Environment
Agency

Evidence

# A waste comparator tool to support end-of-waste applications

Report – SC130040/R16

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

This report is the result of research commissioned and funded by the Environment Agency.

# Contents

# 1    Introduction

This Waste Comparator Tool (WCT) has been produced to support end of waste decision-making by providing a simple means of comparing wastes to their non-waste comparators.

The WCT is a Microsoft Excel based tool. The WCT is designed to collate the data gathered during four phases of comparator work (manufactured fertilisers; materials applied to land; fuels and construction materials; natural gas) into a simple spreadsheet (Excel) tool in which user data can be compared to base data for the appropriate comparator. The individual comparator reports and tool can be obtained [here](here).

This document has been prepared for use by businesses to provide guidance on what the tool can do and on its use.

# 2    Using the tool

## 2.1    Opening the tool

On downloading the tool users should save the file. The tool is a Microsoft Excel workbook compatible with Excel 97-2003 and later versions (the file extension is .xls). The name of the workbook can be changed to meet the requirements of the user.

## 2.2    Enabling macros

The Waste Comparator Tool contains macros. Macros are code modules that carry out certain functions within the tool and need to be enabled for correct functioning of the tool. For security reasons, Microsoft Excel does not allow such code modules to run automatically. As the user of your PC, you have to determine that the code came from a trusted source. There are several ways of enabling macros, and the method you choose will depend on which Microsoft operating system you have installed on your PC, and your current security settings. The following is general advice, and in case of difficulty you should seek assistance from an IT expert.

When you open the tool, there will either be an Options or an Enable button in your toolbar area to enable macros. The tool is programmed to always open at the instructions page. Here you need to activate Macros following the above prompt before pressing the **Begin** button.

## 2.3    Navigating the tool

Navigation buttons on each page of the tool allow the user to navigate on to the next page, go back to the previous or view a page containing additional information. Greyed out buttons on the START page cannot be used until the Terms and Conditions check box has been checked. Once pressed, the user is transferred to the relevant linked page or function. See below for examples of active and greyed out buttons.

## 2.4 Instructions page

The INSTRUCTIONS page provides the user with information about how the tool should be used. Five buttons are available for use:

- **Enter Admin Mode** - This is locked for Environment Agency use only.
- **View References** - Opens an additional page which shows the short and full references for data samples.
- **View Abbreviations** - Opens an additional page which shows a list of abbreviations used within the tool.
- **View Terms and Conditions** - Opens an additional page which shows the tool terms and conditions.
- **Begin** – proceeds to the START page

## 2.5 Start page

### Comparator selection

The user selects a main category from the first drop down menu, this will then allow a comparator to be selected from the second drop down menu, and, where relevant, a sub-category from the third drop down menu.

| Main Category | Comparator | Sub Category |
|---|---|---|
| Manufactured Fertilisers | Triple Superphosphate (TSP) | |
| Manufactured Fertilisers | Other Straight Phosphate Fertilisers | |
| Manufactured Fertilisers | Phosphate Potassium (PK) Fertilisers | |
| Manufactured Fertilisers | Nitrate Phosphate (NP) Fertilisers | |
| Manufactured Fertilisers | Low N (N<19%) Fertilisers | |
| Manufactured Fertilisers | High N (N≥19%) Fertilisers | |
| Materials Applied To Land | Non-Waste Biochar | |
| Materials Applied To Land | Non-Waste Wood | |
| Materials Applied To Land | PAS 100 Compost | |
| Materials Applied To Land | Peat | |
| Materials Applied To Land | Soil Improver | Whole Digestate |
| Materials Applied To Land | Soil Improver | Gypsum |
| Materials Applied To Land | Soil Improver | Liming Materials |
| Materials Applied To Land | Straw | |
| Fuels | Coal | Coking Coal |
| Fuels | Coal | Domestic Coal |
| Fuels | Coal | Steam Coal |
| Fuels | Charcoal | |
| Fuels | Biomass | Straw |
| Fuels | Biomass | Non-Waste Wood |
| Fuels | Biomass | Miscanthus and Willow |
| Fuels | Natural Gas | |
| Construction Materials | Non-Waste Wood | |
| Construction Materials | Natural Limestone Aggregate | |
| Construction Materials | Concrete Blocks | |
| Animal Bedding | Straw | |

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## Administrative details

The user populates the company name, completed by and product name boxes. These boxes must be populated to proceed to the ENTER DATA page, a warning message highlights this.

The user selects how many samples they have (maximum 120).

If the user does not want to enter any of their own data for comparison they can selected the **View Samples** button which opens an additional page where the base data can be viewed.

## Parameter selection

The user selects the parameters for which they hold data by clicking each individual parameter on the list or using the **Select All Parameters** button. Parameter section can be cleared using the **Clear Parameter Selection** button.

The tool contains a lot of data (determinands) for each non-waste comparator. It is not our intention that your wastes need necessarily be analysed for all the determinands (elements) presented. You should ensure that you have fully characterised your material in order to compare it correctly to your chosen comparator. Part of the end-of-waste (EoW) process is to undertake a risk assessment which includes identifying all the elements that are or may be present in your waste (Environment Agency, 2014). Determinands for analysis should be selected on that basis and documented in your submission to the EoW panel.

The beneficial properties of your waste material are an important part of the EoW test:

> 'It should be enough that the holder has converted the waste material into a distinct, marketable product, which can be *used in exactly the same way* as a [non-waste material], and with no worse environmental effects.'

In the case of manufactured fertilisers for instance, the concentration of the relevant plant nutrients are needed to ensure a suitable comparison is being made.

If the user has selected a fuel, some parameters will have the * symbol. These parameters will also be converted if the net calorific value parameter is selected and the user enters data on the ENTER DATA page for that parameter. The conversion takes account of the relative calorific values of the waste and the comparator.

## Data entry

The user clicks the **Enter Data** button to proceed to the ENTER DATA page.

The **View Samples** and **Enter Data** button will be greyed out until the user has checked the terms and conditions check box. The user cannot view any base data or enter their own data until they have checked this box. The terms and conditions can be viewed by clicking the terms and conditions hyperlink shown as blue text. This opens an additional page which shows the tools terms and conditions.

If a user wishes to save the data they have entered on the START page they should click the **Enter Data** button and click the **Save & Exit** button. If the user exits before this process is completed, the data on the START page will not be saved.

## 2.6      Data entry page

The users enter their data on the DATA ENTRY page under each sample heading (Sample 1, 2 and so on). Users are encouraged to calculate the uncertainty of their data and the upper and lower 95th confidence intervals of the 90th percentile can be entered in the relevant part of the data entry page.

If the user has specified and entered 10 our more samples then these statistics have to be entered before a report can be produced.

A guide to calculating these statistics using bootstrapping techniques is provided in Appendix 1. Boot strapping it is a technique to add additional values to a dataset that is too small to calculate confidence intervals, and the additional values are estimated based on the original data. This is explained further at the end of Appendix 1

The tool's data has gone through this bootstrapping exercise (if there are 10 or more stored data for the chosen comparator or sub-category) and a 90th percentile and the 95th lower and upper confidence intervals of the 90th percentile for the base data is shown. The median of the base data is also shown.

Currently a 90th percentile of our data is not available for phosphate potassium (PK) fertilisers (manufactured fertilisers); gypsum and whole digestate (soil improvers – materials applied to land); coking coal and steam coal (coal – fuels); and natural gas. A dash symbol will appear in the stored 90th percentile cell if a 90th percentile is not available.

Once the user has entered their data they have three options:
- **Back** – takes the user back to the START page.
- **Save & Exit** – Saves and exits the tool so a user can come back to enter data or amend at a later date.
- **Produce report** – proceeds to the REPORT PAGE.

## 2.7      Report page

The user can export their report as an Excel file or a pdf file.

The Excel and pdf file shows three pages:
- MAIN REPORT PART 1 – shows the date the report was created, company information entered on the START PAGE, comparator selection and references associated with the base data.
- MAIN REPORT PART 2 – shows the user data compared with the stored 90th percentile and the upper 95th confidence interval.
- BASE DATA – shows the base data used to calculate the stored 90th percentile and confidence intervals and the median.

# 3 Differences between the reports and the tool

Due to difficulties encountered during sample preparation, the limit of detection (LOD) for some analytes was elevated above the target limit of detection. This was particularly the case for many of the organics analyses where all the analytical results were less than a LOD. Due to the difficult nature of some of the sample matrices the LODs achieved varied across different samples.

The Environment Agency considers that these natural, non-waste materials with analysis results all below the LOD do not contain the substances analysed for. A decision has been taken that in these cases the concentration has been replaced by a target concentration corresponding to the lowest LOD actually achieved for that comparator for that element. Those results are highlighted in red in the tables in the Comparator reports. Due to the way our tool operates, all the data for those organic analyses have been replaced by the lowest LOD achieved. The original data can of course be viewed in the relevant comparator report. We consider this a reasonable and proportionate position.

Outside the tool using the statistical package R, the data have been bootstrapped 1000 times to create data sets which have allowed the estimation of the lower and upper 95th confidence intervals of the 90th percentiles. This has only been done for non-waste comparators with ten or more samples. The coding used in R is shown in Appendix 1, along with some guidance on formatting the data to use with the R coding.

# 4 Submitting a report

## 4.1 Submitting a report

You may submit your report in either the pdf or excel format but we would be obliged if you also submit a full copy of the completed excel tool with your data included.

We recommend comparing the concentrations of analytes in the comparators dataset to the concentrations in the waste-derived material, paying attention to the higher values. This comparison does not constitute a pass/fail test or an end of waste view. It will provide an indication of whether the waste material contains similar levels of analytes to non-waste materials and whether an end-of-waste application may be appropriate or that further analysis or improved treatment processes may be warranted. The applicability of the chosen analysis suite to the waste inputs should also be justified in your submission.

This may help resolve queries with your submission and speed up the approval process.

## 4.2 Potential use of your data

If your material achieves EoW it may become an appropriate comparator others could use to apply for EoW themselves. Section 13 of the Terms of Use explains that we may wish to incorporate your data in future versions of the tool (if you achieve EoW). It also explains that you may decline this or have your data not attributed to your company or organisation. We would of course be happy to discuss this with you.

# References

ENVIRONMENT AGENCY, 2014. *End-of-Waste and By-Product Hazard and Risk Assessment*, November 2014.  Bristol: Environment Agency.

# Appendix 1

## R Coding

R is a freely available open source statistical tool which can be obtained from
https://cran.r-project.org/bin/windows/base/

A useful free interface for R is available from https://www.rstudio.com/

The text in the box below is the coding used in the R statistical package to bootstrap and hence calculate the lower and upper 95$^{th}$ confidence intervals of the 90$^{th}$ percentiles of the data.

```
setwd("C:/Sample_Directory")
sd<-read.csv("sample_data.csv")


fun = function(data,i) {
  #  return(exp(quantile(log(data[i]),0.9)))
  return(quantile(data[i],0.9))
}


sample.90ile=NULL;median.boot=NULL;lower95.boot=NULL;upper95.boot=NULL;db=NULL
for (i in 1:161) {
  sample.90ile[i] = quantile(sd[,i],0.9,na.rm=TRUE)
  db = sd[,i]

  boot.quan<-numeric(1000)
  for(j in 1:1000) {
    this.samp<-db[sample(10,10,replace=TRUE)]
    boot.quan[j]<-quantile(this.samp,0.9,na.rm=TRUE)
  }

  median.boot[i]=median(boot.quan)
  lower95.boot[i]=quantile(boot.quan,0.025,na.rm=TRUE)
  upper95.boot[i]=quantile(boot.quan,0.975,na.rm=TRUE)

}

com=rbind(sample.90ile,median.boot,lower95.boot,upper95.boot)

com=data.frame(com)
write.table(com,file="sample_data_bootstrap.csv", sep=",", append=FALSE, col.names=TRUE)
```

**Notes**

RED          Amend as necessary. The first line of code sets the working directory R
             uses (where the sample data must be saved and the R output is saved to);
             the second specifies the comma separated variable (CSV) sample data file
             and names it sd, sd is used further in the code.

| PURPLE | Number of columns of data (this number can be greater than the number of columns) |
|---|---|
| GREEN | Number of samples in dataset, amend as necessary |

The data should be saved as a CSV excel file before being used in R. The data should start in row 2 and be placed in columns beneath the name of the determinand in row 1. For example:
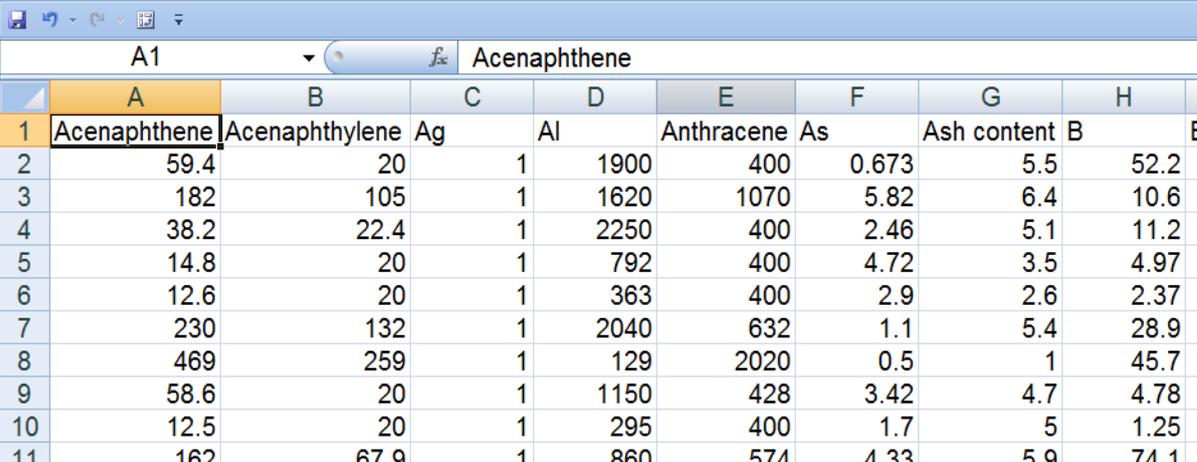
| | A | B | C | D | E | F | G | H | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Acenaphthene | Acenaphthylene | Ag | Al | Anthracene | As | Ash content | B | |
| 2 | 59.4 | 20 | 1 | 1900 | 400 | 0.673 | 5.5 | 52.2 | |
| 3 | 182 | 105 | 1 | 1620 | 1070 | 5.82 | 6.4 | 10.6 | |
| 4 | 38.2 | 22.4 | 1 | 2250 | 400 | 2.46 | 5.1 | 11.2 | |
| 5 | 14.8 | 20 | 1 | 792 | 400 | 4.72 | 3.5 | 4.97 | |
| 6 | 12.6 | 20 | 1 | 363 | 400 | 2.9 | 2.6 | 2.37 | |
| 7 | 230 | 132 | 1 | 2040 | 632 | 1.1 | 5.4 | 28.9 | |
| 8 | 469 | 259 | 1 | 129 | 2020 | 0.5 | 1 | 45.7 | |
| 9 | 58.6 | 20 | 1 | 1150 | 428 | 3.42 | 4.7 | 4.78 | |
| 10 | 12.5 | 20 | 1 | 295 | 400 | 1.7 | 5 | 1.25 | |
| 11 | 162 | 67.9 | 1 | 860 | 574 | 4.33 | 5.9 | 74.1 | |

The output file will have five rows of data.

1. The first row merely numbers each column. We advise inserting a new cell into Cell A1 and choosing 'shifting cells right' so the columns align.

2. The second row, 'sample.90ile' is the 90th percentile of your data.

3. The third row, 'median.boot' is the median 90th percentile of the bootstrapped data.

4. The fourth row, 'lower95.boot' is the lower 95th estimate of the 90th percentile of the bootstrapped data.

5. The fifth, 'upper95.boot' is the upper 95th estimate of the 90th percentile of the bootstrapped data.

# Bootstrapping

Bootstrapping is a statistical technique where the sample population (all the sample data), say 20 samples are randomly sampled with replacement. That is the same sample can be selected a number of times whilst other samples are not selected. Imagine a sack containing 20 balls numbered 1 to 20. You reach into the sack and withdraw a ball, record its number, put it back in and give the sack a shake and repeat another 19 times. So you now have a bootstrapped sample. The process is repeated 1,000 or 10,000 times.

In this Appendix the computer coding specifies 1000 iterations of the bootstrapping. Therefore at the end of running this coding the 90th percentile and the 95th confidence intervals will have been calculated from a bootstrapped dataset of 1000 sets of your sample data.

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