing animals, through surface run off or from leaching to ground water. A total of 14 PTEs were identified as having been measured in SSGW compost: Arsenic (As), Boron (B), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu),

Lead (Pb), Mercury (Hg), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Vanadium (V) and Zinc (Zn). Based on levels that could be present in compost only four of these (Cu; Cd; Cr; Pb) were entered into the exposure model.

43. Even when surface applied at high rates with no livestock lay-off period, PTEs in PAS100 green compost present a negligible risk to grazing animals. Post-ploughing, additional concentrations of PTEs in soil are low. As a result, uptake by the majority of crop types is relatively low. However, the levels of uptake do depend on soil chemistry with low pH, low organic carbon soils associated with higher rates of uptake. For copper, sheep are four times more susceptible than cattle, with risks from non-PAS100 SSGW composts possible under high application rate/acute soil ingestion scenarios. The conservative models used in this study suggest that uptake of Cd by leaf crops might be an issue for long-term application of SSGW compost, and monitoring of foliar Cd concentrations is recommended to ensure that critical limits are not met.

Conclusions

44. Within the limitations of available information, source-segregated green waste compost (and by extension, PAS100 compliant green compost) was found to pose no more risk to grazing livestock, or the environment, than other commonly-used soil amendments, such as livestock manures, paper mill and sewage sludges. Where potential risks were identified, they were greater to sheep than cattle due to their smaller body weight, and their propensity to consume a greater proportion of soil in their diet. Risks associated with uptake of potentially hazardous compounds into fodder crops, and subsequent use of those crops as animal feed, were negligible due to the various dilutions in this exposure pathway. Given the lack of risk to livestock at these levels no human health risks would be expected from consumption of livestock grazing on land treated with PAS100 compliant green compost.

Risk assessment for the use of source-segregated composts in UK agriculture

45. This report describes a comprehensive assessment of possible risks that could occur from using source-segregated composts [SSC] produced to the UK's national specification for compost (PAS100:2011). The objective was to understand the potential for harm humans, animals, the environment and crops by focusing on the extent to which hazards could be present in compost feedstocks and persist after the treatment process; the pathways whereby these hazards may find their way into end uses for SSC; a prioritised analysis of exposure to understand the potential for harm and quantitative risk assessments of hazards which were selected as principal concerns.

46. Wastes are assumed to be treated by PAS100 compliant processes and the resulting SSC materials used for a range of generalised end uses from which residual hazards are assumed to access various environmental pathways leading to exposure of humans, animals, the environment or crops. The approach taken defines where assumptions have had to be made and applies a precautionary approach of 'high hazard' assumptions where evidence is not available. The study assumes both the application of appropriate regulatory controls and compliance with

the PAS100 specification and did not consider non-compliant. The preliminary exposure assessment method used in this work adopts a qualitative ranking approach, incorporating aspects of hazard potency and exposure pathway availability. Assessments of this nature are not predictive in that they are illustrative and intended to allow conclusions to be drawn about the overall significance of potential exposures and the key features that drive risk. This study is necessarily limited by taking a generalised approach to the wide range of feedstock, pathway and end-use combinations achievable for compost use, i.e. unique site-specific considerations have not been considered.

47. The risk assessment uses a two-step approach of a semi-quantitative exposure assessment, followed by a quantitative risk assessment of prioritised hazards, using infectious dose units [IDUs] for pathogens or risk ratios for chemicals. The report includes a description of the methods employed for the study, a generic, ranked exposure matrix of source [feedstock], pathway [method of exposure to a hazard], and end-use [receptor] combinations for PAS100 composts, a series of detailed quantitative risk assessments for scenarios of potential concern with a discussion of the results and conclusions and recommendations.

Semi-quantitative exposure assessment

48. A detailed description of the approach can be found at pages 24-33 of the report at Annex 3. This describes a sequential analysis as follows:

- initial pre-screening of waste types, process technologies and end uses to identify feasible input-treatment-output-end use groupings (see figure 3.1 page 24);
- application of a hazard master list, incorporating evidence for key physical, chemical, and biological hazards associated with the identified waste types (see figure 3.2, page 25);
- screening and prioritisation of hazards from the master list using a four filter system to deliver a set of principal hazards of concern (see figure 3.3, page 26);
- profiling and grouping of waste types by reference to their key hazardous constituents;
- consideration of the treatment effects on hazards in different input waste streams, with subsequent assumptions for the hazards that remain after treatment;
- development of a master list of all combinations of all potential exposure pathways for residual hazards that arise from compost applications in specified end uses;
- semi-quantitative exposure assessment for each end use.

49. High exposure pathways were defined as those where potent, hazardous constituents within feedstocks remain unaffected by composting and have the potential to migrate through the environment in sufficient quantities to cause harm. These were rare except for scenarios with direct, non-attenuated exposure, namely direct ingestion, direct skin contact and prolonged consumption of foods such as ready to eat crops which are likely to be eaten raw to which there has been direct application of compost e.g.as part of a nutrient mix.

Quantitative risk assessments

50. A sequential analysis as follows:

- definition of hazards that might potentially be applicable within each specified scenario;
- development of conceptual exposure models for the specified scenarios;
- dose-response assessment for the specified hazards of concern in each scenario;
- risk characterisation, to generate overall estimates of risk to the receptor (human, animal, crops or the environment as relevant to the specified scenario).

51. More than 10 million different source-pathway-receptor combinations were identified and quantitative risk assessments could only be considered for a small number of scenarios. Those selected represented the full range of exposure scores generated by the semi-quantitative matrix and specific concerns expressed by stakeholders. Where data were not available to undertake a quantitative assessment, e.g. sharps, then a narrative assessment was included. The relevant scenarios were;

- Exposure of sensitive crops to herbicide residues in source-segregated green waste [SSGW] compost applied to agricultural land
- Human exposure to PCBs and PCDD/Fs in ready to eat crops grown in soil amended with SSGW compost,
- Human exposure to marine biotoxins from composted shellfish applied to ready to eat crops
- Human exposure to lead via consumption of eggs from free range hens grazed on compost-amended land
- Human exposure to cadmium via consumption of kidney/liver from cattle grazed on compost-amended land
- Human exposure to PCBs and PCDD/Fs in eggs from free-range laying hens grazing land amended with PAS100 green compost
- Human exposure to arsenic in carrots grown in soil amended with PAS100 green compost
- Uptake of cadmium and lead from SSGW compost applied to cereal crops and
- Human exposure to potentially toxic elements (PTEs) from consumption of ready to eat crops to which ABP compost has been applied.

Conclusions

52. Results from the semi-quantitative exposure assessment demonstrate that exposure pathways with the greatest likelihood of exposure for receptors are those with fewest barriers, particularly direct contact with PAS100 compost through ingestion and consumption of crops that are not cooked, and may not always be washed prior to consumption, referred to as 'ready to eat'. Whilst results from the quantitative risk assessment process cannot be considered as absolute values where generalised assumptions are made, they provide clear indicators of the magnitude for predictions of the potential for harm. QRA assessments for all assessed chemical hazards resulted in risk ratios of 1 or less, so even with the conservative modelling assumptions used estimated daily doses do not exceed the "safe" dose. The authors considered that an appropriate and precautionary approach has been applied to assess the risks associated with the use of PAS100 compost in agriculture and field horticulture. They concluded that the risks associated with the use of PAS100 compost in agriculture and field horticulture were negligible. This conclusion assumes regulatory compliance and strict adherence to the requirements of the PAS100 compost specification. Nevertheless the authors suggest minimising prolonged exposure to any waste-derived material including natural soils remains a sensible precaution.

Risk-based guidance for the use of source-segregated anaerobic digestates in GB agriculture

53. An information gathering exercise to identified plausible high hazard scenarios i.e. scenarios considered to be at the upper end of the risk spectrum, which might be expected in current or foreseeable future practice. These scenarios were intended to be sufficiently, but not unreasonably, precautionary by excluding hypothetical absolute worst case assumptions. They were generally characterised by sources with a high hazard load; pathways where controls and barriers may be insufficient to prevent exposure; and, sensitive receptors. The scenarios were discussed and refined in consultation with stakeholders prior to assessment in one of the following ways: quantitative risk assessment [QRA], use of existing risk assessments, assessments undertaken in parallel projects and a reasoned discussion and explanatory context when insufficient information was thought likely to exist for a full QRA.

54. The following assumptions were made for all scenarios:

- PAS110-compliant processing (with particular reference to the pasteurisation requirements);
- ADQP-permitted source-segregated feedstocks;
- concentration of a contaminant is considered to be at a theoretical maximum for PAS110 compliant processes;
- Whole digestates with a dry matter content less than 15% rather than separated fractions of liquor or fibre;
- batch pasteurisation at 70°C for one hour;
- Digestates in the following categories:

- Sourced from processing plants that could accept only livestock manures, slurries and/or purpose-grown crops (non-wastes), that either:
  - exclude a pasteurisation step; or
  - include a pasteurisation step.
- Sourced from processing plants that could accept animal by-products (ABP) and other 'waste' feedstocks, as defined in the Anaerobic Digestate Quality Protocol, and that include a pasteurisation step; and
- Sourced from processing plants that could not accept animal by-products, but that could accept other 'waste' feedstocks (as defined in the Anaerobic Digestate Quality Protocol), and that include a pasteurisation step.

55. Limitations in published data meant that QRA was not always possible for example, on the fate of plant toxins during anaerobic digestion. Where initial input concentrations for a compound are below the regulatory limit considered protective of health and the environment applying the source-pathway-receptor model cannot result in harmful concentrations. The concentrations of a number of chemical contaminants determined from source data were below such limits and there was no need to undertake a full assessment if initial concentrations were significantly lower than regulatory limits. Contaminant levels in feedstocks would have to exceed the regulatory thresholds for harm to occur, and there is no evidence that this is the case.

Chemical contaminants

56. An assessment was made of the risk to crops, livestock and humans from exposure to a range of chemicals which could be present as contaminants in feedstocks for the digestion process such as PCBs & PCDD/Fs, PAHs and heavy metals. Feedstocks arising from food wastes from the human food chain were expected to have chemical contamination in line with legal limits. Concentrations of heavy metals may be higher in digestates using pig slurries as a feedstock. However, existing monitoring data show that chemical contaminants were present in digestate in very low concentrations. Indeed, the measured concentrations were well below the acceptable levels proposed in the draft European Sewage Sludge Working Document (EU, 2000) and draft European Biowaste Directive (EU, 2001). Moreover, values were similar to those measured in 'background' soil and herbage samples taken from throughout the United Kingdom. The authors concluded that the risk of harm from chemical contaminants was low.

57. These assessments are those considered by COT in 2011 when they concluded that the approaches employed were appropriate and sufficiently rigorous to assess fully the chemical risks associated with application of PAS 110-compliant anaerobic digestates to food-producing land and that any risks associated with the uses would be similar to those from other materials used for these purposes.

58. Digestate containing the maximum concentrations of heavy metals allowed under PAS110 (namely zinc; copper; nickel; cadmium; lead; chromium and mercury) could be applied to agricultural land. Since the quantities of heavy metals applied in

digestate would be very low, would have little effect on the soil heavy metal concentrations and accumulation of heavy metals in crops would be no different from those associated with soil itself. The maximum concentrations measured in English digestate samples were all lower than the maximum permissible levels in PAS110.

Plant toxins

59. The risks associated with the transmission of plant toxins to humans and animals consuming crops grown on land to which digestate has been applied were also assessed to be low. For example, the mycotoxins DON and ZEA will be strongly bound to soil clay minerals and organic matter, and the potential for foliar uptake would be easily mitigated by the use of a bandspreader/shallow injector to apply digestate or soil incorporation following digestate application.

60. There are reported cases of cows being poisoned by ensiled grass that had been heavily infested with ragwort, but the presence of pyrollizidine alkaloids (the toxic compounds in ragwort) had not been confirmed. The use of ragwort in AD systems would be highly unusual. Nevertheless, AD plant operators should aim to eliminate ragwort in feedstock for AD. If it is present at all, they should ensure that it constitutes less than 1% by pre-digested weight of the feedstock.

61. These conclusions are limited to livestock and plants as insufficient plant toxins would reach the food chain via these routes to pose a risk to human health.

Allergens.

62. The section on allergens from the draft report appears to have been deleted. As this was part of a separate exercise it may now be reported separately.

Changes to address COT comments.

WRAP compost risk assessments)

63. The covering letter indicated that the following major changes had been made to try and address the comments made by COT.

- The descriptions of the methodologies used have been completely revised (Doc 2, pp15-36 and Doc 3, pp19-23).
- Reference values for plant toxins have been tabulated (Doc 2, p39) and referenced.
- The presentation and interpretation of estimated toxicological risks should now be more nuanced (for example, see Doc 2, pp30-32), although it could be claimed that the use of a risk-ratio approach to modelling is always likely to tend to binary interpretation of the results.

- Based on the committee's original feedback, the subject of allergens was examined in a subsequent project (this was the basis of the conclusions on allergens reached on the draft report on anaerobic digestates in 2011,TOX/2011/25).

WRAP risk assessment on anaerobic digestates

64. The covering letter indicated that the following changes had been made to try and address the comments made by COT.

- The report clarifies that the selection criteria for the chemicals analysed in digestates were based on prior experience with soil amendments, including sewage sludge. The analytical suite was also selected with a view to informing (at the time) on-going risk assessments on compost and digestate. Although the number of plants now compliant with the PAS110 specification for digestate quality has increased to ten but digestates have not been tested and cross-referenced with the samples from the three sites analysed in 2010.

- The selection of aminopyralid and clopyralid for analysis was based on another WRAP report which highlighted the potential survival of clopyralid and aminopyralid during composting and suggested that these compounds were also likely to survive anaerobic digestion. Although it would have been desirable to analyse for a wider range of compounds, the analytical techniques for extracting and determining persistent herbicides (particularly synthetic auxin compounds) do not appear to be well developed. WRAP are currently supporting a project that could partly address this deficit. However, WRAP has no plans to test further digestate samples for a wider range of herbicide compounds.

- Plant alkaloids and other chemical contaminants will not accumulate in the digestion process, since it is (essentially) conservative, with output volumes very similar to input volumes (the difference being losses as biogas, which is collected to generate renewable energy).

Discussion.

65. The compost reports have been substantially revised which makes the methods used and the arguments underpinning the conclusions clearer. This addresses the major concerns of the Committee in 2010. As such the conclusions on chemical risks can now be considered. Although it was not feasible to consider all potential chemical contaminants those chosen for evaluation were logical and appropriate. Using the assumptions allowed a conservative but not worst case assessment of the risks. For the scenarios considered, this concluded that the risks of chemical contamination from PAS-100 compliant composts were no greater than for other soil treatments. This conclusion could be extrapolated to other chemical contaminants.

66. The comparison to levels in UK soil and herbage suggests that use of anaerobic digestates at the levels used in these scenarios would not significantly modify the amounts present or available for uptake. This implies that there is unlikely to be a significant difference in the risk to humans from consumption of livestock fed on crops fertilised with anaerobic digestate compared to crops grown on untreated land. In the case of PAHs the effect of metabolism by livestock would probably further decrease exposure of humans to any PAHs arising from the digestate.

67. If we consider the information in all the reports as a whole there is unlikely to be a significant difference in the risk to humans from consumption of crops or livestock fed on crops fertilised with composts or anaerobic digestate compared to crops grown on land treated with other soil enhancers or untreated land.

68. The production of good practice guidance provides a means of promoting responsible use of composts or anaerobic digestate.

69. The analysis of the potential risks from allergens are largely based on the anticipated nature of the allergens, the probability that they would not survive the anaerobic digestion process and the absence of evidence of problems from the use of comparable materials. A similar argument would apply to the composting process. Although the supporting data are limited the argument appears logical and cogent but it would still be desirable if evidence to support the inferences was generated.

Questions asked of the Committee

70. Members were invited previously in TOX 2009/39, 2010/01 and 2011/25 to comment on the earlier draft WRAP reports on the risks associated with application of PAS 100 compliant composts and PAS 110 compliant anaerobic digestates to food producing land.

71. Members are now asked to consider whether the previously agreed conclusions on anaerobic digestates would also apply to PAS 100-compliant source segregated composts;

> the approaches employed were appropriate and sufficiently rigorous to assess fully the chemical risks associated with application of PAS 100-compliant composts and PAS 110-compliant anaerobic digestates to food-producing land.
>
> agreed that risks from allergens in the food chain would be negligible, and also with its conclusions on chemical risks, although only for the range of chemicals considered in the report.
>
> possible risks to the food chain considered in this programme of work focussed on environmental contaminants and any future work should take greater account of pesticides and natural toxins.

agreed with the overall conclusion that any risks associated with the use of PAS 100-compliant composts and PAS 110-compliant anaerobic digestates in agriculture would be similar to those from other materials used for these purposes.

72. Members are asked whether there are any particular data gaps that should be prioritised in future research programmes in order to allow additional potential chemical food safety risks associated with anaerobic digestates use to be more fully quantified.

73. Members are asked whether they have any comments on the Renewable Fertiliser Matrix developed by ADAS and included in the good practice guidance (Annex 7). The Renewable Fertiliser Matrix details where renewable fertilisers should and should not be used on agricultural land.

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COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

Minutes of the COT discussion on the compost report in February 2010 and on the digestate report in September 2011

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Item 4: Waste and Resources Action Programme (WRAP) (Reserved Business) – TOX/2010/01

Reserved section – to be released when the report is published

12. In December 2009, the Committee had an initial discussion of the sections relating to chemical hazards in two of the three risk assessments that had recently been carried out under the Waste and Resources Action Programme (WRAP) Confidence in Compost Programme. The Committee had requested that WRAP and their contractors be invited to this meeting to facilitate discussions of the results and clarify outstanding questions on the methodology. Dr Sweet (WRAP), Dr Longhurst (Cranfield University, contractors for the "All Composts in All Agricultural Sectors" study) and Dr Hough (Macaulay Land Use Research Institute, contractors for the "Use of Green Composts in the Scottish Livestock Sector" study) were present, and introduced the reports, their context and the results. They also identified areas such as the marine biotoxins scenario, where further work had already commenced.

13. Members recognised the ambitious scope and scale of the task and considered that the approach taken was transparent and objective but laborious. Whilst it might have been more efficient to have focussed the investigations more, this would have prevented a comprehensive approach. It was suggested that the aminopyralid example could have served as a positive control on the process. A major assumption was that material was composted correctly in accordance with the standard, it would have been useful to identify priorities if these assumptions were not met.

14. In response to questions on whether hazards could be generated during the composting process, the contractors noted that the assessments were based on measured levels of chemicals in composts rather than feedstocks. It was acknowledged there was less information on levels in feedstocks themselves.

15. The risk characterisation approach was seen as a critical element in the evaluation and the basis for the selection of reference values was outlined. This clarified that reference values were selected from earlier authoritative toxicological evaluations, using predefined priorities, and, were only derived de novo from experimental data where no satisfactory previous value could be identified. It was noted that the description of the methodology in the reports was unclear, and the contractors indicated that the relevant sections were to be rewritten before the reports were finalised. It was noted that, due to the limited toxicological database, there was less confidence in reference values derived for plant toxins than other chemicals. It would be helpful to include a table clearly identifying the values and sources of the reference values in the final report.

16. The selection of hazards in the first tier was based on what had been identified in composts or could conceivably be added under the PAS 100 standard. In response to a question on which material should be excluded, it was suggested that grass from golf courses should be excluded due to the use of aminopyralids. However, it was unlikely to be an issue in practice, as incorporating too much grass caused problems with the composting process. It was explained that although the

PAS 100 standard was intended to produce consistent compost, there would be variation in its chemical composition within the maxima set in the standard.

17. Whilst other areas of the WRAP programmes were involved in providing advice to the public on which wastes could be recycled, and in monitoring household wastes, the work under review had assumed that anything could be included subject to the limitations of the PAS 100 standard quality system.

18. The Committee suggested that in some cases the conclusions needed to be more circumspect as some complex exposure scenarios had not been considered. There was a lack of clarity in setting out decisions and assumptions made when constructing some exposure scenarios. When scenarios were chosen for detailed consideration, both high and low perceived risks were included to ensure consideration across the risk spectrum.

19. The description of the risk assessment process employed was inaccurate, and some definitions of terms were incorrect. It was acknowledged that this resulted from attempting to explain the approach to a variety of stakeholders with different levels of knowledge. These sections would be rewritten for the final report.

20. Members suggested that in addition to individual congeners, cumulative risks should be addressed for some hazards e.g. dioxins and PCBs. In addition, it was felt that the simple binary decision of risk or no risk was too definite and an oversimplification. A comparison to total dietary intakes would have helped give context to some of the estimated intakes from compost. It was suggested that the Chemicals Regulation Directorate of HSE might be able to advise on approaches to estimating exposure through toxic residues in animals, since they routinely model pesticide intake from meat and dairy products following usage on crops that may be consumed by farm animals. Alternatively, the failure to analyse this possible pathway of exposure needed to be acknowledged as a limitation of the risk assessment.

21. Members did not agree with the rationale for not completing the scenarios on allergens. This currently stated that allergens would not survive the composting process, but based on evidence from other areas, allergens could survive these conditions although exposures to them would be very low.

22. It was agreed that Members would provide any detailed comments on the text via the Secretariat within two weeks. The Committee wished to see the final versions of the reports before agreeing its conclusions.

Item 7: WRAP risk assessment on anaerobic digestates – TOX/2011/25

30. No interests were declared. As they were part of an unpublished draft report, Chapters 4 and 7 in Annex 1 were discussed as reserved business.

31. In December 2009 and February 2010 Members had discussed two risk assessments carried out under the Waste and Resources Action Programme (WRAP) initiative on "Confidence in Compost". Comments from the COT and also the Advisory Committee on the Microbiological Safety of Food (ACMSF) had been forwarded to WRAP in Autumn 2010, informing revision of these reports. The revised versions were expected to be available later this year.

32. WRAP had also undertaken work on anaerobic digestion, an alternative method of processing waste. The draft WRAP report on the use of anaerobic digestates in agriculture was out for consultation and the FSA had again agreed to consult ACMSF and COT on relevant sections of the report to provide the independent scrutiny that a number of stakeholders had requested. Relevant sections of the WRAP report had been provided to the Committee in TOX/2011/25 along with a copy of PAS 110; the equivalent of the PAS 100 specification used for composts. The risk assessments assumed that PAS 110-compliant feedstock was being used and were intended to reflect normal conditions of use. Members were invited to comment on the risks associated with application of PAS 110-compliant composts to land used for food production.

33. It was noted that the legislative position regarding the use of waste digestates on land was complex as the specific regulatory status of waste depended on various factors and, for example, could be changed by waste treatment processing. The feedstock was from commercial sources and would not contain silage. The digestate that had been used for analysis of chemical contaminants as part of the risk assessment was not yet PAS 110-compliant, as control of feedstocks had not been demonstrated, but work was being carried out towards compliance.

34. Chemical contaminants had been measured in composite samples so that they were representative. The chemicals analysed included polychlorinated biphenyls (PCBs), dioxins, perfluorooctanesulfonate (PFOS) and perfluorooctanoic acid (PFOA). Very few were found above the limits of detection, and thus no further risk assessment had been included in the report. The Committee considered that the sampling had been reasonably representative in that it covered 30% of the plants in England and used triplicate samples taken on two separate occasions, with only one unusual finding. Furthermore, the analyses appeared to have been well conducted. It was agreed that analysis of further samples would be useful once the digestate was PAS 110-compliant. The rationale for the choice of chemicals to be analysed was uncertain but it was possible that they were the ones considered to be of most concern by stakeholders. It seemed unlikely that some of the chemicals selected for study would be present in food at significant levels.

35. The digestate output was likely to show some variability because of variation in the feedstock. Members agreed it would aid risk assessment to know more about what was being digested, and whether certain types of feedstock were associated with high levels of particular chemicals. It was noted that the input was food-based

but also included livestock manure, and that the food component should already be compliant with regulatory limits for contaminants.

36. Members agreed that it would have been helpful to assess a greater range of pesticides and herbicides, particularly if garden waste was being included in the feedstock. It was noted that contaminating herbicides had been considered only in the context of possible damage to crops. Similarly plant alkaloids were assessed only in the context of possible harm to livestock. It would be important to know whether chemicals could be concentrated in the course of the digestion process.

37. The calculations in the report were not always clearly set out – for example the conversion of kg/hectare to concentration in dry matter. The use of toxic equivalency factors (TEFs) in the report was also questioned. These had been used for dioxin-like PCBs, but did not appear to have been used for the dioxins themselves.

38. It was unclear whether the digestate would be used on ready-to-eat crops. Consumers were advised to wash and peel vegetables but this was to address microbiological rather than chemical risks.

39. Exposure to allergens from the digestate was likely to be extremely low. The allergens present were expected to be high molecular weight proteins. Very little evidence was available on whether proteins could be taken up by plants, but based on their physic-chemical properties, it was unlikely that proteins would be taken up by passive processes. Exposure of operators to allergens through direct contact was more likely to pose a risk. It was noted that COMEAP (Committee on the Medical Effects of Air Pollutants) were planning to assess bio-aerosols formed from compost.

40. Members agreed that the approaches employed were appropriate and sufficiently rigorous to assess fully the chemical risks associated with application of PAS 110-compliant anaerobic digestates to food-producing land. However, the basis of the draft EU limits for chemicals used in the risk assessment from the draft Sewage Sludge working document (2000) and draft Biowaste Directive (EU 2001) should be checked.

41. Members agreed with the conclusion of the report that risks from allergens in the food chain would be negligible, and also with its conclusions on chemical risks, although only for the range of chemicals considered in the report.

42. Members noted that possible risks to the food chain considered in this programme of work focussed on environmental contaminants and should take greater account of pesticides and natural toxins.

43. Members agreed with the overall conclusion that any risks associated with the use of PAS 110-compliant anaerobic digestates in agriculture would be similar to those from other materials used for these purposes.

COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

Risk Assessment of the Use of PAS100 Green Composts in Scottish Livestock Production by the Hutton Institute

For copyright reasons the paper in this Annex is not included in the published version on the COT website. WRAP will publish the final report at a future date. The bibliographic details will be updated when the article is published on the WRAP website.

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COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

Risk assessment for the use of source-segregated composts in UK agriculture

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COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

Risk-based guidance for the use of source-segregated anaerobic digestates in GB agriculture

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COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

WASTE AND RESOURCES ACTION PROGRAMME (WRAP)

Making best use of renewable fertilisers

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