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Representative sampling for a full-scale incineration plant test—how to succeed with TOS facing unavoidable logistical and practical constraints

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Introduction

Impregnated wood waste comprises a significant part of all waste produced in Denmark. All impregnated wood waste is gathered at recycling centres. According to Danish law, combined heat and power plants are not allowed to incinerate this type of wood waste, and therefore all impregnated wood waste is exported to Germany for incineration. This is very expensive and not at all an intelligent way to treat wood waste: harmful emission is not avoided and a lot of transportation is involved. In order to consider a more environmentally friendly method for incineration of impregnated wood waste, the Danish Environmental Protection Agency needed additional knowledge. Danish Technological Institute was commissioned to execute a full-scale test at an already existing combined heat and power plant. Together with Renosyd I/S (a heat and power plant near Aarhus) Danish Technological Institute planned and measured all waste streams regarding the incineration of impregnated wood waste. The impregnated wood waste came from five different recycling centres from the area surrounding the heat and power plant involved. The wood waste consisted of railway sleepers, telephone poles, fence posts, boards, window frames and some fractions were in the metre size range, some smaller.

Considerations before practical execution

Renosyd I/S collected and accumulated an estimated amount of 600 tons of impregnated wood at its disposal site 5 km from the incineration plant – see Figure 1. During normal operations, the wood waste will pass a shredder at the incineration plant. However, for this present study sampling behind the shredder was not an option due to physical conditions and safety aspects. Size and mass reduction consequently had to be performed off-line, but these operations could not be made at the incineration plant due to the limited space. Therefore, the sampling campaign had to be performed at the disposal site.

A representative sample of the 600 ton lot was needed for chemical analysis before the incineration tests in order to follow and give a reliable characterisation of all waste streams[3-7]. With the present type of inhomogeneous wood waste in mind, it was of utmost importance first of all to mass and size reduce the lot, Figure 2. The task was to reduce a 600 ton potential, very heterogeneous lot to a laboratory sample of approximately 10 kg; i.e. a sampling rate of 60,000 to 1. Laboratory techniques for further sample reduction were already well established and known to industry.

It was not possible to place the large amount of wood waste on a concrete foundation, but it was found acceptable to place the impregnated wood on the frozen mid-January ground in an isolated pile with no risk of being mixed with other types of wood or waste. The pile was approximately 75 metres long and 15 metres wide, Figure 2. The logistical constraint was that there had to be room enough for lorries to unload the wood waste.

For size reduction, a shredder with a nominal capacity of 40 tons/hour was chosen. The shredder had to be able to size reduce, e.g., large telephone poles to a particle size of 30 cm. The number of increments would be adjusted to the shredder capacity with respect to the total sample mass opted for. Further size reduction in one step was not possible, as the heat and power plant was not able to handle pieces of material smaller than 30 cm. Therefore, a second size reduction step was needed later in the process.

In close cooperation with the workforce at the waste deposit, it was decided that mass reduction could be performed via the one-dimensional stream throw-off from the shredder, Figure 4.2. Increments of a minimum of 100 kg could be taken by using a front loader. The increments were all placed in a separate pile for later additional size and mass reduction treatment, Figure 5.1. The importance of strip mixing (bed blending) should be emphasised

Figure 1. Overview of deposit site (Google maps). The area where the wood waste was placed and handled is marked with blue. The lot comprised the red area.

Figure 2. The original wood waste lot as received at the deposit.

and clearly described to the workforce responsible for taking the increments. A shredder capacity of 20 tons/hour with increment removal every fifteen minutes would result in 120 increments and a total primary sample mass of 12 tons. If the capacity had been only 15 tons per hour and increments were taken, e.g., every thirty minutes, approx. 80 increments corresponding to eight tons of material would have been gathered.

After a second chopping, wood shards of an expected particle size of 10-30 cm were to be further size reduced in a wood chip cutter. An amount of wood waste of 8-12 tons was too large for this equipment, so a further mass reduction was needed for practical reasons. The degree of mass reduction depended on the exact size of the wood pieces. The final procedure in this step was therefore postponed until after the second pass through the shredder in order to make a more qualified decision regarding the amount and specific procedure.

Recommendations for making qualified decisions have to be based on the European Standard EN 14780: *Sampling and sample reduction of solid biofuels.* The standard prescribes a sample amount of at least 120 kg when the pieces are up to 20 cm and of at least 400 kg when the pieces are up to 30 cm. It is worth mentioning that the new DS standard 3077: *Representative Sampling (2013)* explains how scaling the amount of increment with the total lot mass is obsolete – the amount of increment needed scales according to the degree of heterogeneity encountered. Due to the

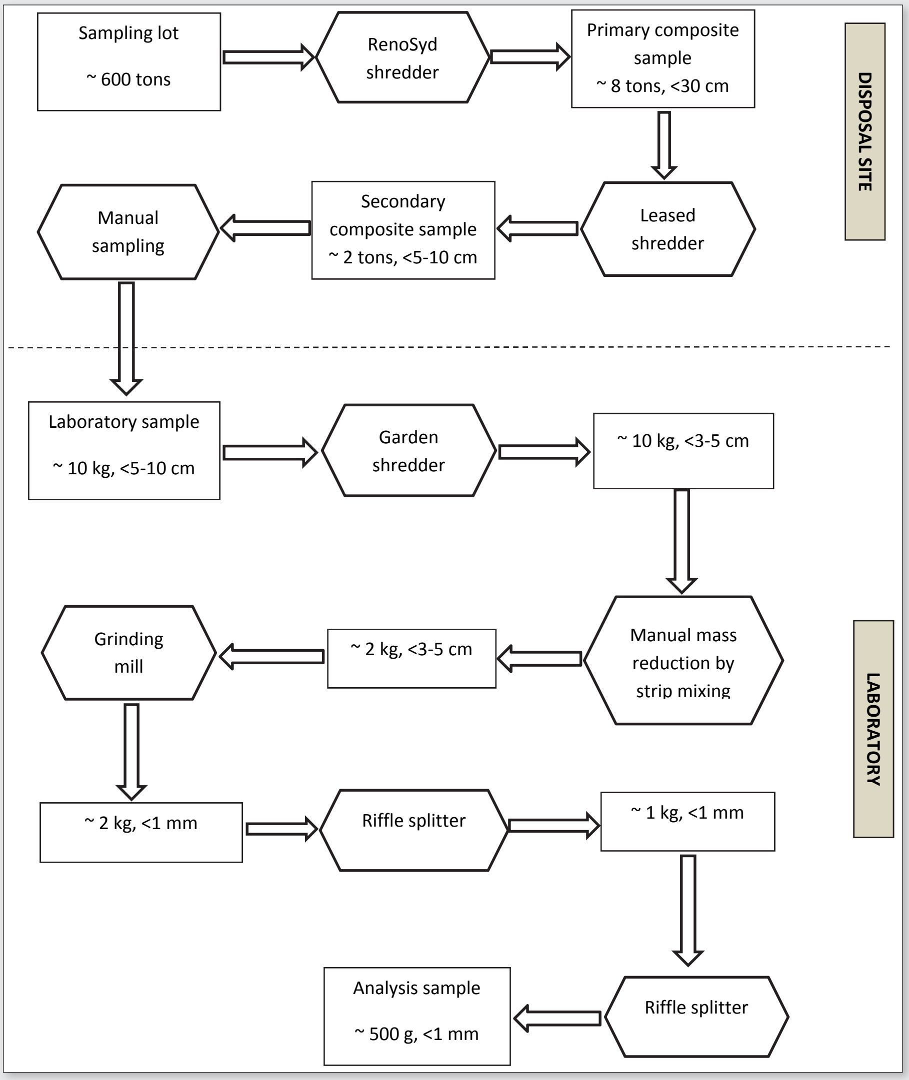

Figure 3. Planned flow diagram of the process described in the present contribution.

expected inhomogeneity of the wood waste compared to wood chips and wood pellets it was decided to do better than the EN standard prescriptions - it was decided that the amount should be at least 4,000 kg before the wood chip cutter-step.

After mass reduction, the sample amount would be cut in the wood chip cutter. Another mass reduction step would then be necessary before ending up with a sample of 10 kg to be handled in the laboratory – see Figure 3.

Sampling Plan

A sampling plan was designed based on the following preliminary considerations that contain the following elements:

- Composite sampling is a must.
- Successive steps of particle size reduction.
- The total lot is moved to secure that all parts are accessible and to make it possible to carry out one dimensional sampling from a free falling stream.
- The heterogeneity of the material, and hence the increment variance, was not known a priori. It was unfortunately not possible to make an estimation (a replication experiment (DS 3077:2013)) within the project budget. The number of increments is therefore a result of a realistic survey of prevailing conditions and based on "good practice and experience".
- Practical execution of on-site sampling

For the incineration trial, a volume of 600 tons was estimated to be necessary, and therefore the total pile made up the sampling lot – see Figure 1. The lot was not divided into sub-lots.

The waste wood consisted mainly of large pieces of telephone poles, fences and building residues and some of them contained metal. When laying up the pile, the material was "pre-crushed" with a "compacter". Sampling from the present pile was not possible for two reasons: large parts of the pile were not accessible, and the large "particle" size could lead to a bias and it would require too large sample volumes. Therefore, the 600 tons of wood waste was size reduced in a shredder, model Arjes VZ 750. That type of shredder was suitable for handling the metal pieces that were found in some of the wood waste. The shredder was placed beside the pile and loaded continuously by a front loader. The feeding of the shredder and the size reduction of the wood waste went smoothly, so the full capacity of 40 tons per hour could be observed most of the time. The estimated effective time used was 15-20 hours, Figure 4.1.

Composite sampling took place as a front loader collected a number of primary increments from the falling discharge from the shredder (one-dimensional process sampling); increments were continuously accumulated in a separate pile at a new location. The first campaign day, an increment was taken every fifteen minutes. This frequency was increased to every 10-12 minutes for the remaining time. It is acknowledged that that gives a sampling bias as the frequency was altered during the process. Based on the practical experience from day one, it was found that improved frequent sampling was desirable, see Figure 4.2.

The total number of increments was *estimated* to be more than 100. The weight of each increment is estimated to approx. 75 kg resulting in a total primary sample of about 8,000 kg. Given a bulk density of approx. 400 kg/m^3 this gives a pile of 20 m^3 consisting of pieces below 30 cm, which can be seen in Figures 5.1 and 5.2.

A front loader bucket-full of the already size-reduced wood waste was tentatively loaded into the shredder for a second pass, but no significant size reduction was found. Another solution was needed, since further size reduction was essential before continuing. After some searching, a smaller shredder was rented to reduce the size of the primary sample to below 5-10 cm, Figure 6.2. The procedure using a front loader to feed the shredder and to extract increments from the falling material stream out of the shredder was a copy of the one used in the first reduction step, again making one-dimensional process sampling possible, Figure 6.1. A secondary sampling was designed on that basis, which consisted of more than 200 increments each of just less than 10 kg. The composite secondary sample was laid up as a longitudinal pile by strip mixing (bed blending) and subsequently flattened to a height of less than 50 cm, Figure 7.

From this pile, a final composite sample of 50 litres was extracted, manually extracting 50 increments with a shovel. All 50 increments were taken at randomly chosen locations and depths. The final

Figure 4. (a) Loading the shredder at step 1. (b). Extraction of increment at step 1. Each increment is approx. 75 kg, extracted every 10-15 minute.

Figure 5. (a) The accumulated primary sample lot (approx. 20 m^3). (b) Particle size distribution after primary shredding at step 1 (see Figure 3). A 20 cm folding ruler for scale.

Figure 6. (a) Extraction of increment at step 2 (size reduction to a particle size below 5-10 cm). (b) Particle size after size reduction step 2. A 20 cm ruler for scale.

sample was placed in a large plastic bucket, sealed and marked before further handling in the laboratory.

Laboratory sample preparation

The final 10 kg (50 litres) sample was particle size reduced in a garden shredder in the laboratory to less than 3 - 5 cm. Manual mass reduction was also performed by strip mixing, resulting in a sample mass of 2 kg, on which another particle size reduction step was made, this time using a laboratory grinding mill. Finally, this 2 kg sample was split (in two steps) into two parallel sub-samples of 500 gram, by using a riffle splitter[8]; the 1 kg sub-sample was discarded after step one. These two parallel samples were then delivered to the analytical laboratory: one for chemical analysis, the other as a backup archival sample.

Potential error sources

Placing the pile on the frozen ground was not optimal. Possible errors in later chemical analyses could for example originate from material in the dirt, giving rise to detection of certain extraneous trace elements. However, this project is decidedly of the "art-of-the-possible" type, a project that simply has to be performed in the real world. In any case, the available funding and time were issues that gave us the possibility to operate as described in this paper.

It was not possible to traverse the free falling stream from the shredder with the front loader completely as prescribed in the TOS literature[6]. However, it is believed that it did not have any important effects, mainly because no segregation was found in this highly non-flowing type of material, Figures 2, 5.1, 5.2, 6.2, 7.

From the minor shredder, a loss of fines was observed from the outgoing stream during operation due to a light wind. The loss is considered negligible as it was *very* low in mass percentage compared to the total mass, and we have no reason to believe that any chemical component was over-represented in this fraction based on visual inspection.

A minor mass loss also occurred in shredder-step 1 due to the removal of metal parts. Small amounts of wood were attached to some of the metal parts after the shredder step, but only a few kg of wood waste out of the total of 600 tons were lost that way.

Figure 7. The composite secondary sample lot flattened to a maximum height of 50 cm. 50 increments were taken at randomly selected locations and depths (using a shovel), making up the final composite sample of 10 kg.

It could probably always be discussed whether the number and size of increments in relation to "particle size" are adequate. In this case, they were considered *appropriate* based on experience, knowledge from EN 14780[1] and a sound judgement on site.

It is emphasised that a perfunctory "replication experiment", DS 3077:2013, unfortunately was out of reach relative to the project budget and time available. It is considered imperative to include such approaches in future projects.

Results

While writing this proceeding, the final report for the Danish Environmental Protection Agency was finalized. Until the Danish Environmental Protection Agency has read and approved the report, it is not possible to conclude whether or not this case study has contributed to change Danish legislation on incineration of impregnated wood waste in Denmark.

Conclusion

It is emphasised that this was not a study in representative sampling. To a high degree, it is a case with severe logistical constraints but it demonstrates the practical application of the underlying theory. Specialized equipment for size and mass reduction, e.g., conveyer belts equipped with proper cross-stream cutters were not an option. However, proper process sampling could still be implemented thanks to the workforce at the deposit site where the sampling campaign was conducted. The local workforce performed the task with enthusiasm and appreciation of the goal and offered many useful suggestions. In addition, it accepted to spend the extra time required. The workforce was also willing to adapt to changes during the process, e.g., renting a smaller shredder when needed within hours.

From a practical point of view, a reasonable solution for downsizing and mass reduction was accomplished. Years of practical experience and underlying knowledge of sampling theory have had a significant impact on the solutions that were exercised.

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