Action B.4 Recycling options and sand purification of inorganic surplus foundry sand, high concentration organic waste sand and dusts

DeB4.6 Life Cycle Assessment report on tested methods

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Content

1. Introduction

Life Cycle Assessment is carried out to assess the environmental impacts of the technologies and methods tested in the Green Foundry LIFE project in the Action B4 Recycling options and sand purification of inorganic surplus foundry sand, high concentration organic waste sand and dusts. This will include monitoring both positive and negative environmental impacts at all steps of the process.

The methods to be presented in this report are:

1) Composting method
2) Washing method
3) Thermal reclamation and
4) Ultrasonic + microwave thermomechanical treatment

The environmental impacts assessed in this report are based on the results and experiences from the pilot scale tests carried out in the Green Foundry LIFE project (LIFE17 ENV/FI/000173) and LIFE Foundrysand project ((LIFE13 ENV/FI/000285) composting tests in 2014-2017. In case of the thermal reclamation method there are also experiences and results from industrial scale application existing in Finland. Washing test experiences are based on the laboratory scale tests by Tecnalia Research&Innovation and discussions with the ECOFOND company which was closed in end of 2018 just after the project started.

2. Composting method

2.1 Constructing the composting site

Positive environmental impacts

- In composting process different organic waste materials can be reused and cleaned instead of landfilling. Therefor it is recommended to look for alternative reuse applications for organic based wastes than to be landfilled.
- Composting of organic waste based materials will reduce the total amount of wastes to be landfilled and increase the recycling of different raw materials.
- There are already existing composting companies producing composting material and mixture soil material. They have all the environmental permits existing for composting process and wastewater treatment system. Such companies can introduce cleaning of foundry waste sand by composting method in their existing business.
- The positive environmental impact for constructing a composting field is that different local waste materials can be reused in composting process and transformed into a valuable new products and materials. This will enhance the circular economy and reduce the need of long distance transportations.
- In case a new area is needed the environmental and construction permits must be applied from regulatory bodies. Composting field will be constructed in a way that there will not be negative environmental impacts in the environment.
    - Asphalt surface is needed with dimensions of double layer asphalt: top layer 1 asphalt cement AB 16/125, thickness 50 mm, top payer 2 watertight asphalt cement 16/125, thickness 50 mm.
    - Wastewater collection and treatment system (biological or municipal treatment plant) at the site will be constructed and there will not be negative impacts on the surrounding ground or water systems. Also waste waters from the surrounding will be blocked.
- In the permit the observation programme is created in cooperation with the local authorities and the environmental impacts (e.g. wastewaters, odors) are regularly monitored.

Negative environmental impacts

- Depending on the site and facilities existing at the planned site, the negative environmental impacts during the construction work may vary.
- *In case the composting site will be constructed from the beginning*, there will be some temporary negative environmental impacts during the construction work. Such as
    - *composting field construction work*
    - *noise* from lorries and construction machines
    - *dust* from ground construction work
    - increased *traffic*
    - *Wastewater collection and treatment systems* construction work
      (closed system or integrated system to the municipal waste water treatment plant)

2.2 Operation and capacity of the composting process

Positive environmental impacts

- In composting process different organic waste materials can be cleaned and reused in new applications instead of landfilling.
- Reuse of local organic waste materials e.g. animal manure (cattle, horse, poultry), garden waste material, wood sticks and twigs, household waste in composting material production.
- Composting process will reduce the total amount of foundry waste sand, dust and other organic waste materials to be landfilled.
- In a composting field, size of 30x150 m = 4500 m^2, the planned annual composting material capacity is 1000 tons.
- The annual capacity of 1000 tons of compost means that 300 tons of waste sand or dust can be cleaned and treated instead of landfilling.
- Aim is that foundries will transport the waste sand and dust to be cleaned by composting process. In a normal composting process the virgin sand is added in the end of the composting and it is transported from the gravel pits. In the piloted composting process the foundry waste sand is added in the composting process already in the beginning of the composting and the harmful organic substances like DOC, TOC, phenols, BTEX, PAHs are degraded during the composting process and the end-product will be clean of harmful substances.
- The clean end-product will meet the national regulations and limit values set for the compost end-product are set in the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011): Substrate – Mixture soil (5A2).
- The end product will be clean and free of harmful substances and it can be used in green-construction purposes as soil material, in noise embankments etc.
- Other organic waste materials like animal manure can be re-used in the composting process as additive material. Normally animal manure is used as source of nutrients in the fields in summertime. Farmers or horse stables have problems during the wintertime when manure can not be used in fields and big storages are needed. Composting process takes place around the year, so this would help farmers with the manure problem in wintertime and farmers would not have to invest in big manure storages.
- The logistic place for a composting field should be considered based on the availability of raw materials from foundries, local farmers and horse stables. Shorter distances would also create savings in transportation costs. Composting site could be established in the near vicinity of the foundries or landfills where other raw materials would be available.
- Composting process itself is a very cost-effective process producing cheap and clean mixture soil composting material from different waste materials. The process itself requires only mixing the composting materials two to three times during the composting process and some electricity for heating and aerating the heaps. Heating and aerating is an alternative treatment to speed up the composting process.
- In case the waste waters are ducted directly to the municipal wastewater treatment plant, then there is no need for any transportation. In the environmental permit the regulations and limit values are set for wastewater quality and these are regularly monitored.
- In the composting process no water is needed for the composting process, so there will not be any waste waters from the process itself. Only rainwaters from the composting site will occur which is collected and treated in the wastewater treatment system or conducted to

the municipal wastewater treatment plant. The composting field is constructed in a way that no rainwater or leachates from surroundings can spread to the composting site.

- There are composting companies already existing with suitable facilities, wastewater collection system and permits, and it is very easy for these companies to start using foundry waste sands as one of the raw materials instead of virgin sand in their composting process. This will also cause cost savings when companies do not have to purchase the pure virgin sand which is needed in the final product.
- The composting process will take in total of 12 months so that potential harmful substances will be effectively degraded during this time period. No effluents and negative environmental impacts into the surrounding ground or water systems are expected.
- The cleaning efficiencies vary from 70-95% depending on the substances. The compost end-product meet the national regulations and limit values and it can be used safely in green construction applications.
- Composting process will not have any remarkable negative impacts in the environment in spite the occasional odors when constructing the compost heaps.
- The composting process is very cost-effective. Actual costs of composting treatment for waste foundry sand is ca. 30 €/ton.

Negative environmental impacts

- The most noticeable issue of the composting process relates to existing odors while constructing and mixing the composting heaps.
- Environmental impacts as odour emissions, dust and wastewaters have been monitored and assessed in the piloted composting tests in the Foundrysand and Green Foundry LIFE projects. These test results demonstrate that the harmful substances in the foundry waste sands are well degraded in the composting process and there are no remarkable negative environmental impacts to the surrounding area.
- *Emissions to air and odour emissions* have been monitored and measured in 2015-2016 during all the steps of the composting process.
  - Carbon dioxide (CO_2) is formed because of the active degradation of microbes during composting. Also the consumption of oxygen is intensive and adequate availability of oxygen is important to ensure the good quality of compost material. CO_2 concentrations were high in the beginning and decreased during the tests. The oxygen level was good and increased during the tests.
  - When the composting is proceeding, the ammonium nitrogen will oxidize into nitrates by nitrification bacteria that are usable for plants. Also when the temperatures are highest some part of the nitrogen will evaporate into air as ammonia.
  - Temperatures of test heaps start to rise rapidly right after construction of the test heaps. Based on the measurement results, there were also high concentrations of CO, formaldehyde, benzene and odours present in some test heaps.
  - In the middle of the tests, emissions were reduced greatly compared to the results in the beginning. In the final emission measurement most of the emissions were under the detection limit values. Methane and carbon monoxide were detected which demonstrate that the composting was not completed yet and the post-composting was needed for 5-6 months.
  - Odours existed mainly in the beginning of the composting tests and while construction work. Odour emissions were reduced remarkably during the tests.

Occasional odours existed while mixing the test heaps but these can be considered minor. During the final measurements only small odour amounts were detected.

- *Wastewater samples* have been analysed always during the tests. Based on the test results there have not been any exceptional high concentrations from the composting tests.
- As a conclusion no remarkable negative environmental impacts are expected to the surroundings, surface, ground water in case the composting process is handled on the site according to the instructions and wastewater treatment system is maintained.
- Temporary odor or dust problems may occur while constructing and mixing the composting test heaps.
- Composting process is not a rapid process and it will take in total 12 months with the post maturing. This should be considered when measuring the compost field. The active cleaning process will take about 5-6 months after which the post-maturing will take place another 6 months. During this time the compost material should be placed on the compost field with a proper waste water treatment system.

3. Thermal reclamation method

Positive environmental impacts:

- Reduces the need of new sand at foundries by 70-95 % as some sand always turns o dust
- Reduces the net lifecycle greenhouse gas emissions from foundry sand by 50-70 %
- Reduces shipping and transportation for sands as those can be circulated locally
- Reduces amount of sand which needs to be landfilled by 70-95 %
- Instead of ending up into the ground from landfilled sand, the resins are burned in the thermal treatment into less harmful substances.

Negative environmental impacts:

- Uses a fossil fuel as energy source, though his can be mitigated in the future by use of biogas
- Thermal reclamation causes GHG-emissions at the reclamation site
- Depending on the resin, thermal reclamation can cause sulfur oxides as flue gases, which have to be treated with appropriate filters.

4. Washing method

4.1 Constructing the washing process plant

Positive environmental impacts

- Through washing, the hazardous elements present in WFS are reduced or eliminated at 36% to 100% efficiency
- The chemical washing of WFS would remove hazardous elements that would otherwise remain active in landfill, potentially coming into contact with other reactive materials
- Valuable landfill space would be freed up for highly toxic materials that have no other alternative
- The best washing efficiency is found in the most commonly used WFS – organic sand from green moulding (source: FEAF), potentially having a wide impact
- Washed WFS contains 80% fewer fines than raw sand and 50% fewer RCS (residual crystalline silica <0.05 mg/m3). In view of forthcoming regulations ((UE) 2017/2398) this reduces health risks and improves foundry worker efficiency (reduced use of restrictive PPE)
- The adoption of this method would reduce the need for new extraction as washed WFS can be reused to make cores, and, in optimal circumstances, new moulds
- By locating a plant strategically close to several foundries, transport related emissions could be minimized and reduced against transportation to landfill
- Chemical washing plants would operate without combustion processes and would be CO2 neutral

Negative environmental impacts (process)

- The process requires large quantities of HCI – 140 litres per 100 kilos WFS. This cleaning agent itself requires neutralizing

- The process requires large volumes of distilled water – 300 litres per 100 kilos WFS (75% recoverable by use of a closed circuit)

4.2 Operation and capacity of the washing process

Positive environmental impacts:

- Compared to the composting method, a washing plant occupies a relatively small area of land (approx. 50% less for the same capacity)
- The washing processes are quiet, C02 and odour free
- Equipment needs little maintenance and is efficient

Negative environmental impacts:

- Operating with HCI requires special personnel protective equipment and acid resistant materials

Advantages and disadvantages of leaching methods

Method	Advantages	Disadvantages
Single acid and washing	Acid solubilises most minerals such as phosphates, carbonates, sulphates depending upon the acid used	Not all the minerals are washed with just one acid
Stepwise acid washings	Two acids could be used with the ability of one acid to remove those minerals which could not be removed in the earlier washings	The use HF, HCl and HNO3 would require special and rugged materials of construction of reactors.

5. Ultrasonic + microwave thermomechanical treatment

Contrary to what was initially planned, microwave and thermomechanical treatment technologies were not retained to treat inorganic sand waste, because in the meantime, CTIF has identified particulary effective hydromechanical and ultrasonic technologies.
As a result, CTIF has developed two innovative processes to clean up inorganic sand waste, and used them as part of the Green Foundry Life project.
These two hydromechanical and ultrasonic treatment processes were compared to a mechanical treatment process by attrition, on a laboratory scale.

5.1 Implementing the hydromechanical method on an industrial scale

Positive environmental impacts

- Reduces the need of new sand at foundries by 95-96%, the 4-5% correspond to processing losses
- Reduces the net lifecycle greenhouse gas emissions from foundry sand by 50-70%
- Reduces shipping and transportation for sands as those can be circulated locally
- Reduces the amount of sand which needs to be landfilled by 95-96%
- The hydromechanical treatment process makes it possible to recycle the sand treated internally, or to reuse it in geo-construction or road engineering
- Modern means that limit the impact on the environment can be integrated into the hydromechanical process to carry out the filtration of the rinsing water
- Rinsing operations can be done in a closed loop to reduce the amount of water consumed per ton of sand processed

Negative environmental impacts

- The sand rinsing operations carried out in an open loop during the hydromechanical treatment generate a quantity of wastewater that must be filtered (5.5 to 8 m^3 per ton of treated sand, depending on the number of rinses carried out)
- Sand must be dried after the rinsing operations
- Wastewater filtration treatment generates 4 to 5% waste (not analyzed to date)
- Hydromechanical treatment requires a minimum of 4 rinses, otherwise the pH of the waterwaste must be regulated

Operation and capacity of the hydromechanical method

Positive environmental impacts :

- The hydromechanical treatment does not generate dust or fumes in the atmosphere
- The hydromechanical process is quiet, CO_2 and odour free
- The water discharged after filtration complies with the standards (checked for aluminium castings but to be checked for steel casting)

Negative environmental impacts :

- The sand drying operation requires a large amount of energy (fluidized bed drying system)

5.2.Implementing the ultrasonic method on industrial scale

Positive environmental impacts :

- Reduces the need of new sand at foundries by 95-96%, the 4-5% correspond to processing losses
- Reduces the net lifecycle greenhouse gas emissions from foundry sand by 50-70%
- Reduces shipping and transportation for sands as those can be circulated locally
- Reduces the amount of sand which needs to be landfilled by 95-96%
- The ultrasonic treatment process makes it possible to recycle the sand treated internally, or to reuse it in geoconstruction or road engineering
- Modern means that limit the impact on the environment can be integrated into the ultrasonic process to carry out the filtration of the rinsing water
- Rinsing operations can be done in a closed loop to reduce the amount of water consumed per ton of sand processed

Negative environmental impacts :

- The sand rinsing operations carried out in an open loop during the ultrasonic treatment generate a quantity of wastewater that must be filtered (6 to 8,5 m^3 per ton of treated sand, depending on the number of rinses carried out)
- The sand must be dried after the rinsing operations
- Wastewater filtration treatment generates 4 to 5% waste (not analyzed to date)
- Ultrasonic treatment requires a minimum of 4 rinses, otherwise the pH of the waterwaste must be regulated

Operation and capacity of the ultrasonic method

Positive environmental impacts :

- The ultrasonic treatment does not generate dust or fumes in the atmosphere
- The ultrasonic process is CO_2 and odour free
- The water discharged after filtration complies with the standards (checked for aluminium castings but to be checked for steel castings)

Negative environmental impacts :

- The sand drying operation requires a large amount of energy (fluidized bed drying system)
- Ultrasonic treatment is noisy and requires individual an environmental protection means

6. Reuse option of inorganic waste sand in geo-construction

In France, the costs and constraints are increasingly important for the landfilling of non-recovered sand waste (≈ 46.5% of the volume currently generated)

Positive environmental impacts of using inorganic binder system waste sand in geo-construction:

Using inorganic binder system waste sand in geo-construction and road engineering will reduce the volume of raw extraction. Reduction in the volume of non-inert and hazardous sand waste discharged by foundries

Negative environmental impacts of using inorganic binder system waste sand in geo-construction:

Nothing to report at this stage of development and feedback.