Layman's report Re-use of surplus foundry sand by composting
LIFE13 ENV/FI/285

Layman's report

Re-use of surplus foundry sand by composting


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Re-use of foundry sand by composting method

The overall objective of the LIFE-Foundrysand project was to support the sustainable production and waste prevention and recycling by studying how different surplus foundry sand types can be cleaned and hazardous organic compounds eliminated by the innovative biological method piloted in the project.

The aim of the LIFE-Foundrysand project was to clean the surplus foundry sand by innovative composting method and to keep contaminated foundry waste sands away from landfills. In coming years landfills have less and less capacity and therefore the aim was to improve acceptance of this generally valuable cleaned and recycled soil material to be re-used as growing substrate in geo-engineering applications.

ACTIONS INVOLVED

Different types of surplus foundry sand specimens were tested and cleaned by this innovative composting method. Furan, phenolic, green sand surplus foundry sand types were mixed with organic materials. Surplus foundry sands containing high concentrations of heavy metals were excluded because those cannot be degraded by composting method.

Composting tests were carried out at two pilot plants, Finland and Spain. The aim was to carry out the composting tests under different climate conditions. Also winter time composting test trials were carried out in Finland and Spain. Each composting test period was 4-5 months after which the post-maturing time of about 6 months was always needed.

All sand specimens from pilot foundries were analysed before composting tests. The degradation of harmful organic substances of surplus foundry sand composting materials was analysed throughout the tests. Samples were collected and analysed in the beginning, middle and end of each test trial. Environmental impact assessment measurements were carried out including emission measurements, odour modelling and waste water analyses from the pilot site. Since composting process creates odours, the small-scale biofilter pilot plants were constructed and odour reduction was measured.

General composting field construction recommendations were produced including environmental impact minimization activities and cost estimations.

In addition small scale laboratory tests were carried out at the University of Helsinki, Department of Environmental Sciences, Lahti to get valuable information of the parameters affecting the composting process.

Project actions started in August 2014 and ended in December 2017.

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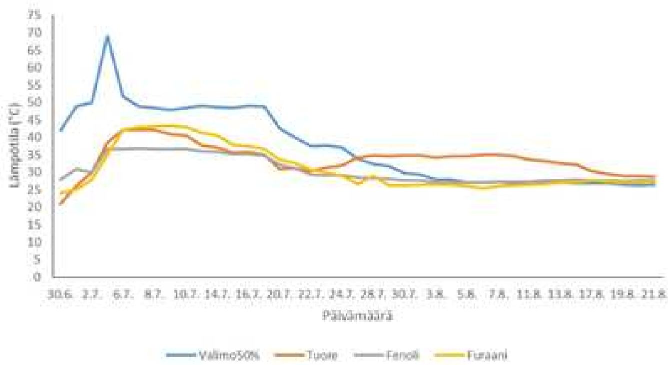
Laboratory scale tests

University of Helsinki (UH) is focusing on a short-term laboratory scale composting test using the same sand specimens as in composting tests in Finland. These controlled small scale indoor experiments are complemented by outdoor experiments at Jokimaa test field in Lahti in order to achieve information regarding to 1) compost construction including different organic material 2) time zero chemical status of compost and different foundry sand types tested (furan/phenol/green sand) for comparative purposes and 3) understanding the composting process and it's limitations in a small scale operational level vs. the test heaps of bigger size.

Figure 1. Small-scale outdoor compost treatment set-up for three foundry sand type in the Jokimaa ground research station.

Additionally also laboratory-scale composting testing, using green, phenolic and furan sands plus a sand-mixture, was performed at the Department of environmental sciences, Lahti. Composters of 250 kg were used. The portions of surplus foundry sand varied in test heaps between 20-33%. Organic materials were added in the test heaps with same recipes as in the full-scale tests. Composting process was followed over a period of 8 weeks.



Figures 2-3. The composters (Biolan 220eco) at the beginning of the composting test in Lahti and temperature changes of composting containers during the tests.

Results

In terms of experimental compost construction laboratory-scale was a challenging starting point especially in Jokimaa outdoor experiments. However, it helped to understand the composting process and it's limitations compared the test heaps of bigger size in Tampere experiments. The size of the containers seemed to be relevant in the composting process. Similarly indoor small-scale composting experiments at the Department of environmental sciences were only partly successful. However, concentrations of PAH compounds, fluoride and phenol index decreased during the composting process. Results also indicated that waste water sludge used in the composting had high concentrations of dissolved organic carbon (DOC), sulphate and phenols.

Full-scale composting tests in Finland

In total 20 composting test heaps size of about 20-50 tons each were constructed and tested at Koukkujärvi waste treatment centre in Nokia, Finland in 2015-2017. Four test trials were carried out including the winter time period composting test (December 2015-June 2016). The portions of surplus foundry sand varied in test heaps between 20-60%. Different organic materials were tested.

Figure 4. Composting test heap in winter period.

Figure 5. Nine test heaps and a meadow field in Finland.

The progress of the composting process was controlled by continuously measurable indicators (temperature, humidity). Composting material samples were analysed from each test heap in the beginning, during and in the end of the test period. Also waste water effluents from the pilot site were collected and analysed and airborne emissions measured.

Regulations

The Finnish regulations of surplus foundry sand are according to the *Government Decree on landfills (331/2013)*: Foundry sand must fulfill the limit values set for the non-hazardous inert waste (soluable metals). The limit values set for the compost end-product are set in *the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011): Substrate – Mixture soil (5A2).* This regulation sets limit values and demands for heavy metals of the end-product (total metals), pathogens (Salmonella and *E. coli*) and impurities (weeds, garbage).

In Spain the compost end-product must meet the limit values set for growing media according to *the Royal Decree 506/2013 on fertilizers, Royal Decree 1039/2012 and Government Instruction PRA/1943/2016* on growing substrates.

In Finland surplus foundry sand must fulfil the non-hazardous inert waste limit values if reused without cleaning. An environmental permit is always needed. In the LIFE Foundrysand project we used the non-hazardous inert waste limit values to monitor the degradation of harmful organic substances from surplus foundry sand composting materials during the composting tests. The cleaned compost end-product must meet the national limit values set for mixture soil (24/11).

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Sampling procedures

The progress of the composting method was followed by continuously recording temperature data loggers in each test heap.

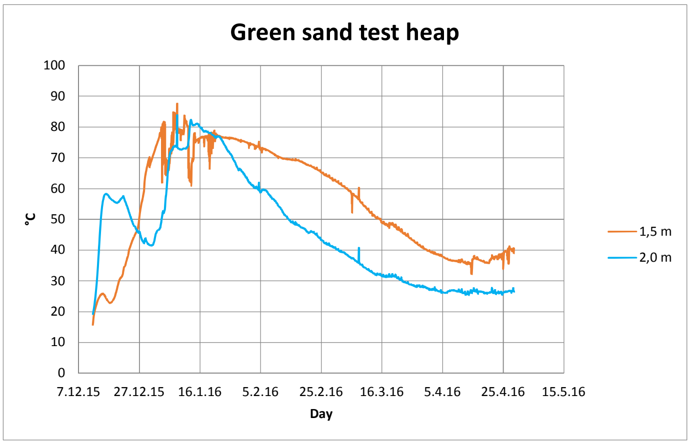


Figure 6. Temperatures were monitored by continuous recording data loggers.

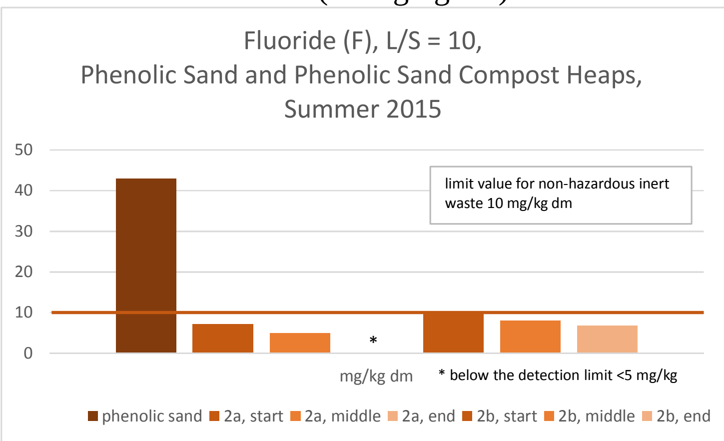
During the project chemical and biological analyses were carried out from surplus foundry sand samples, composting materials and waste waters in the beginning, middle and end of the composting test trials.

Figure 7. Sampling procedure of composting material from teast heaps.

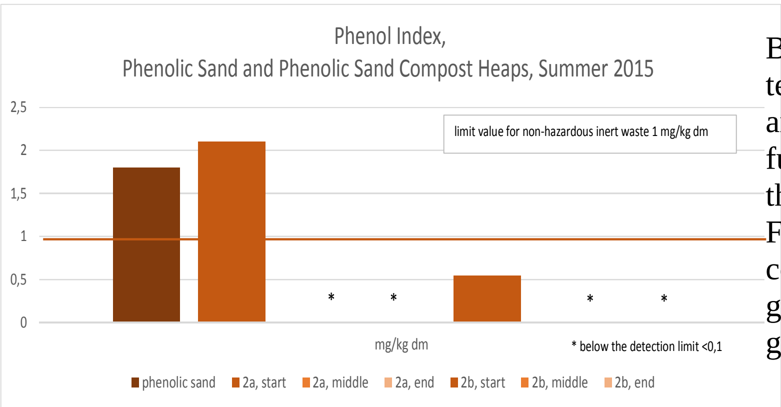
Figure 8. Waste water samples from the pilot site.

Results of composting tests in Finland

Fluoride concentrations were high in green sand (over 50 mg/kg dm) and phenolic sand (over 40 mg/kg dm) samples. The fluoride is most probably coming from the fluoride containing feeders used in the molds used in all sand systems. It is expected that less foundries use the fluoride containing feeders in the future. Substitute materials are available in the market already. During the tests fluoride concentrations were reduced below the limit value (10 mg/kg dm).



Phenol concentrations slightly exceeded the non-hazardous inert waste limit value of 1 mg/kg dm by phenol sand samples. At the end of the composting tests phenols were reduced and the concentration was under the limit value of inert waste. It has to be considered that phenolic compounds origin also from cores produced by the Cold box method.



The limit value of **DOC** (500 mg/kg dm) for inert waste was often exceeded in phenolic and furan sand samples during the tests in 2015-2017. On the other hand the waste water sludge used in composting tests had much higher DOC, sulphate and phenol concentrations compared to the surplus foundry sand samples. However, in the end of the composting tests, the DOC concentrations of the cleaned compost end-product were under the limit value of inert waste demonstrating successful composting process. **TOC** (total organic carbon) concentrations exceeded the limit value of 3% in furan sand and some green sand samples. But there are no limit values set for organic compounds (TOC, DOC and sulphite) in the Fertiliser Products (24/2011) for the compost end-product.

Also other parameters were analysed from surplus foundry sand samples. High **BTEX** concentrations were measured from furan sand specimens of 7,7-29,8 mg/kg dm but they were degraded during the composting tests being under limit value of inert waste in the end-product (6 mg/kg dm).

Waste waters from the pilot site were analysed in the beginning, middle and end of each test period. No remarkable concentrations of harmful compounds existed in waste waters during the tests.

Based on the composting test results the tests were successfully completed in Finland and the innovative compost end-product fulfilled the limit values set in the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011) and the compost end-product can be used as growing substrate in geoengineering and gardening purposes.

Emission measurements of composting heap

Emission measurements were carried in order to evaluate the total environmental impacts of the composting process in addition to the waste water and composting material analyses.

Emissions were measured by AX Consulting Ltd in the beginning, middle and in the end of the composting test in summer 2015 and 2016.

Figure 9-10. Emission measurements of one test heap in Finland.

CO_2 concentrations were high in the beginning of the composting process but decreased during the tests. Oxygen level was good and increased during the test trial. The results demonstrate a good composting process.

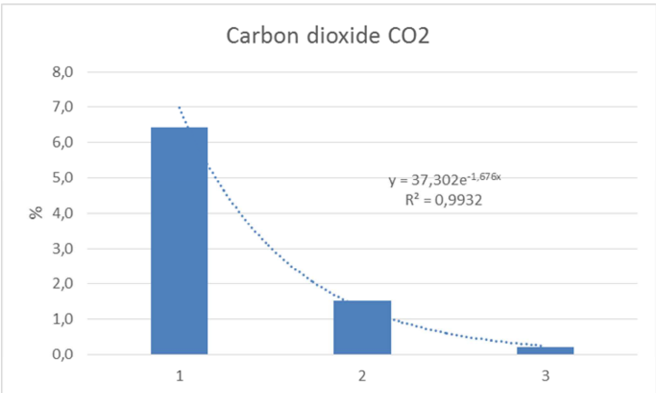


Figure 11. Carbon dioxide concentration from composting test heap in the beginning=1, during=2 and in the end=3 of the composting test.

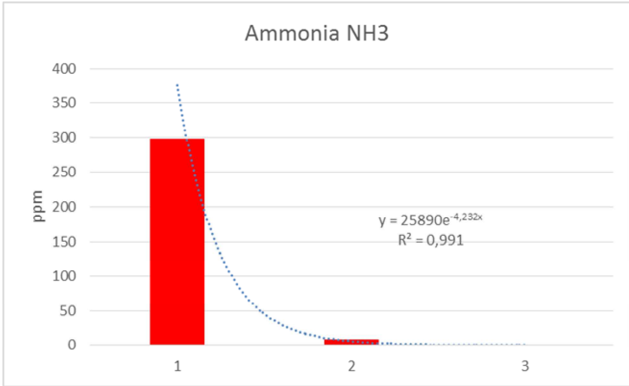


Figure 12. Ammonia concentrations during composting test.

Measurements in the beginning demonstrated also high concentrations of **ammonia** present in the green sand test heap which lowered rapidly.

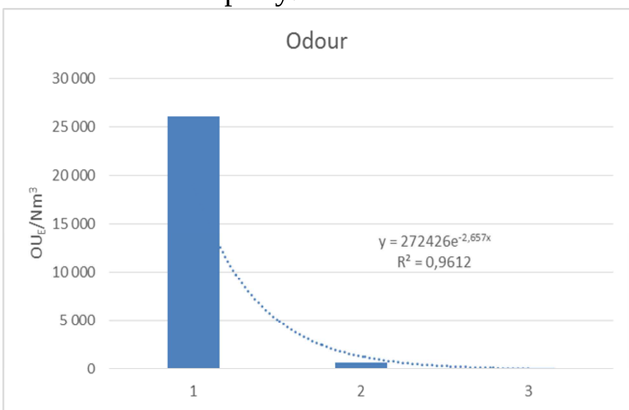


Figure 13. Odour units during the composting test.

Odours existed mainly in the beginning of the composting tests and they were reduced remarkably after the first weeks. Occasional odours existed while mixing the test heaps but these odours can be considered minor. In the end of the composting tests only small odour amounts were detected. Dust particles occurred while constructing the test heaps and sieving the compost end-product.

Biofilter odour abatement measurements

To reduce odours emitted from the composting process, the cleaning efficiency of the biofiltration system was tested during the composting tests. Meehanite built two small-scale biofiltration pilot plants. The cleaning efficiency of biofilters was measured in summer 2016. Odour abatement measurements were carried out by AX Consulting according to the EN 13725:2003 (Air quality. Determination of odour concentration by dynamic olfactometry).

Figure 14-15. Odour abatement of the composting test heap by biofiltration system.

Biofilter abatement measurements were carried out in the beginning of the composting test when the smell was strongest. As a result the odour reductions of the two biofilters were calculated to be about 85-95%.

Exhaust gas concentrations were very low. Some sulphur compounds, like ammonia, ocurred. Odour limit value of ammonia is very low (~ 0,1 mg/m^3). Also VOC emissions were measured but they were very low.

Table 1. Odour measurement results of biofilters in 30.9.2016 (a fresh heap)

Before biofilters	Biofilter	After biofilter	Cleaning efficiency
Ou/m^3		Ou/m^3	%
1 933	BS1	128	93,4
	BS2	274	85,8

The results of biofilter odour abatement measurements demonstrate good cleaning efficiency. The odour reduction by biofiltration system can be recommended, especially while constructing the composting heaps in the beginning.

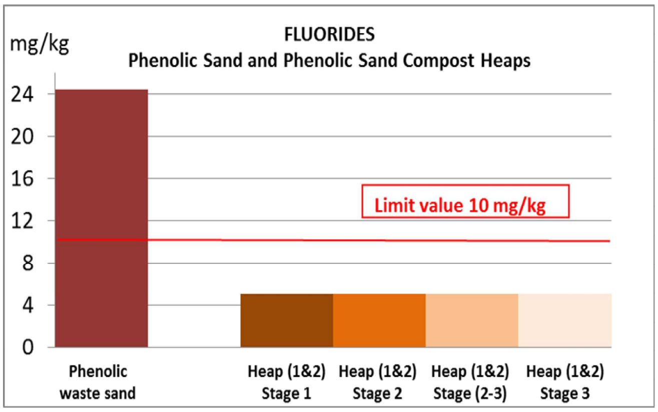
Full-size composting tests in Spain

In total eight composting test heaps size of 13-54 tons each were constructed and tested at a pilot site managed by Komposgune, S.L. in Spain. The site is located in the village of Ormaiztegi, in the Basque Country, northern Spain, 50 km from the Cantabrian Sea. Tests were carried out over three years in three test periods starting in 2015 and finishing in 2017. Green, phenolic and silicate sand types were tested. The proportion of surplus foundry sand in relation to organic material was between 15-18%.

Figure 16. Pilot site at Composgune, s.L Spain

Results

Initial trials in 2015-2016 showed that the composting of waste foundry sand is potentially an effective way of recycling this industrial by-product. Initial concentrations of hazardous compounds in the surplus foundry sands, such as fluoride, phenols, PAH and BTEX, diminished sufficiently during the process to fall within the required limit values: 10 mg/kg for fluoride, PAH 55 mg/kg, BTEX 6 mg/kg.



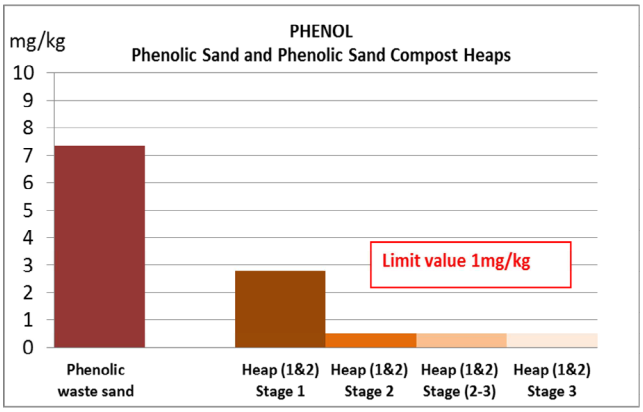


Figure 17-18. Fluoride and phenolic concentrations of phenolic sand samples and during the composting tests.

Test heap samples of phenolic sand from the summer of 2016 were found to contain higher concentrations of fluorides (Fig. 17), chlorides, sulphates and phenols (Fig 18) in the beginning of the composting process compared to the compost end-product. This is similar to results with green waste sand from autumn 2015-2016 tests. The levels of soluble and heavy metals were under the inert waste limit values in both phenolic and green sand types. Both the phenolic waste sand and green waste sand samples also contained BTEX and PAHs compounds under the inert waste limit values established. The test trials showed that the composting of phenolic and green sands effectively cleans them.

Based on test results from autumn 2015 to spring 2016, and those from summer 2016 to winter 2017, we can conclude that the innovative compost end-product complies with the limit values set out for growing media according to the Royal Decree 506/2013 on fertilizers, Royal Decree 1039/2012 and Government Instruction PRA/1943/2016 on growing substrates after the post-maturing time.The results demonstrate that hazardous organic compounds such as phenols and PAHs were reduced by 97%.

In summer 2017 silicate waste sand test trials were implemented. The silicate moulding process uses an inorganic binder (silicate) to bind the mould sand, and is used in many steel foundries.

Silicate waste foundry sands do not contain high concentrations of harmful compounds found in phenolic sands, which contain more phenols and fluoride. Compared to green sand samples, silicate sand samples also had lower BTEX concentrations. The end-product of silicate sand also fulfilled the limit values set for compost end-product.

The experiments in Spain demonstrated that the proposed composting method is a viable way to recycle waste foundry sands in new end-products.

Figure 19. Sieving of the compost end-product.

Emission measurements

In addition to analyzing the composting material and waste water, airborne emissions of the test heaps were also measured during the composting test periods. The aim was to evaluate the total environmental impact of the composting test.

Fig 20. Emission mesurements of a phenolic waste sand composting test heap in Spain.

In order to aerate the heaps and facilitate composting, the heaps were turned-over approx. every two weeks. We found that carbon dioxide (CO_2) was formed due to the active degradation of microbes during composting. Oxygen consumption remained stable at over 20% throughout the process. Methane (CH_4) emissions in the beginning were higher than in the middle, and disappear in the end of the test period.

Conclusions

Through piloting in 2015-2017 960 tons of surplus foundry sand composting material was cleaned with the innovative composting method. The hazardous organic compounds (like phenols, PAHs) were cleaned with the efficiency of about 95%.

The results demonstrate that the harmful organic substances of surplus foundry sands such as phenols, BTEX, fluoride and PAHs were effectively degraded during the composting tests. The cleaning efficiency of 97% was reached e.g. with phenols and PAHs. The compost end-product fulfilled the national limit values set in Finland and Spain. The *Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011): Substrate – Mixture soil (5A2) in Finland* and *the Royal Decree 506/2013 of 28 June on Fertilizer in Spain*. The cleaned foundry sand end-product can be used in geo-engineering purposes.

It is very important to know where the surplus foundry sands are origin: steel foundry, iron foundry, etc. Results demonstrated that surplus foundry sand qualities differ greatly between foundries but also in a foundry depending on the type of casting. The data collection and sand sample analyses in each case foundry are relevant.

The composting method can be recommended as the cleaning method when high concentrations of harmful organic substances are present in surplus foundry sands. Composting method is not suitable for all surplus foundry sand types. Waste sands and dusts including heavy metals cannot be cleaned by composting method. All surplus foundry sands and dust specimens must be always carefully analysed in forehand and based on the results suitable treatment methods will be presented. The aim is that majority about 70-80% of the surplus sands could be cleaned by composting method because it is an efficient and cost-effective method for recycling and reusing the waste sands. Other treatment methods such as a stabilisation or incineration can be recommended for certain specimens (dusts, heavy metals).

In the future foundries are guided to separate different waste sand specimens carefully so that only minimum amount of foundry sands or dusts containing heavy metals should be either incinerated, stabilized or placed on landfilled.

Environmental acceptance of surplus foundry sands requires reliable knowledge on the sand composition and its variation especially regarding environmental properties. A quality control system is needed if the certification of used foundry sand as a composting material is aimed for. Reliable analyzing methods for waste characterization and quality control and the importance of the sampling procedure are emphasized in re-use of surplus materials. The surplus sand quality control and sand samples process manual was produced in the LIFE Foundrysand project. This guideline provides a clear and contemporary advice to foundries, compost manufacturers and local authorities to ensure the consistency in quality of the surplus/waste sand produced in foundries.

Environmental benefits

- Surplus foundry waste sands are cleaned by composting method. The compost end-product can be reused in geo-engineering applications as growing media;
- At the end of the project the method is ready to be used and utilised in foundries in Finland, Germany and Spain using phenol sand, green sand and furan sand systems;
- To keep contaminated foundry waste sands away from the landfills. Surplus foundry sand specimens containing heavy metals cannot be cleaned by composting method. Those must be separated and treated by other methods;
- To save the capacity of landfills for residues which have not the capability of being re-used;
- To re-use industrial waste and produce new end-products suitable in other applications (e.g geo-engineering construction, road construction, green field construction purposes);
- To produce new spin-off products for composting companies or waste treatment centres for markets (new composting materials)
- Replace the use of costly virgin gravel to be mixed with the composting material by cleaned surplus foundry sand.
- To create a relief in environmental burdens by re-use of the contaminated surplus foundry sands in combination with other organic waste material;
- To establish and improve acceptance of this generally valuable cleaned and recycled material for growing media applications. The foundry surplus sands can in some cases be quite little contaminated compared to other much riskier and hazardous waste but the amounts of tons of foundry waste sand are very high (around 18 M tons in Europe each year) and thus these wastes will be more and more problematic for the landfills with limited capacity.
- To improve the acceptance for foundries in general when they are seen more environmentally friendly by reusing their waste into new end-products by eco-friendly biological method.
- To improve the acceptance for foundries to recycle and separate different waste sand specimens and dusts suitable for different reuse purposes in the future.

Transferability

Some 100,000 tonnes of surplus foundry sand is annually produced from Finnish casting processes. In Spain the annual waste sand amount is ten times higher, 1 Mil. tonnes/y. In Europe, totally estimated 18 Mil. tons of surplus foundry sand is produced annually of which about 13 Mil. tons could be cleaned by composting method and reused in geoengineering and growing media purposes. So the market potential is high. This sustainable composting system or service can be transferred to the areas where several foundries operate in the same region to clean the surplus foundry sand for reuse purposes. There are about 4,000 foundries in Europe - estimated 200 of them could apply this new method by 2020 and around 1,000 by 2025. These foundries represent the silica sand foundries that could apply the composting method in cleaning the surplus foundry sand. The barriers for the replicability and transferability of the composting method are related to the national laws and regulations and strict limit values set for harmful organic compounds existing in surplus foundry sand. The regulations and limit values vary in each country.

This composting method can be taken into use by composters, waste treatment centres who already have the environmental permits existing and who could receive and treat surplus foundry sand in their production. Restrictions for the transferability of this method are related to the current environmental laws and existing environmental permissions that do not allow the reuse of foundry sand without an environmental permission in Finland or other European countries.

The composting method can also be used for cleaning other types of waste sands which are not all tested in this project. Such sand types could be olivine and zirkone sand specimens. Also contaminated soil materials could be cleaned by this method. Materials containing heavy metals cannot be composted because heavy metals are not degradable.

Both foundries and composters/waste treatment centres can have high economic benefits from this arrangement. The foundries do not have to pay high deposit fees and the composting companies will get the sand they need to be added in composting material in the end cheaper or for free instead of buying costly virgin gravel.

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Project data

Project title	Re-use of foundry sand by composting
Project location	Finland
Project start and end date	08/2014-03/2018
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Project website	www.life-foudnrysand.com
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