Re-use of surplus foundry sand by composting
LIFE13 ENV/FI/285

Progress Report
Covering the project activities from 1/08/2014-31/03/2018

Reporting Date
25/04/2018
LIFE-Foundrysand

Project Data

Project location	Finland
Project start date:	01/08/2014
Project end date:	30/09/2017 **Extension date:** 31/03/2018
Total Project duration (in months)	43 months
Total budget	2,051,644 €
Total eligible budget	1,992,144 €
EU contribution:	996,070 €
(%) of total costs	50 %
(%) of eligible costs	

Beneficiary Data

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1. List of content

2. Executive Summary

The overall objective of the LIFE-Foundrysand project is to support the sustainable production and waste prevention and recycling by studying how different foundry sand types can be cleaned and hazardous organic compounds eliminated by the innovative composting method piloted in this project. The aim of the LIFE-Foundrysand project is to keep contaminated foundry waste sands away from landfills that in coming years have more and more limited capacity, and to establish and improve acceptance of this generally valuable cleaned and recycled soil material to be used for geo-engineering applications in the future.

Two original partners decided to withdrawn from the Foundrysand project in February 2015 because of unforeseen large increase of pilot site construction cost and change in work load.

A new suitable partner was found by the coordinator and the preparations of the new pilot site environmental permit were started (Action A1). The new partner is Pirkanmaan Jätehuolto (Tampere Regional Solid Waste Management Ltd) and they have an existing waste treatment center (landfill) in Nokia. Some clarifications were requested by authorities and the revised environmental permit for pilot tests in Koukkujärvi, Nokia was received on 18^{th} June 2015. The pilot site preparation work was completed in August 2015.

In the new project structure AX and the new partner Eurofins Viljavuuspalvelut Ltd (Eurofins) divided the activities in the Action B5 Biological and chemical control. AX carried out the sampling procedure, collected the samples with Meehanite and delivered them to Eurofins. Eurofins did all the biological and chemical analyses and delivered the results to AX/Meehanite.

There were some delays in the Action B1 Surplus sand quality control and sand samples in foundries to produce the guidelines of treating and handling the surplus foundry sand in foundries. There was a revision of the MARA degree (Valtioneuvoston asetus eräiden eräiden jätteiden hyödyntämisestä maanrakentamisessa 591/2006, Government decree of some waste reuse in geoconstruction work) ongoing in Finland in 2015-2017 by the Environmental Ministry. Currently the reuse of surplus foundry sand always needs an environmental permit in Finland. The revised MARA degree will enable the reuse of the some surplus foundry sands in geoengineering purposes in the future. The revision work is carried out by Finnish Environmental Ministry and Finnish Environment Institute. The decree was delivered to the EU member states in June for comments and it is expected back in spring 2018. The suggested new limit values and sampling procedures are now taken into account in the guidelines and they are presented in the

Compost processing on laboratory scale (action B2) tests started in March 2015 by Helsinki University. Small scale tests were carried out in Jokimaa experiment field site in Lahti and in laboratory premises. Results were presented in the Deliverable B2 Compost processing on laboratory scale. The results of these tests in 2015 were not satisfactory and therefore more laboratory scale tests were needed to get more information of the optimal and critical parameters affecting for composting method. The tests were carried by AX Consulting personnel in cooperation with Helsinki University personnel in 2016. Results are presented in Deliverable B2_2 Additional laboratory scale tests. Based on the first laboratory tests results in 2015, it also turned out, that some surplus foundry sand can be toxic. Therefore additional toxicity tests were agreed with project partners and approved by monitoring team member Ms Sonja Jaari to be carried out by HU in 2016. Results are presented in Deliverable B2_3 Ecotoxicity testing and effect-directed analysis (EDA) of waste foundry sand.

In action B3 Composting tests in Finland altogether 20 small-scale composting tests and the meadow field were successfully carried out in 2015-2017. Results of composting tests are presented after each test period in Deliverables B3. After the end of the composting tests the cleaned surplus foundry sand composting materials met the national regulations and limit values set in the *Dec*ree *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 and pathogens (Salmonella and E. coli).

In action B4 Composting tests in Spain altogether 8 composting tests were carried out by Tecnalia. Results were reported after each test period in the Deliverables B4. Meehanite personnel monitored the tests in cooperation with Tecnalia and visited the pilot site in Spain in the beginning of March in 2016. Tecnalia visited the Finnish pilot site for learning in June 2016. In Spain the new end-product has to meet following regulations and limit values of the *Royal Decree 506/2013 of 28 June on fertilizer* to be used as the growing media.

According to the Grant agreement it was promised that 17 tests heaps in Finland and 12 test heaps in Spain will be carried out and about 500-600 tons of surplus foundry sand composting material will be cleaned. In total 28 composting test heaps were tested in Finland and Spain and 960 tons of surplus foundry sand composting material were cleaned during the project. Each test heap fulfilled the national limit values set for the compost end-product. Also the meadow field test demonstrated that the harmful organic compounds were reduced from the humus and no environmental impacts were detected in waste waters during the tests.

Practical constructions recommendations were produced for composters of cleaning the foundry sand by composting method (Action B6).

The overall progress of the project activities was followed in action C1 Project monitoring by project partners. In 2014-2017 15 quality control meetings were arranged where results and future activities were discussed. Progress and test results were discussed with Meehanite and AX in face-to-face meetings on weekly or monthly bases during the tests.

Communication activities are reported in actions D and they progressed as planned. Two notice boards were placed on pilot site for test trials in Koukkujärvi, Finland and Irun, Spain. Project partners participated in 24 different national or international events/ seminars/meetings/conferences. Nine oral presentations were given in conferences and seminars in Finland and Spain. One poster presentation was presented in USA in 2016. 30-40 contacts (meetings/emails) in Finland and Spain with relevant stakeholders were made and project dissemination material has been distributed to 100-150 stakeholders during the project. Project website was opened in January 2015 (www.life-foundrysand.com) and will be updated after the end of the project.

Project leaflet, roll-up and poster models were updated in March 2015 with new partners and these were delivered to the partners for dissemination purposes. Four articles were published in the AX magazine.. Poster presentation was held by Prof. Olli-Pekka Penttinen from Helsinki University in SETAC Orlando World Conference on 6-10.10.2016. Two articles were produced by Tecnalia.

Project seminar was arranged on 27th of April 2017 in Tampere for authorities, foundry representatives and composting companies and waste treatment plants and centres. There were 40 participants among foundrymen and authorities and composting companies.

Project management activities are carried out in actions E. In 2014-2017 20 project meetings were arranged. Steering Committee meetings were merged into project meetings because the project consortium is very small and same persons were involved in the project activities, financial and technical reporting and quality control meetings. Costs were reported to the coordinator every 4th month by partners. Meehanite is responsible for technical and financial reporting to the Commission in progress reports.

Inception report was submitted to the Commission on 30th of April 2015 covering the period of 1st of August 2014 to 30th of April 2016. Midterm report was submitted on 3rd of June 2016 and the Progress report on 31st June 2017. Final report is delivered on 15th of January 2018.

Three monitoring meetings were arranged with NEEMO EEI Monitoring Team and in the last meeting in September 2016 also the technical desk officer Mr Santiago Urquijo Zamora and financial desk officer Ms Marija Simic were present. Ms Katja Lähteenmäki was changed to project monitoring member in November 2017.

In spite of the withdrawn of two original partners no changes in the project actions and overall objectives occurred. Project actions were in timetable and objectives were successfully reached. Based on the project outcomes the surplus foundry sands can be effectively cleaned by innovative composting method. All activities were implemented as planned according to the Grant Agreement. Project activities were ended in December 2017, three months before the deadline by the end of March 2018.

3. Introduction

The aim of the LIFE Foundrysand project is to keep contaminated foundry waste sands away from landfills which in coming years have more and more limited capacity, and to establish and improve acceptance of this generally valuable cleaned and recycled soil material to be used for geo-engineering applications in the future. In Europe, around 18 M tons of foundry waste sand is left over every year and in many cases big landfills do not have enough capacity to deposit those large amounts of waste sand. In most countries several smaller landfills are being closed and replaced by large so called "EU landfills", so the distances and transport costs to the landfills are also increasing for the foundry companies and alternative ways of treating those wastes in a more environmental friendly way have to be found. The main idea is to study the quality target of the piloted specimens to fulfil the product requirements for re-using the cleaned sand as geo-engineering applications. Therefore, the specific objectives are to:

- develop a new method for cleaning and re-using foundry sand through composting;
- produce guides on practical level for foundries and suppliers of the cleaning service in Europe;
- implement the procedure for foundries to minimize their wastes, for reducing the operational costs for foundries and therefore saving energy;
- improve acceptance of this valuable material (the cleaned foundry sand) for agricultural and geo-engineering applications, especially in areas of low humus content in soils this can be a valuable exercise to create soil as an artificial layer in order to improve fertility, and to substitute synthetic fertilizers.

There is a future vision of this sustainable composting system (or service) that 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 4000 sand foundries in Europe – estimated 200 of them could apply this new method by 2020 and 1000 in Europe by 2025. At the moment only the foundries equipped with the thermal sand reclamation can treat surplus sand in sustainable way. They do it in recycling but not in disposing yet while this is expensive and not obligatory.

In the first phase the innovative composting method, an optimized process will be established including the optimized receipts, optimized reaction conditions, adequate quality control and detailed product specifications. Based on these experiences an economic validation of the method will be carried out. That is the basis to convince the future consumers and financers to guarantee the sustainability (there is a clear and proven market need).

The targets of the project address and support the following EU Targets (Mainstreaming sustainable development into EU policies: 2009 review of the European Union Strategy for Sustainable Development; Brussels, 24.07.2009):

- Climate change (and clean energy);
- Sustainable (consumption and) production and waste prevention;

- Conservation and management of natural resources.

The project activities support the EU Waste Frame Directive (2008/98/EC) in increasing the reuse of the industrial waste in other applications and increasing the recycling of waste instead of landfilling. Project aim is to reduce the amount of surplus foundry sand to be landfilled and to find cost-effective innovate method to reuse the industrial waste in geo-engineering applications.

4. Administrative part

4.1 Description of the management system

Overall progress of the project activities is controlled by the coordinator (Meehanite). Coordinator, Mr Markku Tapola, who is responsible for project technical implementation and progress of pilot tests and planning the future test arrangements. Project manager, Ms Sara Tapola is responsible for financial and technical reporting for the Commission. Partners are responsible for cost reporting assisted by the project manager.

In total 21 project meetings were arranged. Dates, agendas and participants of meetings are presented in table below. In project meetings progress of actions, results, and future activities with test arrangements were planned and discussed. Also the administrative and financial issues were handled.

Project coordinating beneficiary and associated beneficiaries

Coordinating beneficiary

Meehanite Technology Oy was the coordinating beneficiary of the project. Meehanite is a young company (established in 2009) in the field of environmental engineering like emission control, odours abatement and energy saving options of different industry sectors. Meehanite personnel have been working as coordinating beneficiary in four LIFE projects since 2006. Meehanite was responsible for administrative and financial reporting of the project (Action E1). Meehanite was the contact partner with the Commission and was responsible for progress reporting, midterm and final reporting. Meehanite requested financial documents and invoices from beneficiaries about every 4th month. Or more often when needed to update the current costs.

Meehanite was also responsible for project progress and monitoring activities and quality control in Action C1. Meehanite participated in producing the project dissemination materials and notice boards (Actions D1 and D4). The dissemination materials are reported in section 5.2.2 Dissemination activities.

Meehanite was responsible for action B3 Composting activities in Finland.

Associated beneficiaries

AX-LVI Consulting Ltd:

AX-LVI Consulting was established in 2006. The Environmental Unit of AX Consulting is specializing in environmental engineering and air pollution control design, measurement services (industrial processes, industrial hygiene, boiler, noise and HPAC), energy analyses, safety studies, risk analyses and life cycle assessment.

During piloting studies all relevant environmental impacts were investigated. These were: dust that was emitted from a plot test heap in normal condition and after mixing treatment, gases and odours (according the odour panel standard EN13725) and noise emission were measured in the beginning, middle and end of the test period. The impacts dispersion was modelled around the test site in 2015. Weather conditions (temperature, wind, rain, humidity, cloudiness, shine) were controlled continuously at pilot site by AX.

AX was responsible for the biological and chemical control of the field tests in action B5. AX carried out the sample procedure of the composting materials and waste waters. Samples were delivered to Eurofins for analyses. AX reported the results.

Additional laboratory tests were carried out by Dr Dan Yu from AX in HU laboratory premises in 2016 since the first laboratory test results were unclear and not satisfactory and did not give enough information of the relevant parameters of the composting process (B2).

Tecnalia Research & Innovation:
Tecnalia was responsible for field tests in Spain (Action B4). Composting field tests were tested in Spain in order to study the climate impacts in this innovative composting method. Tecnalia constructed the tests heaps and reported the results. Tecnalia carried out the laboratory tests mostly in their own laboratories. Tecnalia had a test field area in Irun where the test heaps located.

Helsinki University:
HU was responsible for the laboratory scale tests (Action B2). Small scale containers each of size about 200 kg were used for composting tests. Same sand specimen were used as in composting tests in Koukkujärvi pilot site. Duration of each treatment was about three months. Laboratory tests were carried out in summer 2015. Also outdoor experiments at Jokimaa test field in Lahti were made.

Prof. Olli-Pekka Penttinen is responsible for the Helsinki University activities.
Laboratory personnel were carried out the analyses with Ms Pollari, Ms Mari Dahl and Mr Vili Marttila (hired for project purposes).

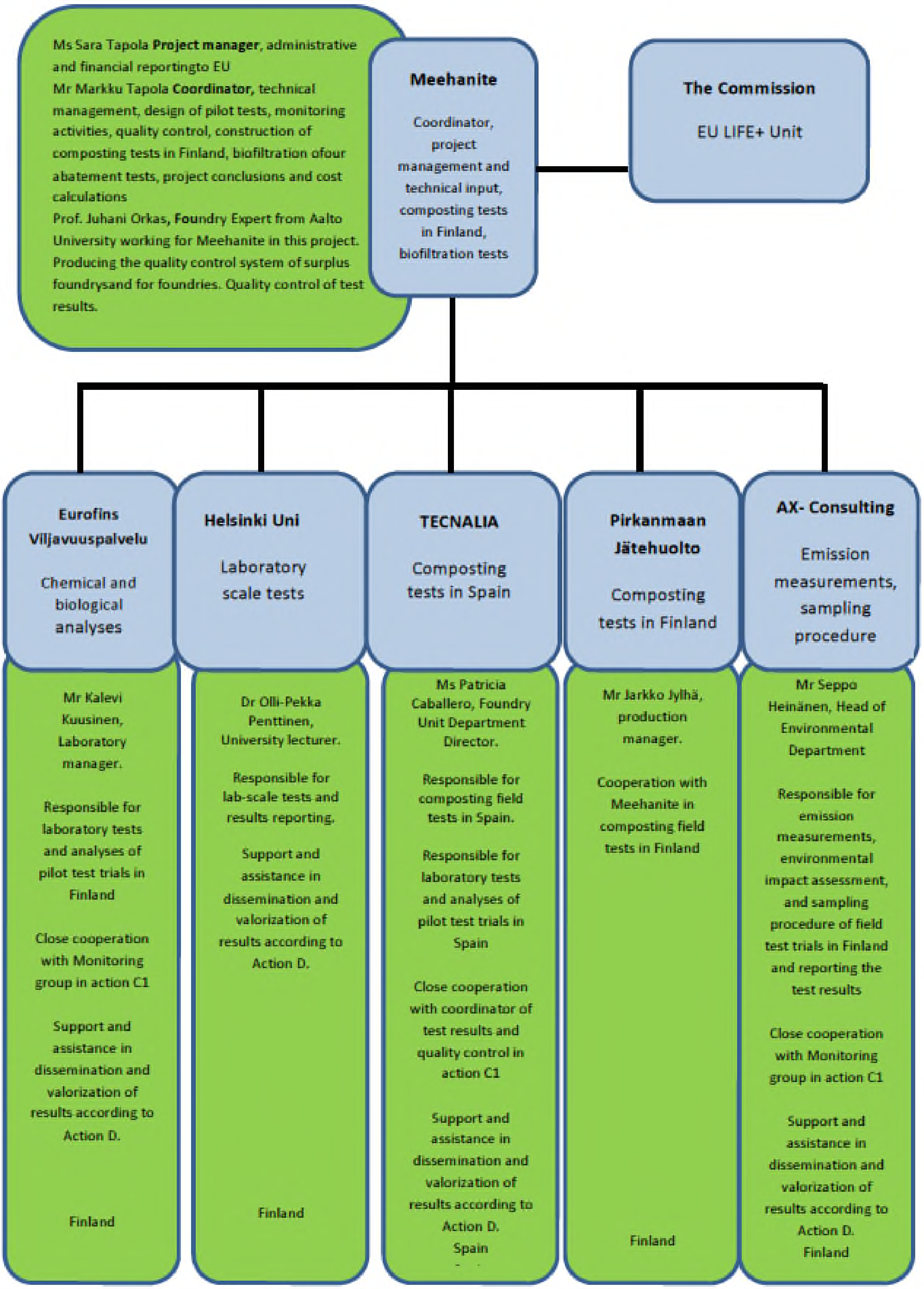
HU participated in several seminars during the project. HU also produced a poster presentation which was presented in USA.

Pirkanmaan Jätehuolto:
PJH provided the composting pilot site at Koukkujärvi for project purposes and helped with the test arrangements and monitoring activities in Action B3 Composting tests in Finland. The size of the test field was about 2000 m^2 at the Koukkujärvi landfill area They will also took care of the end-product material and was used at the landfill site for covering the purposes.

Viljavuuspalvelu Eurofins:
Eurofins Viljavuuspalvelut Ltd has over 16.000 employees across 200 sites in 36 countries, Eurofins is the leading international group of laboratories providing an

unparalleled range of testing and support services to the pharmaceutical, food, agricultural, environmental and consumer products industries and to governments Eurofins in Mikkeli worked in the project for composting material and waste water analysis services. AX and Meehanite gathered the samples and delivered them to Eurofins for analyses. Eurofins analysed all the sand specimens, composting materials and waste waters of composting tests in Finland (Action B5).

Project organigramme



The overall progress of the project

Action Number/name of action	**2014**			**2015**				**2016**				**2017**				**2018**
		III	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**
A1. Preparation of compost sites in Finland and Spain	Planned															
	Actual															
B1. Surplus sand quality control	Planned															
	Actual															
B2. Compost processing on lab scale	Planned															
	Actual															
B3. Composting in Finland	Planned															
	Actual															
B4. Composting in Spain	Planned															
	Actual															
B5. Biological and chemical control	Planned															
	Actual															
B6. Conclusions and project outcomes	Planned															
	Actual															
C1. Project monitoring	Planned															
	Actual															
D1. Notice boards and the Layman's report	Planned															
	Actual															
D2. Website and social media	Planned															
	Actual															
D3. Events	Planned															
	Actual															
D4. Publications and the dissemination materials	Planned															
	Actual															
E1. Project management and reporting by Meehanite	Planned															
	Actual															
E2. Networking with other LIFE projects	Planned															
	Actual															
E3. After LIFE communication plan	Planned															
	Actual															
E4. Project auditing	Planned															
	Actual															

5. Technical part

5.1. Technical progress, per task

5.1.1 A1 Preparation of compost sites in Finland and Spain

Implementation time of the action according to the Grant Agreement was 08/2014-06/2015. Pilot site preparation work was completed in August 2015. In Spain the pilot site of Tecnalia was already existing and ready for test arrangements. In spite of small delay this action was completed successfully.

The pilot site in Finland located at Koukkujärvi waste treatment center, Nokia, 25 km from Tampere. PJH provided the pilot site for project purposes and composting tests in 2015-2016. Meehanite was responsible for test arrangements.

The pilot site in Spain located in the center of the Basque Country, Ormaiztegi and Tecnalia was responsible for test arrangements.

5.1.2 B1 Surplus sand quality control and sand samples process in foundries

Implementation time of the action according to the Grant Agreement is 10/2014-03/2015. This action was started later than planned in January 2015 and completed in April 2016.

Surplus sand quality control and sand samples process in foundries was produced for foundries.

A revision work of the MARA-decree (Valtioneuvoston asetus eräiden eräiden jätteiden hyödyntämisestä maanrakentamisessa, Government decree of some waste reuse in geo-construction work, 843/2017) was ongoing in 2015-2017 by the Finnish Environmental Ministry and Finnish Environment Institute. Surplus foundry sands are now included in the MARA-decree and it sets the limit values for surplus foundry sands to be reused in geo-construction purposes. In many cases the limit values are very strict for foundry sands and therefore other treatment of cleaning methods such as composting process can be recommended.

Environmental acceptance of surplus foundry sands requires reliable knowledge on the sand composition and its variation especially regarding environmental properties. This information is also necessary for promoting the foundry sand utilization. A quality control system is also 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 sampling are emphasized in re-use of surplus materials.

The guideline was developed to provide clear and contemporary advice to foundries, compost manufacturers and local authorities to ensure the consistency in quality of the surplus sand produced in foundries. The report contained information of the sampling methods, analytical methods, and national limit values and requirements for surplus foundry sand.

The foundries must have a quality assurance system which, when followed, will produce identifiable and traceable information as to whether the surplus foundry sand meets the requirements set for it in national legislation, hereinafter ‘environmental acceptability’. The quality assurance system must include at least the following matters:

1) the surplus sand type, plus an estimate of the amount generated each year in the production;
2) quality control investigations, specifying sampling plans and times, sampling methods, composite and partial sample amounts and sizes, and sampling quality assurance;
3) guidelines for the storage and treatment of surplus sand and for its acceptance, if the plant treats sand from a number of different points;
4) persons in charge and their qualifications;

5) an evaluation and audit plan;
6) monitoring and reporting, including documentation of investigation results.

Environmental requirements, acceptance criteria and determination methods for surplus foundry sands**:**

The surplus foundry sand may contain some leachable contaminants, such as phenols, DOC, TOC, fluoride and BTEX that could have absorbed by sand during the moulding and casting processes. The existence of heavy metals is normally low. Surplus foundry sand specimens which contain heavy metals will not treated by composting method.

The proposed surplus foundry sand threshold values for composting procedure are given in Table 1. Those threshold values comply with Mara-decree (843/2017) and Government regulation on landfill (331/2013).

Table 1. The proposed threshold values for surplus foundry sands in composting use.

Harmful substance	Threshold value leaching mg/kg LS = 10 l/kg
Antimony (Sb)	0,7
Arsenic (As)	2
Barium (Ba)	100
Mercury (Hg)	0,03
Cadmium(Cd)	0,06
Chrome (Cr)	10
Copper (Cu)	10
Molybdenum (Mo)	6
Lead (Pb)	2
Nickel (Ni)	2
Zinc (Zn)	15
Vanadium (V)	3
Selenium (Se)	1
Fluoride (F^-)	150
Chloride (Cl^-)	11000
Sulfate(SO_4^{2-})	18000

The environmental acceptability of surplus sand generated in foundry production shall be investigated on a regular basis. The quality control investigations shall focus either on the continuous stream of surplus sand generated at the foundry or on treated/aged sand that is delivered for composting purposes. The leaching and content of harmful substances contained in the surplus sand must be determined from at least one composite sample before the sand is delivered for composting.

The largest mass amount of surplus foundry sand that can be investigated by a single composite sample is 5000 tons. The sub-samples shall be taken in such a way that they represent the entire waste batch under investigation. Surplus sand sub-samples are taken from a falling stream or from the storage pile. Minimum size of the sub-sample is 4 dl = about 1 kg. The minimum number of sub- samples in one composite sample is 50.

The sub-samples are marked so that each sample can be uniquely identified. Important information includes the sampling site, the sampling time and the name of the responsible person. The sub-samples are then packed on lidded bucket with foundry markings and delivered to the testing laboratory without pre-treatment. One sub-sample of each composite is stored also at the foundry premises as a reference sample in case more analyses are needed.

This kind of surplus foundry sand quality control systems will be taken into use in foundries in the future. Foundries will need to assort different foundry sand specimens suitable for different treatment or cleaning methods in order to reduce the amount of waste sand to be landfilled and to find more cost–efficient ways to reuse the foundry sand.

This action was completed successfully in spite of delay in MARA decree revision work which set the limit values and sampling procedure for the reuse of foundry sand in geo-construction purposes. Those foundry specimens which do not fulfil the limit values of MARA can be treated and cleaned by composting method and reused as growing media (mixture soil).

5.1.3 B2 Compost processing on laboratory scale

Implementation time of the action according to the Grant Agreement is 08/2014-12/2015. **Three sets of laboratory tests** were carried out and the results are presented herein.

1. **Composting tests in 2015-2016:**

University of Helsinki (HU) was focusing on a short-term laboratory scale composting test using the same sand specimens from composting tests in Koukkujärvi pilot site (Action B3Composting tests in Finland). The controlled small scale indoor experiments were complemented by *outdoor experiments at Jokimaa test field in Lahti* (Fig 1) in order to achieve information regarding to 1) compost construction including horse manure and straws, 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 station.

Laboratory-scale composting testing (Fig 2) included small-size composters (4*200 liter containers), using green, phenolic and furan sands plus their mixture (Foundry 50%), was performed at the Department of environmental sciences, Lahti. The composters were filled in Tampere with the same compost material from the test heaps which constructed at Koukkujärvi pilot site in June 2015. The portions of surplus foundry sand varied in test heaps between 20-33%. The composting process was followed over period of 8 weeks.

Figure 2. The composters (Biolan 220eco) at the beginning of the composting test in Lahti.

Results:
Temperature of composting piles remained relatively low in the Jokimaa outdoor tests during composting (Fig 3).The results reflect both low outdoor temperature and small compost pile size. In the laboratory composting tests under controlled room temperature equal time-related temperature pattern was observed and the compost temperature never exceeded 50 °C during composting process of eight week (Fig 4).

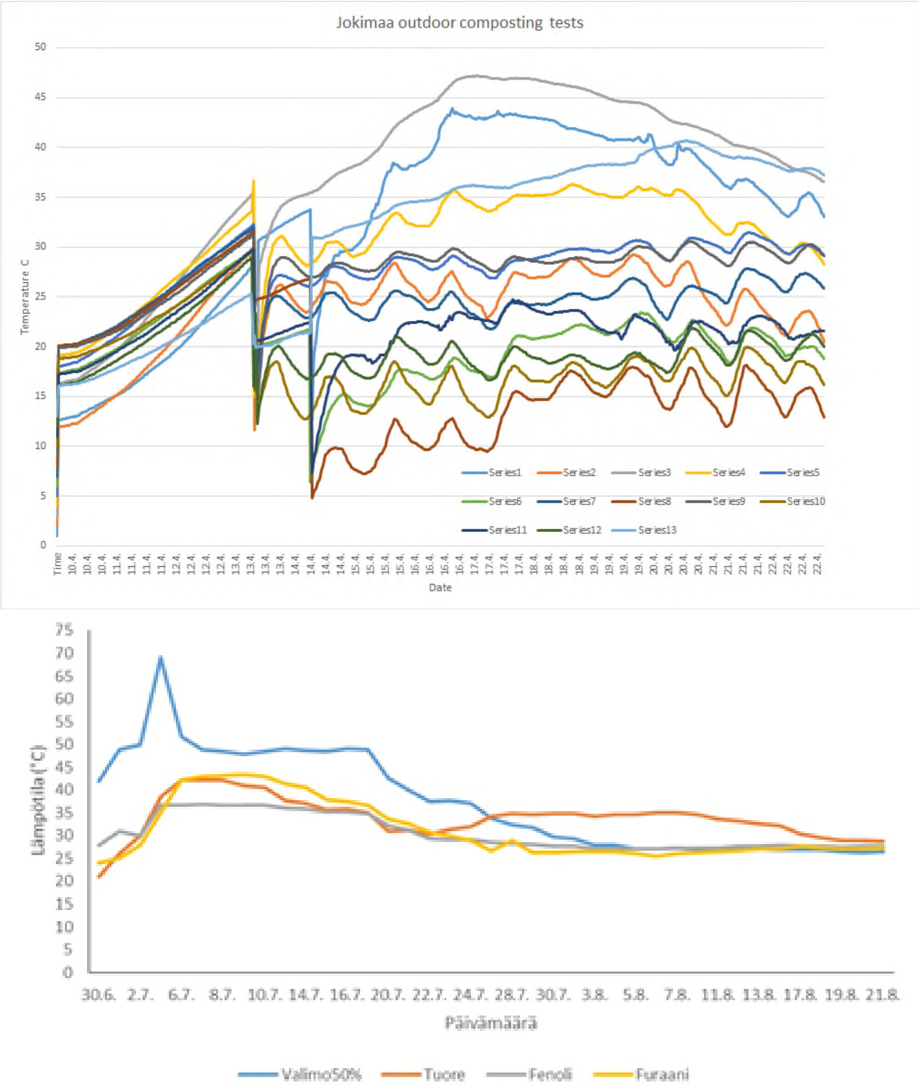


Figure 3-4. Temperature changes in the outdoor (above) and indoor (below) test composts during spring and summer 2015 including phenolic, furan and green foundry sand specimens and their mixture sand compost (blue line in right hand side figure).

Foundry sand specimens have major differences in their chemical characteristics. Furan sand had the lowest pH and the highest DOC concentration. Phenolic sand had the highest phenol index but also high fluoride concentration. The green sand had the highest metal concentrations, and also relatively high BTEX level.

The total concentrations of total PAHs were decreased during foundry sand compost tests (Fig 5). Changes in PAH concentrations during composting process were directly related to the fate of small and volatile PAHs. So partly chemical properties were more important than composting process. However, a concentrations decrease pattern was similar between low and high molecular weight PAH compounds (but total concentration of low PAHs was higher).

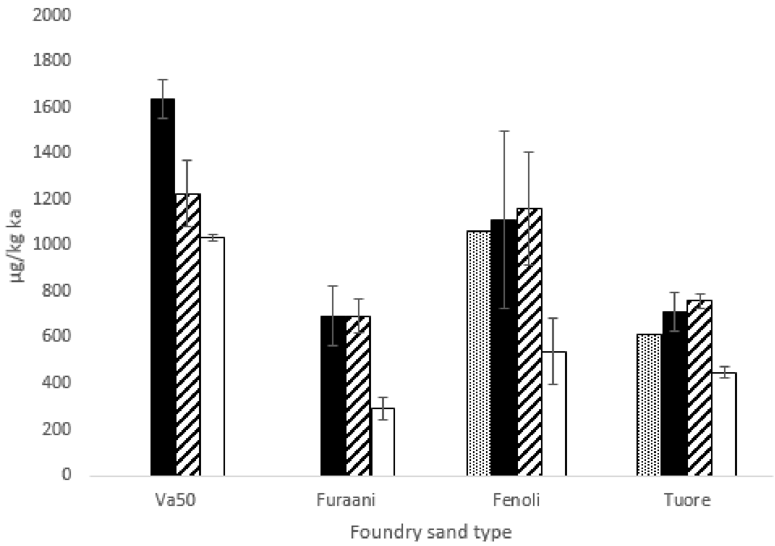


Figure 5. Changes of total PAH concentrations during eight weeks composting tests

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 the field test experiments. Based on the results the volume of the composting material was important for the temperature increasing in heaps and for the success of 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 DOC, sulphate and phenols before mixing with other composting materials (like foundry sands). And opposite to Koukkujärvi experiments, in the end of the composting tests, these concentrations were partly over the limit values demonstrating unsuccessful composting process. End concentrations of fluoride and presence of pathogen *E. coli* (>1000 cpu/g was exceeded only in one treatment) were another negative indicators.

Based on the results of the first tests, additional laboratory scale tests and ecotoxicity tests were decided to be made (project meeting on 11.5.2016 in Tampere). Ms Sonja Jaari from NEEMO was also present in the meeting and she found the additional tests justified.

2. Additional laboratory-scale tests in 2016: Optimized composting condition

Proper conclusions of the first laboratory scale tests and outdoor experiences in 2015-2016 were not reached because the temperatures did not rise above 50 degrees during tests. The purpose of this additional test was to investigate the optimal composting conditions and the driving abiotic parameters for cleaning different surplus foundry sand types by compositing process, and to exam the degradation efficiencies of the hazardous organic compounds in the surplus foundry sand.

Three test heaps, each containing ca. 9 kg homogeneous mixture of foundry sand and organic material at 4:6 ratio (40% foundry sand plus 60% organic material), were placed into three respective containers according to the different foundry sand types: furan sand, phenolic sand and green sand. All test containers were kept in an enclosed incubator supplied with a constant temperature and a continuous aeration through external air pumps (Figure 6).

- Temperature: The temperature of the incubator - ambient temperature of the composting process - was maintained at 50 °C throughout the entire test, in order to support the growth of certain groups of microbes such as the Actinobacteria and *Bacillus* which have been described as indicators of the well-functioning composting. The temperature sensors connected to online temperature loggers were placed in the middle of all test heaps to record the temperature continuously.
- Aeration and porosity: The porosity indicates the water holding capacity of composting material, which is essential in achieving good aeration throughout the composting process. To ensure the aeration, peat was added to all test heaps.
- Humidity and moisture content: The moisture content of three test heaps were maintained by watering, to ensure the transfer of nutrients and the microbial activity. On a biweekly and triweekly basis the humidity levels were measured.
- Other routine measurements consisted of air flow, pH and oxygen level, on a biweekly or triweekly basis.

Figure 6. Set up of lab-scale composting piles.

The lab test was carried out from June to October in 2016. Samples from the composting test piles were delivered for further analysis in Eurofins.

It was challenging to set-up the experimental piles due to the space limit of incubator and the demands on temperature, aeration and humidity.

- The temperature of the incubator - ambient temperature of the composting process - was maintained at 50 °C throughout the entire test. The temperature of the test piles stayed this level throughout the tests. The rather low temperatures might be explained with the time because the composting test heaps had been constructed at Koukkujärvi pilot site two weeks before delivering the compost material to Lahti where temperatures above 60-70 degrees had been measured.

- The green sand composting material at the start point was proven to be immature and the amount of *E. coli* present exceeded the limit value of 1000 cfu/g; however, in the end of experiment no pathogens were detected in any foundry sand piles and all composting materials were stable and mature.
- The DOC concentrations in green sand and phenol sand were relatively high in the beginning of the experiment. With time, green sand DOC values dropped to below the limit value however phenol sand DOC values remained higher than 500 mg/kg DS.
- Fluoride concentrations in all test piles increased through time. Fluoride end concentration in green sand exceeded the limit value 10 mg/kg DS.
- Phenol index and total BTEX were below the detection limit throughout the experiment. Total PAH concentrations in all piles were below the limit values, as well, a significant degradation was observed.
- The accurate cleaning efficiency rates were not able to be calculated because of the low concentrations of surplus foundry sand s already in the beginning.

Improvements should be taken into account to make any further additional lab-scale composting test more successful. In this study, fluoride end-concentration in green sand composting material and DOC end-concentration in phenol sand were higher than the limit values; only furan sand composting end-products fulfilled all the limit values requirement described in the Decree of Landfills (331/2013) and the Decree of the Ministry of Agriculture and Forestry on Fertilizer Products (24/2011) for mixture soil used as a substrate (5A2).

Based on these tests there are challenges to get the temperature to increase in small-scale laboratory tests and in small-scale outdoor experiments. Also the concentrations of harmful organic substances were rather low in all surplus foundry sand specimens so high degradation rates were not reached.

3. Ecotoxicity testing and effect-directed analysis (EDA) of waste foundry sand:
Ecotoxicity impacts of waste foundry sand were assessed in Department of Enviromental Sciences (University of Helsinki) on June 2016 – May 2017.

Metal moulds are often produced from quartz sand treated with various binders. The sand eventually ends up as waste that has a great utilization potential. This is to some part limited due to a diverse group of contaminants in the sand. The aim was to address the ecotoxicity testing of these waste sand specimens, along with the associated environmental effects in case of reusing the sand.

Waste foundry sands (WFSs) from three different Finnish iron foundries were examined. Based on the binders used in the mold production, the sands were categorized as green, phenolic or furan sand specimens. Water and solvent extracts (Fig. 7) from these sands and their composting products were examined with a biotests battery (Fig. 8), including acute toxicity tests on aquatic species and mechanism specific in vitro –tests (aryl hydrocarbon receptor (AhR) activity and genotoxicity). Effects of the sand specimens mixed with natural soil were observed with enchytraeid reproduction test. An effort was also made to connect the observed effects with specific contaminant classes, through effect-directed analysis.

Figure 7. Preparation steps (extraction and fractionation) of samples

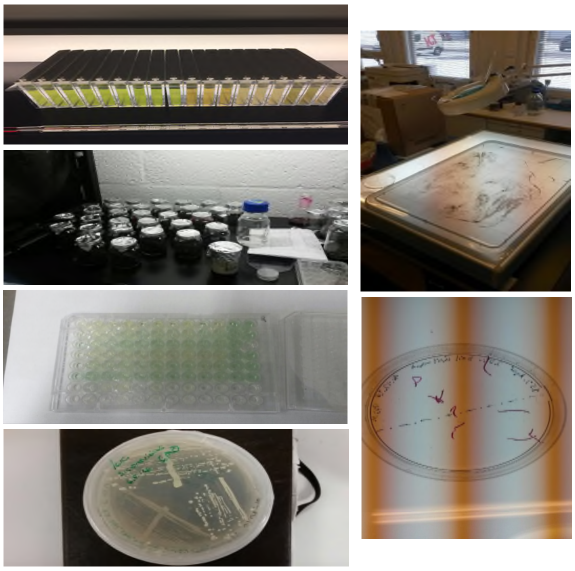


Figure 8. Biotests (algal test, yeast assay, genotoxicity test and enchytraeid reproduction test)

Foundry sand specimens showed major differences in their chemical characteristics. Preliminary results from the laboratory tests indicate high variation in toxicity between foundry sand specimens, fractions and model species.

The foundry sand effluents had a clear impact on the mobility of *Daphnia magna*, but results from algae growth inhibition test were more ambiguous. The water effluents had no impact on the light production of *Aliivibrio fischeri*, but the solvent extracts yielded a negative response. Evidence of genotoxic effects and AhR-activity were also observed in the solvent extracts. The WFSs did not have significant effect on the survival or reproduction of *Enchytraeus crypticus* in 10 – 30 % mixtures with natural soil. Starting compost material was characterized with high responses in all biotests, but in the end, only green sand expressed cytotoxicity and AhR-activity.

Uncontrolled reuse of WFSs is not recommended without caution, as they have shown adverse effects in various different biotests. Biotests are a useful tool for monitoring of environmental effects, as they include the aspects of mixture effects, unknown contaminants, transformation products and bioavailability. Even more comprehensive approach can be attained by integrating biotests and chemical analytics. Combining the data obtained by these two different methods is extremely challenging and requires further attention for more precise results.

No major adverse effects were observed in the enchytraeid reproduction test. The highest concentrations (30 m%) of phenolic- and green sand slightly decreased the reproduction and survival of the enchytraeids, respectively. Furan sand (63 %) was most toxic to *V. fischeri*, followed by green- (37 %) and phenolic sand (23 % inhibition). Genotoxicity was not detected in the WFSs samples, but in almost all of furan sands fractions. Estrogenic and AhR-activity was observed only in phenolic and green sands, androgenic activity was not observed. Initial phase of the compost was characterized with extremely high responses in all biotests, but in the end (5 months), only green sand expressed cytotoxicity and AhR-activity.

WFSs differed clearly from reference quartz sands, but their toxicity was not in an alarming level. The biotests results were not clearly connected with each other, nor with the received initial chemical data. Additional fractionation needs to be performed for the identification of harmful components, as the fractions were still rather complex. The initial composting sample was not a good reference point, since the un-mature compost material produced high responses in the biotests. From the final composting samples, only green sand expressed cytotoxicity and AhR-activity. These could be linked to persistent pollutants in the green sand though there was some indication that the compost in question was not mature, which may disturb the biotests.

5.1.4 B3 Composting in Finland

Implementation time of the action according to the Grant Agreement is 4/2015-12/2017. There is no delay in this action.

Altogether 20 test heaps and a meadow field test were constructed and tested in Finland during 2015-2017. In the Grant agreement 20 test heaps and a meadow field were written. In Finland, the total amount of cleaned surplus foundry sand composting material in 2015-2017 was 655 tons.

Meehanite was responsible for this action. This action was completed as planned. More tests were carried out than planned to test different surplus foundry sand specimens.

1. Summer tests in 2015:

Six test heaps were constructed at Koukkujärvi pilot site in June 2015 (Fig 9, 10). Test heaps were made in cooperation with project partners, Meehanite Technology Ltd and Tampere Regional Solid Waste Management Ltd (PJH). AX-LVI Consulting Ltd (AX) was responsible for the sampling procedure and airborne emission and waste water effluent measurements. Chemical and biological analyses were carried out by Eurofins Viljavuuspalvelu Ltd (Eurofins).

During the summer tests in 2015 also the environmental impact measurements were carried out and they are reported herein.

The size of the each test heap was about 20 tons. The portions of surplus foundry sand varied in test heaps between 20-30%. The most commonly used foundry sand types like furan, phenolic and green sand specimens were used in composting tests and other organic materials were added in test heaps. Specific recipes are confidential information.

Figure 9. Foundry sand specimens from Finnish foundries and other organic materials.

Figure 10. Six composting test heaps ready in summer 2015.

Analyses:

The progress of the composting process was controlled by continuously measurable indicators such as temperature. Surplus foundry sand specimens were analysed before mixing with other composting materials in order to know the start concentrations of studied ingredients. Mixed composting materials were analysed in the beginning, middle and end to follow the degradation of harmful compounds during the composting process.

Waste waters from the pilot site were collected to a basin and analysed in the beginning, middle and end of each test period.

Airborne emissions and odours were measured in the beginning, middle and end of the tests in 2015.

Regulations in Finland:
Compost end-product: The compost end-product must meet the limit values set in the *Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011): Substrate – Mixture soil (5A2).*
Waste waters: There are no national limit values for the waste waters in Finland. Many waste water treatment plants have their own requirements and limit values for the waste water quality. In this project limit values of Ekokem instruction 1/09: Älä päästä haitallista ainetta viemäriin ("Don't let harmful substance go to a sewer") were followed and updated by the RSAA authorities in the test permit.

Composting tests started in June and ended in November 2015 (Fig 11).

Figure 11. Test heaps in the end of the composting test.

Results:
Fluoride concentrations were high in green sand and phenolic sand samples before starting the compost tests. 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 because of the environmentally harmful compounds. Substitute materials are available in the market already. During the tests fluoride concentrations were reduced below the limit values.

Phenol concentrations of phenol sand samples exceeded the inert solid waste limit values. It has to be considered that phenolic compounds origin also from cores produced by cold box method.

Organic material had higher concentrations of harmful organic substances (DOC, sulphate, phenols) than was in the surplus foundry sand samples. In the end of the composting these concentrations were reduced.

Based on the results of the summer 2015 composting tests, we came into the conclusion that the tests were successfully completed and the compost end-product fulfilled the limit values set in the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products 24/2011 and therefore the end-product can be used as substrate and for gardening purposes.

Since the organic material used in these tests included very high phenol, DOC and sulphate concentrations (analysed before mixing in test heaps with other composting materials and surplus foundry sands) it was decided that further tests will be made with other organic materials.

Results of the environmental impact assessment of the composting method carried out in 2015:
Foundry Sand -project studied the environmental impacts of surplus foundry sand composting method. The focus was on emissions into the air and waste waters.

Air emissions from one compost test heap were measured three times during the summer and autumn 2015. The compost heap was covered during the measurements and the waste gases were conducted through the air chimney on top of the compost heap (Fig 12). The concentrations of different gaseous compounds emitted from the heap were measured with FTIR and FID analysers. Also samples from waste gas were taken to adsorption filters, which were sent to a chemical analysis.

Figure 12. Air emission measurements of one test heap.

The emission measurements were used to calculate the annual release of pollutants into the air. Also the specific emission of the treatment for a ton of foundry sand was calculated. The result was that for every ton of foundry sand composted 63 g/a of ammonia, 3,8 kg/a of carbon monoxide, 130 kg/a of carbon dioxide, 230 mg/a of benzene and 220 g/a of methane is released.

Odours were measured from one test heaps parallel the air emission measurements (Fig 13).

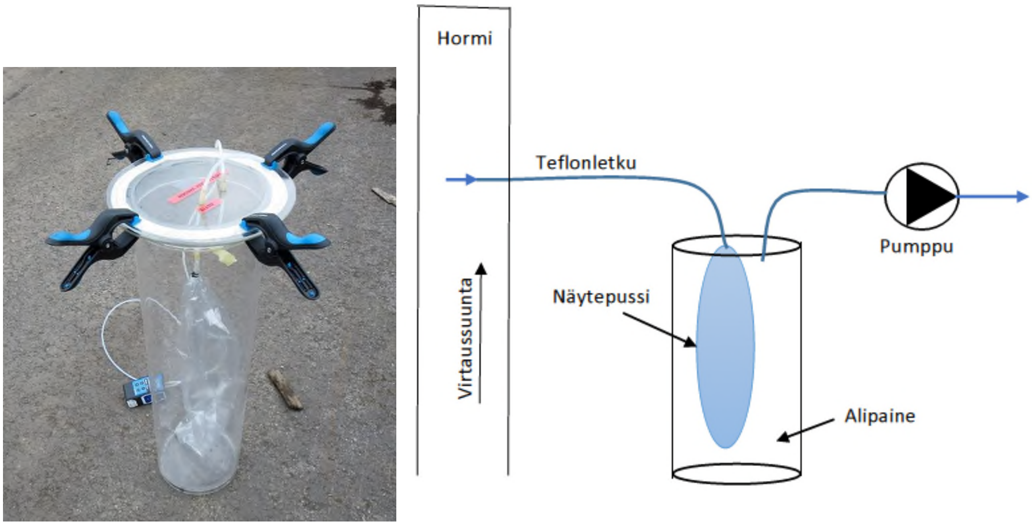


Figure 13. Odour emission measurement and equipment.

A dispersion model was used to calculate the environmental effects of the pollutants (Fig 14). Odour was recognized as the most significant pollutant of the treatment. Odour can be distinct for over 2 % of time at distance of 1 kilometer from the compost site if com-posting is carried out on a larger scale. For other pollutants the dispersion calculation results showed no concentrations that were harmful to environment or people according to the Finnish legislation.

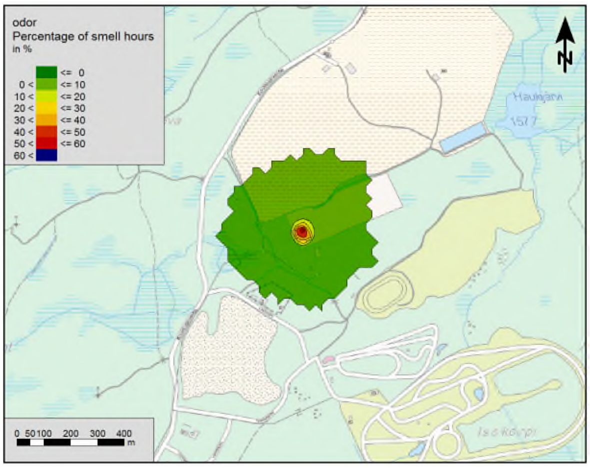


Figure 14. Dispersion modelling of the odours in the surrounding of the pilot site were calculated. Results are presented in percentages (%) of smell hours.

The concentrations in waste waters were examined by conducting the waters from the test site to a collecting basin. No exceptional concentrations were observed.

No harmful environmental effects were discovered or they were really minor. This was in a case where foundry sand composting is carried out with enough distance to closest habitation to prevent the inconvenience of odours and the waste waters are treated properly.

2. Winter tests in 2015-2016:

Winter tests started in December 2015 and ended in June 2016 with three test heaps (size of 43-50 tons each, Fig 15). The winter heaps were twice the amount compared to the summer test heaps. The heating and aerating system was built to heat up the heaps.

Figure 15. Continuous measurement of the test heaps in winter time and the aerating system of the winter test heaps.

Results:

Composting tests started in December 2015 and temperatures started to increase directly after the construction up to 60-70 degrees. The pathogens are destroyed when the temperatures increase above 55 degrees for a couple of weeks.

Based on the analysed results the tested foundry sand specimens were already rather "clean". No remarkably high harmful organic compound concentrations existed in any of the foundry sand specimens. Many of the analyzed compounds were under the limit values set for inert waste (331/2013) already before starting the composting tests.

Fluoride concentrations were above the limit value in the green and phenolic sand specimens (Fig 16) (limit value 10 mg/kg). Fluoride concentrations in test heaps were under the limit value in the end of the tests. It was assumed that fluoride was dissolved into the rest of the material (organic portion).

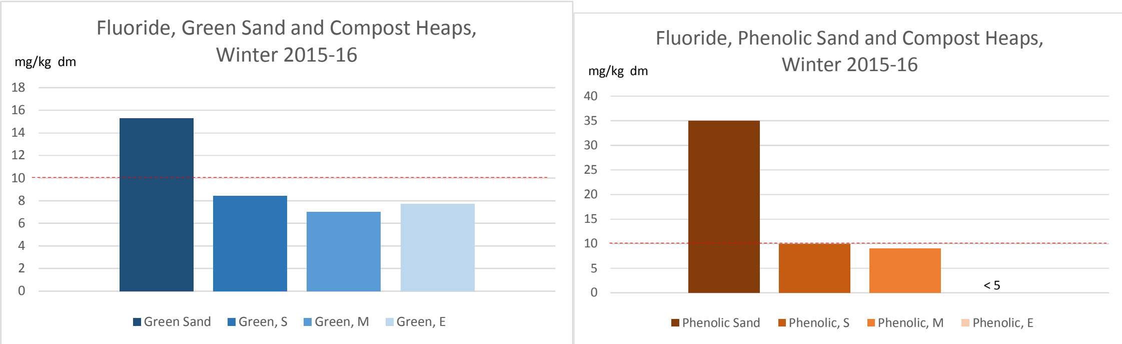


Fig 16. Fluoride concentrations of green and phenol sand samples in the beginning and in the end of the composting tests when concentrations were under the limit value.

Higher concentrations of BTEX compounds of 29,8 mg/kg was detected only in the furan sand sample (limit value of 6 mg/kg) but they were degraded during the composting process .

There were no exceptional high concentrations of harmful compounds (excluding high TOC concentrations) during the winter tests.

Based on the results of the winter-spring 2015-2016 composting tests, the tests were successfully carried out and the harmful organic substances were reduced during the composting method. End-products fulfilled the limit values set for the mixture soil (24/11) and it can be used as substrate and for gardening purposes after a proper post-maturing time. After the composting tests the cleaned composting material was transported to landfilling purposes at Koukkujärvi site.

3. Summer 2016 tests:
Nine test heap were constructed (each about 20 tons) (Fig 17). Furan, phenolic, green sand and cement foundry sand specimens were tested. Sampling procedures were carried out as in previous test (beginning, middle and end of tests) (Fig. 18)


Figure 17. Nine composting test heaps and the meadow field were constructed 05/2016.

Figure 18. Sampling procedure from each test heap was made in the beginning, middle and end of the test period. Composting materials and waste waters were collected and analysed.

Results:
As earlier, also the summer 2016 the surplus foundry sand specimens were rather “clean” and no remarkably high concentrations of harmful compounds were detected. Many of the concentrations were below the limit values of the non-hazardous inert waste before starting the actual composting tests.

Fluoride concentration of green sand and cement sand specimens exceeded the limit value of 10 mg/kg. During the tests fluoride was degraded in green sand and cement sand test heaps and concentrations were under the limit value at the end of the tests.

High BTEX concentration was measured only in furan sand sample (12,6 mg/kg dm) but it was degraded during the composting test.

No remarkable concentrations of harmful compounds existed in waste waters either during the tests.

Based on the results the end-products fulfilled the limit values set for the mixture soil (24/2011). After the tests the cleaned composting material was used in landfilling purposes in Koukkujärvi site.

Results of biofilter tests:
To reduce the odours emitted from the composting heaps two small scale biofilters were constructed by Meehanite, and the cleaning efficiency of the biofilters were measured in summer 2016 (Fig 19). Odour abatement measurements were carried out by AX according to the EN 13725:2003 (Air quality. Determination of odour concentration by dynamic olfactometry).

Figure 19. Odour abatement of the composting test heap by biofiltration system.

Two biofilter measurements were carried out. The first measurement was carried out after two months starting the composting tests and there were practically no odour left. Second biofilter odour abatement measurement was carried out in September with a new test heap. The results present a situation in the beginning of the composting process. The odour reductions of the biofilters were calculated to be about 85-95% (Table 2). Slight differences were noticed between the two biofilters.

Table 2. Odour measurement results of biofilters on 30.9.2016.

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

The odour abatement results demonstrate good odour abatement efficiency. The odour reduction by biofiltration system can be recommended, especially while constructing the composting heaps. After the composting heaps are ready, no heavy odours exist anymore requlary.

4. Meadow test in summer 2016:

The meadow field was constructed in May 2016 (Fig 20, 21) and test ended in September. The size of the meadow was 200m^2. The meadow ground layer was constructed of organic materials, sand and gravels. Drainpipes and a waste water collection system of the meadow field were built. Phenolic and furan foundry sands from pilot foundries were mixed on the top layer of the meadow field. The meadow was divided in four test grids (each of 50m^2) and fescue hay and broad beans were sowed and a veiling was placed (Fig 22). Also an irrigation system was constructed and installed.

The degradation of harmful organic substances in the meadow was measured in the beginning, middle and end. Also waste waters were analyzed. The plant biomass calculation was carried out to determine the vegetation growth in different surplus foundry sand grids representing *furan sand/fescue, furan sand/beans and phenolic sand/fescue and phenolic sand/beans*.


Figure 20. Meadow test arrangements were constructed in May 2016.


Fig 21. Meadow field planted in four grids.


Figure 22. Vegetation at the end of the test period in September 2016.

Figures 23. Plant biomass calculations of the meadow test grids.

All vegetation above the ground was collected from the test squares (Fig 23). It was not necessary to determine the root length because the biomass of roots corresponds to the vegetation growth above the ground.

Figures 24. Weighing and drying the plant biomass samples of the meadow test.

Weighing and drying of the samples from meadow biomass calculations were made at AX laboratory (Fig 24).

Results:
Based on the results below the most dense vegetation growth existed in furan foundry sand grids (A and B) (Fig 25). The thickest growth was with fescue hay on the furan sand grid A. Also the bean growth was much thicker in furan sand grid compared to the phenolic sand one. The difference compared to phenolic sand grids was obvious. One reason for the rich growth could be explained with the higher sulphite concentrations that exited in the surplus furan sand. pH was an average 7 in phenolic sand soil (C and D grids) and 6 in furan sand soil (A and B grids).

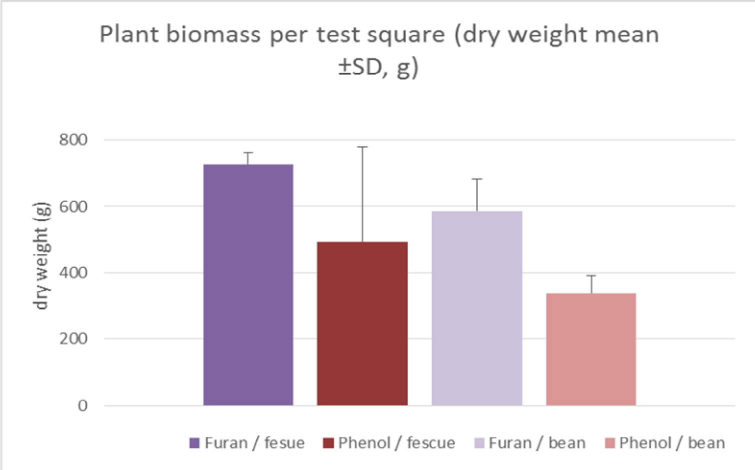


Figure 25. Plant biomass results per test square,

The outcome of meadow field test is that the harmful organic substances of surplus foundry sand specimens were reduced in the meadow field test. The mould samples from four grids were analysed in the beginning, middle and end of the meadow test. Also the waste water effluents of the meadow field were gathered and samples were analysed. No high concentrations in the waste waters or mould samples were detected during the four months.

Secondly, there where obvious differences in vegetation growth in the test grids. All four test grids had vegetation and no negative impacts of surplus foundry sands in mould layer were seen. Very dense vegetation growth existed in both furan foundry sand grids and the most thickest growth was in the fescue hay furan sand grid. The difference compared to phenolic sand grids was obvious. One reason for the rich growth could be explained with the higher sulphite concentrations that exited in the surplus furan sand.

5. Composting tests in summer 2017:

The sizes of the two test heaps were 11 and 16 tons (Fig 26, 27). Green sand and green sand dust were used and organic materials.


Figure 26. Composting test heaps were constructed in July 2017.

Figure 27. Pilot test heaps in August 2017.

Test heaps were equipped with online temperature data loggers and the progress of composting was followed weekly. The foundry sand specimens and mixed composting materials were analysed in the beginning and end of the test. Composting period was 6 months (July- December).

Temperature:
The temperature increased very quickly to 70 degrees in both heaps (Fig 28). The composting process was most active during the first 3 months when the temperatures were over 50 degrees. Temperatures decreased being at the end of the tests only about 10 degrees.

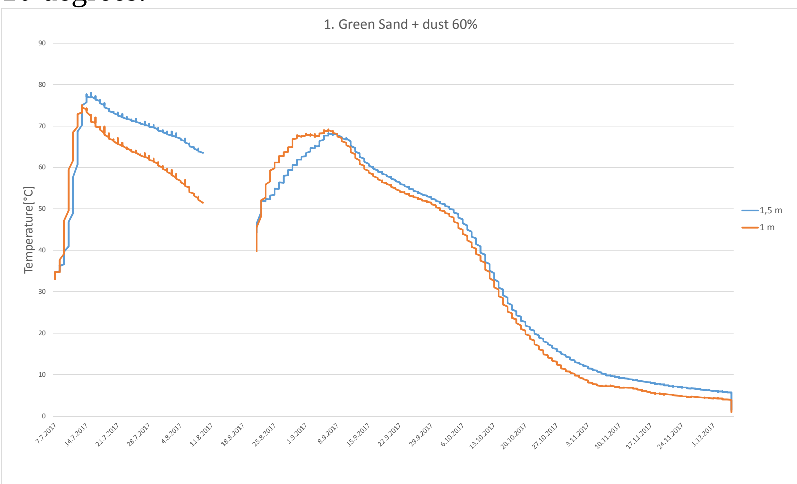


Figure 28. Temperature in test heap of 60% sand portion in summer 2017.

Results:
Dust specimens contained more harmful substances compared to the green sand specimen. Fluoride, BTEX, TOC and sulphate concentrations exceeded the inert waste limit values (331/2013). The amount of dusts from the total volume in test heaps was small. During the tests the all harmful substances were degraded and the limit values set for the compost end-product (24/11) were fulfilled. Only TOC and DOC concentrations were above the inert waste limit value but there are no limit values for the compost end-product. The high organic substances in end-products may be due to the lower temperatures of the test heaps because tests were carried out during the late autumn-winter time which affected to the temperatures of test heaps.

Based on the results of the summer 2017 composting tests, we can state that the harmful organic substances were degraded and the end-products were clean but not yet mature. In total 12 months are needed to get mature mixture soil to fulfil the limit values in the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011).

5.1.5 B4 Composting in Spain

Implementation time of the action according to the Grant Agreement is 4/2015-12/2016.

According to the Grant agreement it was planned to construct and test 12 tests heaps. By the end of the project 8 test heaps was tested in Spain. In Spain, the total amount of composting materials including surplus foundry sand which was cleaned by composting method was 304 tons. The total volume of cleaned surplus foundry sand composting material was fulfilled according to the GA.

Deliverables are submitted in progress reports and are attached as electric format in the Final report. Summary of tests are presented herein**.**

In order to evaluate scope, different sand mixes including green sand, phenol sand, silicate sand and furan sand were trialed in Spain. Different foundry waste sands were mixed with different organic materials and a suitable recipes were tested during 2015-2017.

Regulations in Spain:
In Spain the compost end-product must fulfil the limit values set in the Royal Decree 506/2013 on fertilizers, Royal Decree 1039/2012 and Government Instruction PRA/1943/2016 on growing substrates.

1. **Autumn 2015- spring 2016 tests:**

First tests started in September 2015 following a fact-finding visit to the Finnish plant in June 2015. Using their set-up as a reference for like-for-like comparison (but in different climate and with different foundry sand types) Tecnalia initiated two test heaps (Fig 31). The initial results for Spain are presented herein.

Figure 31. Monitoring visit at pilot site by Meehanite Technology in March 2016 (Tecnalia and Meehanite personnel).

The location of the test heaps required a site with the appropriate environmental permit already in place. In our case, Composgune, S.L, was chosen. This site is located in the centre of the Basque Country, Ormaiztegi, northern Spain, 50 km from the Cantabrian Sea. The size of the heaps was restricted to those stipulated in the permit terms and conditions obtained by Composgune, S.L. from the Basque authority.

First two test heaps were constructed at the pilot site in September 2015. The heaps were made in coordination with project partner Meehanite Technology at Ormaiztegi pilot site. Tecnalia was responsible for the sampling procedure and airborne emission and waste water effluent measurements. Chemical and biological analyses were carried out by Tecnalia laboratory division and external accredited laboratory. Results reported by Tecnalia and checked by Meehanite.

The weight of the test heaps was approx.13 tons and the proportion of surplus foundry sand was about 18% (Fig 34). Mixes of the most commonly used foundry sand types such as green sand and silica sand specimens were used in composting tests.

The composting process was monitored through the continuous measurement of temperature and pH (Fig 32). Analysis of the composting material in each heap was carried out at the beginning, in the middle and at the end of the experiment. Waste water seeping from the heaps (from both natural rainfall and simulated rainfall added to compensate for the below average rainfall during the trial) was channeled to a deposit for analysis. These measurements were carried out in phases one and two, and again in two and three. Airborne emissions were measured during stage three when these were expected to be at their height. Temperature monitoring was carried out using two thermocouples in each heap.

Figure 32. Two green sand test heaps were built in the centre of the Basque Country, Ormaiztegi, northern Spain.

Results:

Fluoride concentrations were high in green sand and they origin from fluoride containing feeders during casting. This is higher in green sand (iron casting) due to the higher absorption capacity. It is expected that fewer foundries will use the fluoride containing feeders in the future as substitute feeder systems are coming onto the market. However, fluoride concentrations reduced to level below the limit values in both foundry sand types by the end of the process. It was assumed that the fluoride was transformed and dissipated by the organic material.

Water seeping from the heaps had high concentrations of DOC, sulphate and phenols in the beginning. However, at the end of the composting tests these concentrations were under the limit values.

In the middle of the tests the phenol concentrations ranged from 76 to 100 µg/Kg m.s, but at stage 3 this decreased to 4 µg/Kg m.s in heap one and to <1 µg/Kg m.s in heap 2. Regarding BTMX compounds, they were degraded completely by the end of the composting process.

In addition to analyzing the composting material and waste water, airborne emissions of the green sand test heap were measured during the three stages of composting test period. The aim was to evaluate the total environmental impact of the composting test.

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.

Based on the results of the autumn 2015-summer 2016 composting tests, the experiment was successful 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. The results demonstrate that hazardous organic compounds such as phenols and PAHs were reduced by 97%.

2. Summer 2016 – spring 2017 tests in Spain:

Two phenolic surplus sand test heaps were piled up (Fig 33). The proportion of waste foundry sand was 15%.

Figure 33. Material mix of the heap 1and heap 2.

Results:
In general, concentrations of soluble, heavy metals and hazardous components in the phenolic waste sand as well as the composting material were under the stipulated limit values for end products according to the legislation on waste disposal to landfill, fertilizers and substrates. So these foundry sand specimens fit well to be cleaned by composting method.

Hazardous components were degraded sufficiently during the composting process. In the beginning of the composting test, chloride and fluoride concentrations showed high values but at the end of the test, these values fall within the limit values. No remarkable fluoride concentrations were detected in waste water samples analysed during test.

In case of phenol, this also exceeded the required values for inert solid waste but it has to be considered that phenolic compounds origin from cores produced by the Cold box method. Moreover, at the end of the composting tests, these concentrations were under the limit values demonstrating successful composting process.

DOC (Dissolved Organic Carbon) and TOC (Total Organic Carbon) concentrations were higher than limit values due to the nature of the materials. Likewise this also happened in the case of BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) in waste water seeping from the heaps, related to each other and originated from materials used in the composting process.

Compost end-product from phenolic waste sand, despite containing higher concentrations of fluorides, chlorides, sulphates and phenol at the start of the composting process, showed similar results as end compost material from green waste sand developed in autumn 2015-2016. The level of soluble and heavy metals required according to the legislation was under the limit value in both types of sands. Likewise both phenolic waste sand samples and green waste sand samples contained BTEXs and PAHs far under the limit established. Therefore, the trials showed that the composting of phenolic waste foundry sand is potentially an effective way of recycling this industrial by-product.

It is very important to know the origin of the sand: steel foundry, iron foundry, etc. Depending on this we can obtain relevant and different results.

3. Summer 2017 tests in Spain:

For this test **four heaps from silicate waste sand** were piled up in the pilot site (Fig. 34-35). The proportion of waste foundry sand in the four heaps was 15%.
Silicate sand is an inorganic binder system used in steel foundries.

Figure 34: Pilot site at Konposgune S.L. in Spain.

Figure 35. Test heaps were mixed every 15 days by a forklift truck. Air emission were also measured at the end of the composting period.

Results:

Due to nature of silicate moulding process, in general, the concentrations of soluble, heavy metals and hazardous components in the silicate waste sand were under the stipulated limit values. This was also the case in the compost end-products where the concentrations were very low according to the legislation of inert waste to landfills and fertilizers. One exception was with nickel.

All the figures for soluble metals were below the limit value set for the inert waste. Only DOC (Dissolved Organic Carbon) concentrations (598 and 573 mg/kg) slightly exceeded the limit value of inert waste (500 mg/kg dm).

Soluable concentration of nickel was under the limit values of 0,4 mg/kg in silicate sand sample. The total concentration of nickel was high (870-880 mg/kg dm) in the beginning of the composting materials. In the end-products the limit values of nickel of 100 mg/kg dm was slightly exceeded. Nickel is commonly used in stainless steel production. All other limit values of total concentrations set for the compost end-products were fulfilled in all test heaps.

Silicate sand pH was 11.1 due to the moulding process. This level is a basic character of the olivine sand. There is no limit value for pH set in the inert waste. In the end-products the pH was about 7.

The composting trials demonstrated that the composting of foundry surplus silicate sand is one of the most potentially effective way of recycling this industrial by-product and to generate a new compost material for geoengineering purposes.

Based on the results over the test period of three years (from the autumn 2015 to autumn 2017), we can say that the tests were successfully completed and the innovative composting end-product will comply with the limit values set in the Decree of the Ministry of Agriculture and Forestry on fertilizers in Spain and thus the end-product can be used for gardening purposes after the post-maturing time.

The experiments carried out demonstrated that the proposed method is a viable way to recycle waste foundry sand in different climate conditions.

The amount of test heaps was not fulfilled according to the Grant agreement (12 test heaps were promised). In total 8 test heaps were constructed. But the volume of the surplus sand composting materials of 304,3 tons exceeded the amount promised in the Grant agreement. With the exception of one test heap where slightly high nickel total concentrations existed, all test heaps fulfilled the limit values set for the compost end-product.

5.1.6 B5 Biological and chemical control

Implementation time of the action according to the Grant Agreement is 04/2015-03/2017. Action completed in November 2017 when final analyses were made and reported.

In the Grant agreement it was written that 17 test heaps will be carried out in Finland and 12 test heaps in Spain. In total of 1900 analyses would be made.

By the end of the project 20 test heaps plus a meadow field test was carried out in Finland and 8 test heaps were tested in Spain. In total 6229 biological and chemical analyses and tests were made in Finland and 2367 analyses and tests in Spain during the project.

Sampling procedures, analyses needed and limit values was produced in the project. this report provides clear instructions to foundries, composting companies and laboratories how to carry out the sampling procedures and what analyses and which limit values must be followed in order to fulfil the limit values and regulations of the compost end-product.

Results of analyses and tests are presented in the Action B3 and Action B4 Deliverables after each test period and also shortly presented in the Final report under the action in question.

Following parameters and compounds were analysed during tests

Surplus foundry sand analyses:

1. Progress of the composting process and environmental impacts must be followed with chemical analyses according to the permit. Before constructing the composting test heaps, heavy metals (dissolved) of Al, Cd, Cr, Cu, Fe, Ni, Zn, Pb ja Hg must be analysed from the surplus foundry sand specimens. Same parameters and compounds must be analysed also from the end-product.

Composting material analyses:

2. Analyses from each test heap (foundry sand+other organic materials) must be made in the beginning, middle and end of tests. Following analyses must be made: fluoride, heavy metals (total and dissolved) (Al, Cd, Cr, Cu, Fe, Ni, Zn, Pb and Hg), PAH, BTXE, phenols, TOC and DOC. In the end also coliformic bacteria, salmonella and germeability test, compost maturity test (CO2 production) and rooth length index test are made. Temperature measurement (data loggers).

Waste water analyses of test heaps:

3. Waste waters of the test field must be gathered for analyses from the collecting well. Analyses must be made in the beginning, middle and end of the tests for following parameters:

- pH, electrical conductivity, chemical oxygen demand (COD), biochemical oxygen demand (BOD7ATU), total nitrogen, ammonium, total phosphorus, solid matter and heavy metals (Al, Cd, Cr, Cu, Fe, Ni, Zn, Pb and Hg). Additionally, in the end of each test period thermotolerant coliformic bacteria must be analysed from the waste waters.

Summary of all analyses:

Analyses in Finland:

- In summer 2015: Six test heaps were constructed and analysed (surplus foundry sand samples + composting materials in the beginning, middle and end + waste water analyses). Altogether 1,763 analyses were made.
- In winter-spring 2015-2016: Three test heaps were constructed and analysed (surplus foundry sand samples + composting materials in the beginning, middle and end + waste water analyses). Altogether 1,060 analyses were made.
- In summer 2016: Nine test heaps were constructed and analysed (surplus foundry sand samples + composting materials in the beginning, middle and end + waste water analyses). Altogether 2,961analyses were made.
- In summer 2017: Two test heaps were constructed and tested and altogether 475 analyses and tests were made.

In Finland 20 test heaps and the meadow field were constructed and tested. Altogether 1,763+1,060+2,931 + 475= **6,229 biological and chemical analyses** were made during the project in Finland.

Analyses in Spain:
Altogether 8 test heaps were constructed and tested in Spain. Altogether **2,367 biological and chemical analyses** were carried out during the project in Spain.

- In autumn 2015-spring 2016: Two test heaps were constructed and tested. Altogether 655 analyses were made.
- In summer 2016- spring 2017: Two test heaps were constructed and tested. Altogether 521 analyses were made.
- In summer 2017: Four test heaps were constructed and analysed. Altogether 1,191 analyses were made.

5.1.7 B6 Conclusions

Implementation time of the action according to the Grant Agreement is 01-03/2018.

The deliverables produced in this action:
1) Practical guide "Surplus foundry sand quality control in foundries (03/2018).
2) Report" Applicability of cleaned foundry sand recycling in Finland, Germany and Spain (limit values, applicability and market approach and carbon footprint calculations)" (12/2017).
3) Practical guide "Constructing recommendations for composters of cleaning the foundry sand by composting" (12/2017).

This action focused on the demands of foundries, that is, how to release the surplus foundry sand in a way that it can be used for composting and with the demands of the compost material manufacturers:

The main project deliverables are listed herein.
1. **Deliverable B6_1 Surplus sand quality control and sand samples process in foundries**. The content of the deliverable is presented under Action B1. The report is a practical guide on how the foundries have to separate the surplus foundry sand specimens suitable for composting process from other sand specimens, it presents the limit values to be followed and sand sampling procedures in foundries.

2. **Deliverable B6_2**" **Applicability of cleaned foundry sand recycling in Finland, Germany and Spain and Carbon Footprint Calculations**.

   The report contains limit values, applicability and market approach and carbon footprint calculations. The economic side conditions are presented. Also the price of the new product (mixture soil) and the investment and transportation costs are calculated. Aim is to provide relevant costs related to composting site construction work, maintenance costs and product costs for the potential companies. The market situation is analysed in the countries Finland, Germany, and Spain. This part gives general market figures on compost but will take especially notice of the price structure, the legislation, the distances between foundries, compost sites, and consumers. Also the carbon footprint calculation is provided.

   The market analysis, European legislation survey and current treatment methods of surplus foundry sand in Europe and a carbon footprint calculation was provided by external consulting company. The tender was delivered in October 2016 to five applicants and two answers were received.

   The contract was made with B-B-H Beratungsbüro für industriellen Umweltschutz Dr. Joachim Helber, Duisburg.

Summary of the Deliverable B6_2" Applicability of cleaned foundry sand recycling in Finland, Germany and Spain:

To start with the market approach the demand for a sophisticated alternative to common foundry waste sand utilization or dumping had been examined. Hazardous foundry sand turned out to be really rare. Therefore, a new method would not contribute much to this sector of waste but much more to the sector of average foundry sand which has to be dumped in spite of no adequate re-use opportunities or which will cause a future problem as dumping capacities are shrinking rapidly. As a consequence, the prices for surplus foundry sand treatment cannot be orientated on the high-end level of hazardous waste but have to be oriented on average dumping fees. These dumping fees vary remarkably within the European Community so that this important profitability parameter of a compost plant has to be aligned on local situation.

In a second step the availability of input materials was checked. Of course, surplus foundry sand is not regarded short in availability. In case that price for composting is low several million tons of this quite useful (but primarily slightly contaminated) residue could be treated.

Horse manure was thought to be the bottleneck in the beginning of the project. But it turned out that this is not the case as more than 5 million horses are nursed within the EU-28 member states. There are many stable owners who would be happy if they were freed from paying high prices for transport of horse manure or even for the incineration of this "animal-side-product". Therefore, it is believed that manure is sufficiently available and free of charge as long as compost producers are willing to collect the manure from the stables or to contribute to the costs of freight. In future times the competition is expected to become somewhat stronger.

Sewage sludge from municipal wastewater treatment plants can partly substitute the horse manure as similar aerobic bacteria settle within this material. Some years ago sewage sludge availability was quite unlimited as nobody wanted this material. Meanwhile a development has taken place to treat the sludge after dewatering by aerobic composting. By doing so sanitation takes place and this result in a quite accepted compost material – as long as persistent hazardous components are absent or on an acceptable level. The overall production of dry sewage sludge within EU member states is about only one-tenth of the wet horse manure generation. Sludge may be acquired for free if transport costs are taken over. Other potential and tested organic materials were not introduced in this report.

Medium coarse forest residues are available "unlimitedly". *But*, branches, barks and shavings from trees have very low bulk densities. Therefore, the transport costs become significant in case those sources are not within short distances. Different sources must be regarded when the deliverance of the forest residues is organized directly from the forest owners. To overcome this, chipping of the material may be considered to increase bulk density but then the material starts to cost between 10 and 20 EURO per ton.

So, generally spoken, availability is not a principal problem but an issue of individual and local offers and prices.

On an international scale – Finland, Germany, and Spain have been compared – the differences are not that large. The appearance of horse stables must not be reduced to rural areas but are related to cities and industrial zones as well in conjunction with sewage plants. In this way the distances to forest and wood industries and the distances to consumers of the compost material seem to be the cost driving factors. Of course, in Germany all sources and sinks seem to be somewhat closer together because of the more close-meshed structure.

Although the national environmental legislation is governed by the EU legislation there are remarkable differences between the examined EU-member countries. To a major extent this can be fixed to differences in sanitary standards. Whereas the principles are quite equal the details are of concern: So the re-use of surplus foundry sand in composting is denied at all in Germany whereas in Finland and Spain – under controlled circumstances - that is foundry sand of high purity – this material is allowed for composting. This is a fundamental contradiction because the composting method under investigation has its strength and economic impact in purifying contaminated material.

Although the standards for process and ready composts are different within the EU it is expected that in farer future the "harmonization" development will proceed.
The study has assembled the national legislation for foundry waste management, horse manure, sewage sludge, fertilizers and soil improvers as well as compost application limitations. The situation is remarkably complex. That is the reason why no details can be presented in this conclusion. Even within the related chapter 3 of the study often references were cited instead of detailed descriptions. By doing so a – hopefully - useful overview was created.

Chapter 5 of the study deals with the investment and running costs for a new compost plant using the ingredients of compost in question. The components of an adequate compost plant are the same like with composting of green cuts (yard wastes), food waste and sewage sludge or similar. Sorting and analyzing costs are closely related to the cleanliness of the input material so there an advantage may be derived from avoiding municipal sewage sludge application.

Investments in industrial composting plants are reported in a very wide range of roughly 2 to 10 million EURO for an annual 35,000 tons input. Space consumption depends on the chosen technique (i. e. windrows versus heated rotating drum – but post-maturation of the raw compost always needs quite a lot of space. Local weather conditions influence the throughput efficiency (I, e. in Finland maturation takes much longer than in Spain). For open windrow technique 14,000 to 20,000 m^2 should be calculated. If composting is forced into solid buildings with technical ventilation this would be a big cost investment. Tight ground construction with drainage system is a minimum requirement. Further important cost drivers are sorting, transport in case of material collecting service. Principles of cost balancing are shown by examples and listings. In the end the earnings by such a process are strongly individual and site-dependent. As dumping fees are expected to go up earnings from compost operation may be expected to improve as well. On the other hand future business trends cannot be identified clearly - not only because of the general cost development for labor, construction, fuel etc. but also because of a strongly increasing offer of compost driven by food residues and private green municipal collection and utilization, sewage sludge composting and growing competing applications for bio-wastes (i. e. bio-gas generation and electric power production). Composting is further regarded a local business as transport costs have to be considered seriously.

A reduced carbon footprint balance has been attempted. As system boundaries for this balance the process itself had been chosen. As basic information some field emission measurements from the project were available. As title defines carbon footprint calculates the carbon dioxide emission during lifetime and is therefore a reduced environmental life cycle assessment. Some definitions regard carbon balances solely others take the generation of greenhouse gases as a whole into account. In latter case for composting fugitive nitrogen compounds, mainly dinitrogen oxide and ammonia are included. Nitrogen compounds were not studies here intensively (but were low). CO, CO_2 and hydrocarbons were measured and some fugitive organic compounds were identified derived from composting by aerobic bacteria.

In general, the emissions of carbon dioxide have to be distinguished: anthropogenic emissions count within a carbon footprint balance but carbon dioxide from renewable sources does not. The anthropogenic contribution comes from surplus foundry waste sand in the shape of polymeric organic binder or coal dust product (less than 2 mass-% of the whole input) and from the consumption of energy during composting (fuel and electricity). Municipal sewage sludge may contribute to it as well but by small portions - if at all.

From the balances it can be derived that for one typical example of the investigated (= emission measured) receipts within the project only 17 % of the carbon dioxide equivalent had an anthropogenic origin. When in total 26.42 kg CO_2 equivalents/ton raw input material were emitted, 0.67 originated from surplus foundry sand ingredients, 3.87 were from energy consumption on compost site and 21.88 kg CO_2 equivalents/ton raw input derived from bio-organic material degradation.

The measured/calculated carbon emissions are comparatively very low, much lower than reported elsewhere. This encouraging result should be verified on occasion.

3. Deliverable B6_3 Practical guide “Constructing recommendations for composters of cleaning the foundry sand by composting”

General construction recommendations, guidelines and investment costs are presented for composting companies and waste treatment centres which could start implementing the cleaning of surplus foundry sands by composting method.

Conclusions and results of the innovative composting method tested in Foundrysand LIFE project:

Based on the results the composting method can be recommended as a 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 specimens as written in the project proposal. Surplus foundry sands and dusts which include heavy metals can not be degraded 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. But the aim is of course that majority of all the surplus foundry sands could be cleaned by composting method because it is a very efficient and cost-effective method. Other treatment methods such as a stabilisation or incineration can be recommended for certain specimens. The foundries are guided to separate different sand specimens carefully so that only minimum portion of foundry sands or dusts containing high concentrations of heavy metals should be stabilized, landfilled or incinerated. This would cost-efficient and would save space on deposits.

Based on the project test results, only some harmful organic substances exceeded the inert waste limit values (Decree of landfills 331/2013) in the surplus foundry sand specimens e.g. phenols, fluoride and BTEX. With some foundry sand types DOC and TOC concentrations exceeded the limit values of inert waste but the Fertiliser Products Decree (24/2011) has not limit values for organic compounds for the compost end-product when it is used as growing substrate. Also other harmful substances were measured from the waste sands and composting materials during the project. No high concentrations of PAHs but no high were met. PAH compounds are carsinogenic. The existing PAHs were degraded during the composting tests (not soluable).

Emission measurements from the test heap were carried out in the beginning, middle and end of the composting process. Exhaust gas concentrations were very low. Some sulphur compounds, like ammonia, occurred. Odour limit value of ammonia is very low (~ 0,1 mg/m^3). Also VOC emissions were measured but they were very low (under 10 ppm). Because VOCs are volatile they are partly reduced already at the foundry “back yards” while waiting for transportation. Based on the Foundrysand project results very low VOC concentrations were measured in the beginning of the composting tests. In case VOC emissions will be reduced it would be recommended to cover the foundry waste sands it the foundries back yards and if needed during the first weeks of composting and to treat the waste gases and emission e.g. by biofiltration system. Foundrysand project results demonstrated that airborne emissions were formed only during the first weeks after constructing the composting test heaps and then reduced radically. The biofiltration system tests demonstrated the odour reduction of 85-95%.

The composting process will take place in a place with asphalt ground layer and waste waters treatment system according to national environment permit regulations and where environmental impacts are monitored regularly. In the future the composting companies could replace the use of virgin sand by cleaned surplus foundry sands to be added in their compost end –product. Based on the project environmental impact assessment no high concentrations of harmful substances were measured from the waste sands, test arrangements, waste waters or air emissions. As presented in the construction recommendations the composting heaps could be also covered to avoid waste waters or even odours from the composting heaps. When the heaps are placed in a hall or covered by tarpaulin, the emissions can be reduced and treated e.g. by biofiltration system.

The analyse results demonstrated that the surplus foundry sand specimens contained only low concentrations of harmful organic substances before starting the composting method and the concentrations were reduced during the composting process. When the concentrations were very low already in the beginning it would not be cost-effective to treat the foundry sands by any other energy intensive way such as thermal incineration. In Foundrysand project the composting method cleaning efficiency was monitored in the beginning, middle and end of the tests. After the end of the composting tests the existing low harmful organic substances were even reduced and the compost end-product fulfilled both the non-hazardous inert waste (331/13) and compost end-product (Fertilizers product 24/11) limit values. So, would it be environmentally beneficial to treat the foundry waste sands by thermal incineration to get “really” pure sand or instead to reuse industrial waste in other applications e.g. by cleaning surplus foundry sands (specimens free of heavy metals) in composting process and to get a ready compost end-material suitable for gardening purposes. The compost end-product fulfils the limit values and it is “pure enough” to be reused as geo-construction purposes.

Incinerating the surplus foundry sands is not alone economically or environmentally friendly method because the surplus foundry sand metal concentrations are very low and because the energy itself is produced by fossile fuels causing air emissions. The surplus foundry sand volumes in Europe are about 18 milj. tons annually. Thermal incineration is very energy intensive and should not be recommended in the first place as a common treatment method for all surplus foundry sands even if the result would be almost “pure” sand.

5.2 Dissemination actions

5.2.1 Dissemination: overview per activity

5.2.2.1 Action D1 Notice boards and Layman's report

The notice boards (Fig 36) describe the project clearly and they were displayed at strategic places on pilot sites in Finland and Spain. The LIFE logo was placed on them.

At the end of the project the Layman's report was produced (Appendix 6).

Figure 36. Notice board at the pilot site in Finland.

5.2.2.2 Action D2 Website and social media

The main project results and activities are informed on the project website (www.life-foundrysand.com).

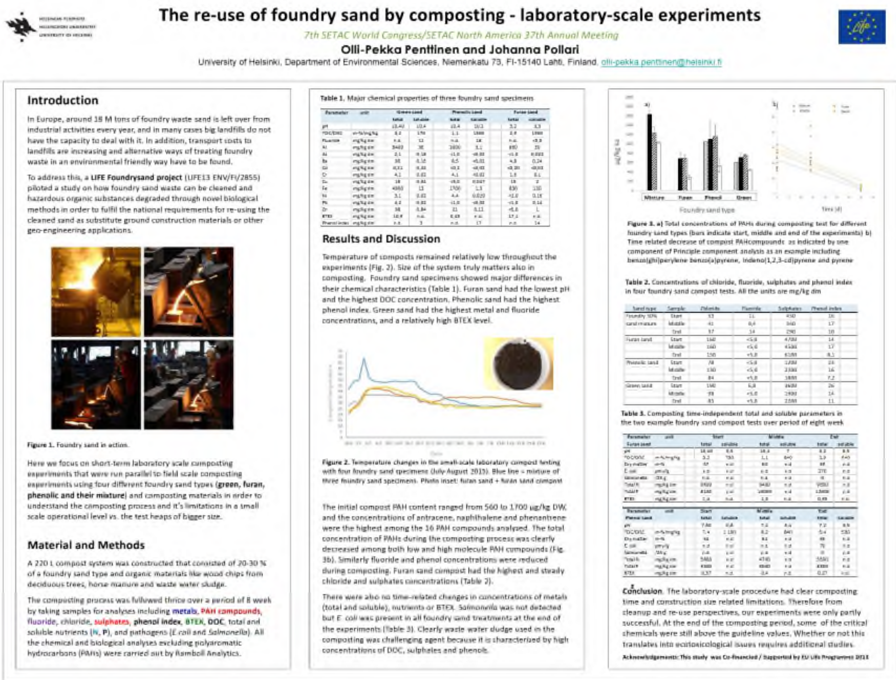
5.2.2.3 Action D3 Events

List of all Foundrysand project **dissemination events** in 2014-2018 is presented in Deliverable C1 Monitoring activities in 2014-2018 (Appendix 2). **In total 24 seminars/events/exhibitions were participated** by partners during the project of which 9 were oral presentations. These are listed herein.

Oral presentations of Foundrysand LIFE -project in 2014-2017:

1) Markku Tapola (Meehanite) gave a presentation at **Life 2014 info seminar** and workshop in June 2014 arranged by Ministry of the Environment in Finland. *40-50 participants*.
2) Markku Tapola gave a presentation at **Finnish Foundry Technical Association seminar** (SVY) on 5.2.2016 in Tampere, Finland.

3) Ms Mari Dahl (HU) gave presentation at "**Mutku päivät –conference**" with a theme of sustainable soil restoration in Finland" on 28-30.3.2017 in Tampere for "Haitta-aineiden tunnistaminen sedimenteistä ja maa-aineksista vaikutusperusteiden analyysin avulla".
4) Prof Olli-Pekka Penttinen (HU) gave a presentation on "harmful substances in Foundry sand" at **Lahti Science Day** on 15.11.2016, Finland.
5) Prof Olli-Pekka Penttinen participated in the **7th SETAC World Congress in Orlando, FL, USA**, from 6-10 November 2016 he had a poster presentation (also oral presentation of poster) during the congress.



6) Sara Tapola, Markku Tapola and Prof Juhani Orkas (Meehanite) and Seppo Heinänen (AX) gave presentations at **Foundrysand LIFE project seminar** on 27.4.2017 in Tampere, Finland

7) Participating in **FEAF (Spain Foundry Association) seminar** in October 2016 in Spain where Patricia Caballero gave a short presentation of cleaning the surplus foundry sands by composting method. 28 *participants.*
8) Participating in **SPRI (Basque business and Department of Environment and Regional Planning development agency) seminar** on 4th November 2016. Presentation by Patricia Caballero. Participants: 7 foundries, 2 persons from FEAF, 3 persons from Basque government environment and 2 persons from IHOBE (the Basque Environmental management company).
9) **CAEF Commission meeting for Environmental work group Porto Purtugal on 18-19.10.2017**. Prof Juhani Orkas is a member of this Committee. Oral presentation of the Foundrysand project results. *20 participants.*

5.2.2.4 Action D4 Publications and the dissemination material

Project second and revised leaflet was produced in March 2015 after the access of two new partners by April 2015.

Roll-ups were also renewed and produced in May 2015 to partners.

Altogether six (6) articles and one poster were produced during the project.

- Three articles at the AX magazine were produced by Meehanite and AX personnel in Finnish in 2014-2016. On article in AX magazine in 2017 .

- Tecnalia has produced two articles in Spanish in 2016.

- A poster presentation at 7th SETAC World Congress in Orlando by Prof. Dr.Olli–Pekka Penttinen in October 2016 (attached in progress report in June 2017).

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LIFE logo (flag) was used in reports, presentations, publications. In addition the sentence “Supported by EU Commission LIFE Environment Programme 2013” was used.

5.3 Evaluation of Project implementation

Evaluation of the project implementation actions is presented in Table below.

Task	Foreseen in the revised proposal	Achieved	Evaluation
Action A1. Preparation of compost sites in Finland and Spain	Construction and preparation work of the pilot site by the end of May 2015. Environmental permit for project pilot tests to be applied from national authorities.	Yes, completed. Yes, completed.	Because of the partnership changes of a new pilot site was searched in March-April 2015 and a new environmental permit was made in May 2015 for the new site. The new partner, PJH, provided a new site at waste treatment center in Koukkujärvi, Nokia. The change caused less than one month delay with the preparation work at site. Pilot tests in Action B3 were started 3 weeks later than planned. The environmental permit in Finland was received on 18th June 2015 from the Regional State Administrative Agency. The pilot site in Spain was at Composgune, S.L. This site is located in the center of the Basque Country, Ormaiztegi and it had the permission from the local authority (Composgune). This action was completed successfully and pilot tests were started as planned in summer 2015 in Finland and Spain.
Action B1. Surplus sand quality control and sand samples process in foundries	The guidelines of quality control and treatment of surplus foundry sand in foundries.	Yes, completed.	A guideline for the Finnish foundries was developed to assist them in setting quality control system criteria to control the quality of surplus foundry sand suitable for composting purposes. This action was completed successfully in April 2016 and the final deliverable was updated in Action B6 by 12/2017. The results of this action are visible right after the project.
Action B2. Compost processing on laboratory scale	Small scale experiments on laboratory scale have was carried out to investigate the driving parameters for the process under controlled conditions, not only to receive repeatable results but also to define the optimal process	Yes, completed.	Outdoor field tests were carried out at the Jokimaa field station in Lahti for soil and sediment studies in 2015. Parallel also small-scale laboratory tests were carried out in 2015-2016. Results were not satisfactory and therefore additional lab scale tests

	conditions for field tests.		were repeated in 2016. Also toxicity tests were carried out based on the results from the first lab scale tests in 2015. Based on the results the small scale lab tests were found out challenging due to the small amount of compost material in one container (á 250 liters /each) compared to the "real-life composting test heaps"(20-40 tons/each). Tests were successfully completed with big heaps, but relevant information was received form the lab scale tests even if tests were not completely successful. Also toxicity tests of foundry sand specimens were studied. Some sand types appeared to be more toxic than others. More tests are needed in the future. The results of this action are visible right after the project.
Action B3 Composting tests in Finland	In total 17 test heaps and a meadow test were constructed and tested. Hazardous organic compounds of surplus foundry sand will be cleaned by about 95%. Through piloting around 500-600 tons of surplus foundry sand composting material will be cleaned with the innovative composting method. During piloting studies all relevant environmental impacts were investigated.	Yes. Achieved. Yes. Achieved Yes. Achieved Yes. Measurement completed.	**20 small scale composting test heaps** were constructed and tested in 2015-2017. Also meadow field test was carried out in 2016 at Koukkujärvi pilot site. The composting end-products fulfilled the limit values set in the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products 24/2011 and the end-product can be used as mixture soil for gardening purposes. **In total 960 tons of surplus foundry sand composting material** was cleaned in Finland and Spain during the project. The environmental impacts were measured and evaluated during the project in Finland and Spain. Air emissions, waste water effluents form pilot sites were measured. The dispersion modelling of odours during the composting process was calculated by AX. Emission measurement and waste water results are also presented in the deliverables of Actions B3 and B4. The results of this action are visible

			right after the project.
Action B4. Composting tests in Spain	In total 12 small scale pilot tests will be carried out.	Completed.	In total **8 test heaps were tested in Spain**. There was a restriction in the permit that only two test heaps were allowed to be tested at the time. Even if less test heaps were tested in Spain, more tests were carried out than planned in Finland. Also the total volume of the cleaned surplus composting material was achieved in Finland and Spain. Based on the results in Spain the tests were completed effectively and organic hazardous emissions like phenols were reduced by 97 %. The results of this action are visible right after the project.
Action B5. Biological and chemical composting	Biological, physical and chemical parameters will be sampled and over 1,900 analysed from the pilot tests in Finland and Spain will be carried out.	Yes. Achieved.	Because of the withdrawn of one partner, Biopap Ltd, a new partner was needed. Eurofins Viljavuuspalvelu Ltd provided all biological and chemical analyses in the project. Eurofins Scientific is an international life sciences company which providing a unique range of accredited analytical testing services to clients in over 40 countries. In Spain laboratory services were provided by accredited laboratories Tecna Labaqua, S.A and Neiker. This action was completed successfully. **6,229 analyses were carried out in Finland and 2,367 analyses in Spain.**
	Deliverable “Report on the analytical methods and results” will be produced by the end of the project.	Yes. Completed.	Sampling procedure and analyses were agreed in the environmental permit with the local authorities. Deliverable B5 “Report on the analytical methods, sampling procedure and list of analyses” is ready. Results of the tests in Finland and Spain were reported in deliverables under Actions B3 and B4 after each test period. The results of this action are visible right after the project.
Action B6.Conclusions and project outcomes	1) Report "Applicability of cleaned foundry sand	Yes. Completed.	1) Deliverable B6_2 Applicability of cleaned foundry sand recycling in

	recycling in Finland, Germany and Spain (limit values, applicability and market approach)".		Finland, Germany and Spain" was produced by a subcontractor and Meehanite. Replicability and transferability of the composting method implemented across Europe will be visible in 2-5 years after the project.
	2) Practical guide "Construction recommendations for composters of cleaning the foundry sand by composting".	Yes. Completed.	2) Deliverable B6_3 Practical guide construction recommendations" was produced by Meehanite. The practical guides and construction recommendations are presented as principals without details because each national authority will set requirements of their own for each case individually based on regulations and the environmental permit of the applier.
	3) Practical guide "Surplus foundry sand quality control in foundries"	Yes. Completed.	3) Deliverable B6_1 Surplus foundry sand quality control in foundries was updated during the Action B6 activities. Results of the implementation of the manual in the foundries will be visible in 2-5 years after the project.
Action C1 Project monitoring	Three Progress reports of monitoring the impacts (2015-2018)	Yes. Completed.	Deliverable C1 Monitoring activities covering the project duration of 2014-2018.
Action D1 Notice boards and Layman's report	2 notice boards will be produced	Yes. Achieved.	2 project notice boards were placed on pilot sites (Finland and Spain)
Action D2 Website and social media	Project website life-foundrysand.com	Yes. Completed.	Project website was opened in January 2015. Relevant information was placed on site and they will be maintained by the coordinator 5 years after the end of the project.
Action D3 Events	5-10 events will be participated by the project consortium	Yes. Achieved.	In total 24 events/seminars/exhibitions were participated of which nine (9) were oral presentations.
Action D4 Publications and the dissemination materials	3 technical publications	Yes. Achieved.	In total **six (6) articles** were released and **one (1) poster presentation**. **Laymans report** produced.
Action E1 Project management and reporting by Meehanite	Partnership agreements will be made. 4 progress reports will be delivered to the Commission. Project meeting memos will be produced	Action is progressing as planned	Revised partnership agreements have been produced and delivered to the Commission on 23rd November 2015. Inception report was delivered in April 2015. Midterm report was delivered in June 2016. Progress report was delivered in June 2017.

			Final report was delivered in May 2018. Memos were emailed to partners.
Action E2 Networking with other LIFE projects	10 contacts in other LIFE projects	Yes. Completed.	2 relevant LIFE projects have been found and contacted. Cooperation possibilities are planned in 2018.
After LIFE Communication plan	After LIFE Communication Plan will be produced	Yes. Completed.	Deliverable E3 After LIFE Communication Plan ready
Action E4 Project auditing	Project auditing will be made at the end of the project	Yes. Completed.	Audit report ready

5.4 Analysis of long-term benefits

1. Environmental benefits
   a. Direct / quantitative environmental benefits

   <u>The highlights of the project are:</u>

- As the result of the LIFE-Foundrysand project the contaminated surplus foundry sands can be kept away from the landfills;
- Through piloting in 2014-2017 960 tons of surplus foundry sand composting material was cleaned by the innovative composting method;
- In total of 20 test trials was carried out in Finland with different foundry sand types (furan/phenol/green/cement sand);
- In total of 8 test trials was carried out in Spain with different sand foundry sand types (green/phenol/silicate sand);
- Additionally small scale composting test trials were carried out on laboratory scale by Helsinki University in Finland;
- The hazardous organic compounds (like phenol index, PAHs) were successfully cleaned with the efficiency of more than 95%. The final composted end-product has fulfilled the regulations and limit values set in *the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011): Substrate – Mixture soil (5A2);*
- The increase of re-use of industrial waste material by in other applications instead of dumping in landfills.
- The new compost end-product is ready to be used in geo-engineering applications right after the end of the project when the national requirements are met.

   b. Relevance for environmentally significant issues or policy areas

The targets of the project address and support the following EU Targets (Mainstreaming sustainable development into EU policies: 2009 review of the European Union Strategy for Sustainable Development; Brussels, 24.07.2009):

- Climate change (and clean energy);
- Sustainable (consumption and) production and waste prevention;
- Conservation and management of natural resources.

Within the goal "climate change impact" it shall be found out if the new process will be advantageous with respect to methane, CO, and CO_2 production by microbiological degradation.

The project activities support the EU Waste Frame Directive (2008/98/EC) in increasing the reuse of the industrial waste in other applications and increasing the recycling of waste instead of landfilling. Project aim is to reduce the amount of surplus foundry sand to be landfilled and to find cost-effective innovate method to reuse the industrial waste in geo-engineering applications. The cleaned foundrysand be used for construction purposes e.g. in green field construction work, noice embankments, football fields, etc.).

The European Commission adopted an ambitious Circular Economy Package in the beginning of 2016, which includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs. The revised legislative proposals on waste set clear targets for reduction of waste and establish an ambitious and credible long-term path for waste management and recycling. LIFE-Foundrysand project objectives are in line with the concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material.

2. Long-term benefits and sustainability

   a. Long-term / qualitative environmental benefits:

<u>The highlights of the project are:</u>

- The new innovative composting method was developed to clean surplus foundry sand. 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 can not be cleaned by composting method. Heavy metal containing sand specimens must be separated;
- To save valuable landfill space for residues which have not the capability of being re-used – especially not in such a highly valuable way;
- 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, bio-moulder products and moulder recipes including cleaned 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 geo-engineering (e.g. road construction) 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.
- To calculate the feasibility and effectiveness of the new method for Finland, Germany and Spain as pilot countries;
- To produce the manual for surplus foundry sand quality control in foundries. The manual can be adopted in about 200 silica sand foundries in Europe and that way to reduce dramatically the amount of surplus sand to be landfilled and
- To save money for European foundry industries by opening a further route of re-use of surplus foundry sand in other purposes and avoiding costly deposition in landfills.

b. Long-term / qualitative economic benefits:

In most countries several smaller landfills are being closed and replaced by large so called “EU landfills”, so the distances and transport costs to the landfills are also increasing for the foundry companies and alternative ways of treating those wastes in a more environmental friendly way have to be found. Aim is to reduce the transportation need of waste foundry sand to the centralized landfills that can locate far from the foundries.

In the future surplus foundry sands suitable for composting purposes could be transported to local composters or waste treatment centres for composting process or several foundries together could compost the sands themselves in suitable areas. The re-used and composted foundry sand could be a new spin-off product for foundries and a new end-product for composting and waste treatment companies. Based on the composting test results from the Foundrysand project the new compost end-product meets the requirements set for the “mixture soil material” (Fertiliser Products (24/2011) and is applicable for geo-engineering and green field construction purposes in Finland and Spain. So, instead of paying the high landfill fee costs, the foundries themselves could sell out the new product for geo-engineering purposes and get incomes in the future or they can transport the surplus sand to composter companies with lower costs for treatment.

c. Long-term / qualitative social benefits:

Socio-economic assessment of the project dealing with future visions of the sustainable composting system that can be transferred to areas (sand deponies) where over 200 foundries operate to clean surplus foundry sand for re-use purposes will be made. 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. The impacts of "centralised" foundry sand composting system were assessed through out transportation, logistical, employment and economical points of view. Also the impacts on local employment growth, end-product utilisation by different end-users were assessed. The results are presented in the deliverable B6_1” Applicability of cleaned foundry sand recycling in Finland, Germany and Spain made by subcontractor Prof Joachim Helber in cooperation with Meehanite.

d. Continuation of the project actions by the beneficiary or by other stakeholders.

- Foundrysand project website will be available at least until 2023. Deliverables (public versions) are available for public audience. The coordinator is responsible for maintaining the website.
- The recommendations for composting method use and construction work developed during the Foundrysand project can be implemented in Finland and in other EU countries
- The surplus sand quality control and sand samples process in foundries can be implemented in foundries representing the same sand specimens as tested in the project (furan, green sand and phenolic sand) in Finland and in other countries.
- Feasibility study and the market approach was implemented in Finland, Germany and Spain. Based on the studies there are different laws and regulations set for reuse of foundry sand in other applications in each country that have to be followed. Barriers of surplus foundry sand reusing potentials are commonly related to very strict limit values for harmful substances in each country and differences inside the countries. In this project we aim to provide more accurate information and results of the composting method to authorities to make the environmental permit procedure more easier and more coherent between countries.
- After the end of the project the composting companies can continue with the composting method. The environmental permit is needed.
- Pilot foundries involved in this project are provided with detailed instructions of the quality control system based on the project results.
- Pilot foundries involved have relevant and detailed analyse results of their surplus foundry sand specimens tested in composting process and they are ready to implement the cleaning process after the end of the process. Other foundries interested in the process need to make accurate analysis of their waste sand specimens.
- Meehanite will continue with the dissemination activities and know-how distribution work of the composting method.
- Meehanite will continue working with the authorities and composting companies related to the environmental permits, regulations and environmental impact assessment.
- Results will be actively disseminated in relevant events and seminars by project partners after the end of the project.

3. Replicability, demonstration, transferability, cooperation:

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, in total estimated of 18 Milj tons of foundry sand is produced annually of which about 13 Milj tons could be cleaned by composting method and reused in geoengineering 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. In Finland the Government Degree of 331/2013 sets regulations and limit values for waste foundry sand reuse possibilities. The regulations and limit values vary in each country. Our aim is to provide authorities relevant information and results of the cleaned foundry sand to enable the reuse possibilities.

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. The re-use of foundry sand in composting purposes requires nowadays always an environmental permit in Finland. Discussions with Finnish authorities (ELY-keskus, Aluehallintovirasto RSAA) have been made to give more information of the innovative treatment method and project results to make the environmental permit procedure more easier and shorter for new appliers in the future.

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. This is not the question of sand types alone but especially the residuals coming from the mould bonding system. 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. The aim is to sell this method for composting companies and waste treatment centers in the future. A novelty search of different organic raw materials and different surplus foundry sand types was carried out in this project to find out that there are no patents existing for different composting raw materials tested in this project.

The composting method can be also used for cleaning the contaminated soils and humus materials where organic harmful compounds are present.

Restrictions for the vide transferability and replicability of the innovative composting method in European countries lay on the current environmental laws and regulations and existing environmental permission procedures. In some countries any kind of industrial waste composting is not allowed. The general attitude is still against the reuse of industrial wastes in geo-engineering applications such as surplus foundry sands even though the Waste Directive 2008/98/EC supports and fosters the reuse of wastes. The LIFE Foundrysand project provided results of the composting tests and environmental impacts. The LIFE project aimed to foster the circular economy by cleaning surplus foundry sands and reusing it in geo-engineering purposes. Based on the project results the concentrations of harmful organic substances were in many cases below the limit values of inert waste (331/13) already before the composting tests. So, many of the surplus foundry sand specimens tested in the beginning fulfilled the non-hazardous inert waste limit values already before starting the composting tests. By the end of the composting tests the existing harmful organic substances were degraded and the end-products were under the limit values set for Fertilizers Product 24/11 on mixture soil material. The innovative composting method is efficient and ready to be taken into wide use across Europe. Discussions and cooperation between authorities, foundry representative and composting companies are ongoing. Proper investigations and analyses of the surplus foundry sand qualities are always needed and the quality control systems of foundry sands will be created in each foundry. This way the innovative composting method can be recommended for the cleaning of surplus foundry sands.

4. Best Practice lessons:

Based on the project results from pilot tests in Finland and Spain the new compost end-product meets the limit values of “mixture soil material” (Fertiliser Products (24/2011) and it is applicable for geo-construction and gardening purposes. The composting method seems to be efficient enough in reducing the hazardous organic substances from surplus foundry sand specimen. Results have been presented to relevant authorities and regulatory bodies in project meetings on 9.9.2015 and 25.11.2015 and in project seminar on 27.4.2017 and 19.1.2016. The MARA decree was revised in late 2017 (843/2017) and surplus foundry sand was included in the list of waste to be reused in the geo-construction purposes. Unfortunately it seems that the limit values of MARA of certain organic compounds are far too strict to different foundry waste sands as such in geo-construction purposes. It seems that foundry waste sands must be treated and cleaned first by other treatment methods (e.g. by composting). The reuse and recycling of surplus foundry sand was also a topic theme in the CAEF meeting in Porto Portugal on 19.10.2017 where Prof Juhani Orkas presented the project outcomes. By presenting the good results to relevant environmental authorities and foundrymen the aim is to convince that this is a feasible and safe method. Foundrysand project aims to provide all analyses results to authorities when they evaluate the environmental impacts. By this way our aim is to make the environmental procedure easier for composter companies and waste treatment companies to start to implement this composting method.

5. Innovation and demonstration value:

The state of the art with respect to the primary quality of the foundry residues in question is a wide variety in quality. This variety is not only characterized by (widely different) concentrations of hazardous chemicals but also by the habit of mixing together different types of sands or even materials which should be kept separate from the surplus sand (like refractories, filter dusts, shot-blasting grains etc.).

These different qualities have primarily been investigated during the last three decades by different investigators like [Bradke (1993); Lemkow & Crepaz (1994); Orkas (2001)] and have been proven by thousands of waste declaration analyses.

The idea of composting was promoted mainly in the Nordic countries of Europe and the United States. The most prominent and complete example may be the CASKAD project – co-financed by EU funding (2005). These developments have slowly accessed markets but are not at all yet common or tested properly.

These activities aimed at the clarification of the question how this class of materials can be deposited safely. Most of the foundry waste sand cannot be directly re-used without cleaning. Also the material which this Foundrysand project is dealing with in the testing phase has a quality (in terms of the level of contamination) which would be rejected by the mentioned regulations and limitations and thus needs to be cleaned properly to be re-used applying this innovative composting method.

Negotiations and discussions with foundries and relevant authorities like RSAA, Centre for Economic Development and Transport and Environment and the environmental authority in Nokia municipality were arranged in 2015 to introduce this innovative method and end-product for potential end-users construction companies, municipalities, farmers, etc).

The new tools, quality control manual for foundries and sample procedure have been created in this project in order to make this innovative composting method easier to take into use. Negotiations of these requirements and monitoring the process and environmental permit issues with relevant authorities have been carried out during the project.

6. Long term indicators of the project success:

- Number of composters/waste treatment companies applying the innovative composting method in cleaning the surplus foundry sand by composting method
- Number of foundries applying the innovative composting method in cleaning the surplus foundry sand by composting method

- Amount of surplus foundry sand treated by composting method (tons)
- Amount of new end-users for the new end-products (geo-engineering, road construction, green area construction, etc applications)
- Amount of foundries applied for the “surplus sand quality control and sand samples process in foundries” system
- Amount of environmental permits or other announcement procedure to relevant authorities for taking into use the innovative composting method
- Reductions in landfill use for dumping the surplus foundry sands (tons)