Tested surplus foundry sand recycling and reuse methods

Work carried out by CTIF for treatment tests :

- Mechanical treatment trials,
- Hydromechanical treatment trials,
- Ultrasonic treatment trials,

- Characterizations of sand samples carried out before and after treatment, to observe the impact of different technologies on inorganic sands and to choose the batches of sand to be submitted to leaching tests for identifying reuse options (sands before treatment, sands the least well cleaned and the best cleaned sands).

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Tested surplus foundry sand recycling and reuse methods

Differents waste sands inorganic :

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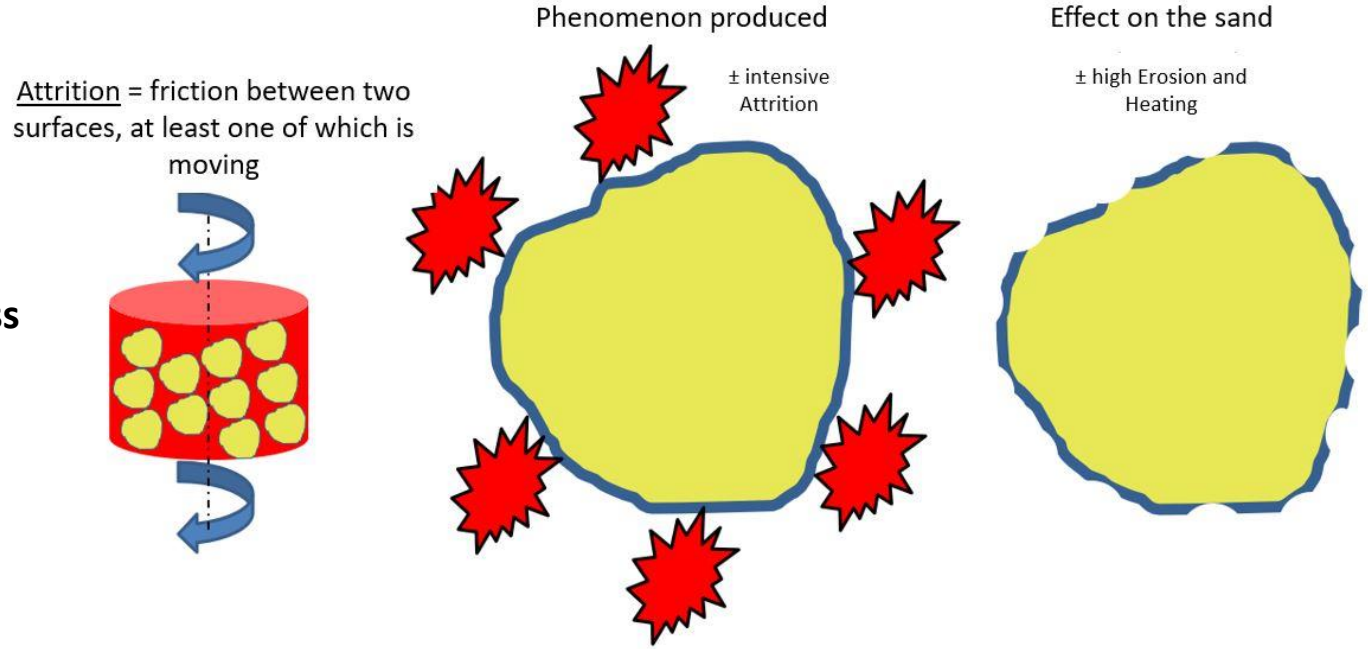
« The publication refle
ion contained »

Tested surplus foundry sand recycling and reuse methods

Comparison of mechanical/hydromechanical/ultrasonic technologies and identification of the most effective process for cleaning inorganic sand :

Mechanical treatment process



Source : CTIF

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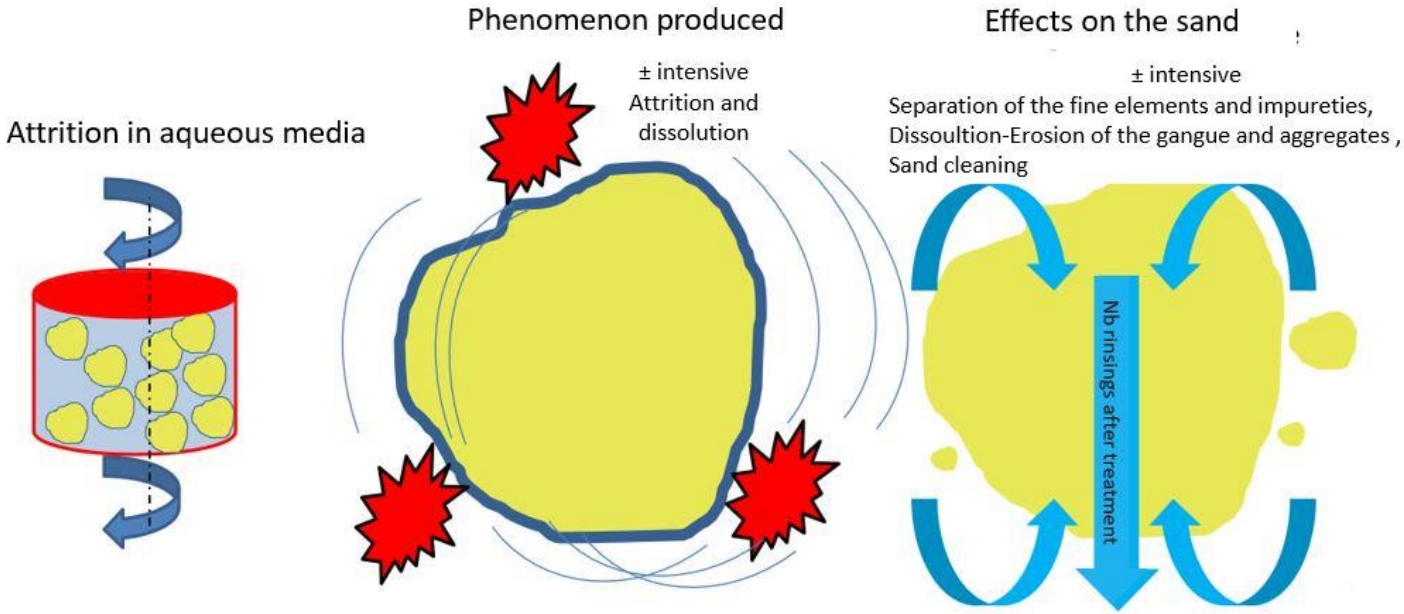
Tested surplus foundry sand recycling and reuse methods

Comparison of mechanical/hydromechanical/ultrasonic technologies and identification of the most effective process for cleaning inorganic sand :

Hydromechanical treatment process



Source : CTIF

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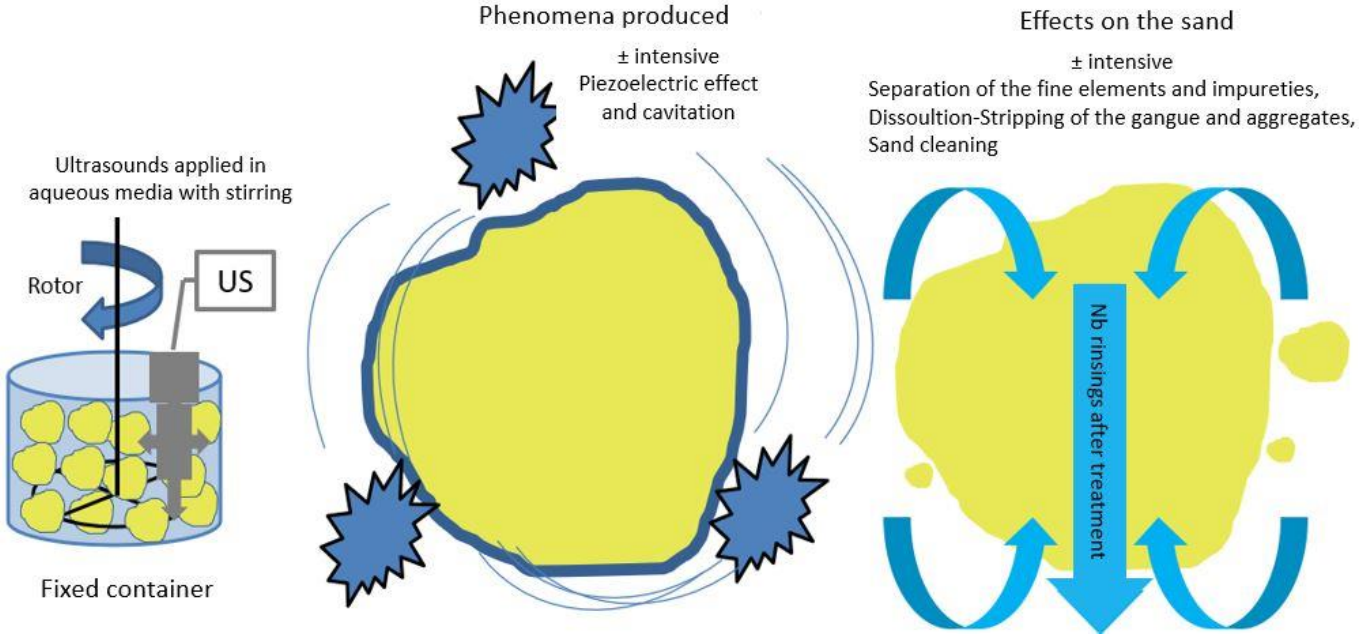
Tested surplus foundry sand recycling and reuse methods

Comparison of mechanical/hydromechanical/ultrasonic technologies and identification of the most effective process for cleaning inorganic sand :

Ultrasonic treatment process



Source : CTIF

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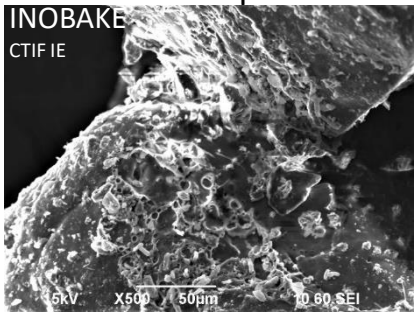
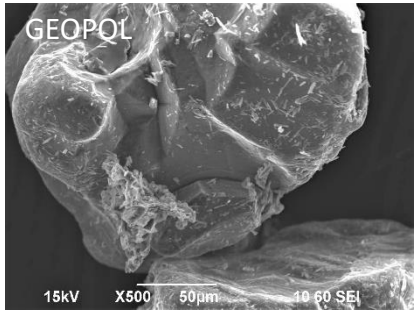
Tested surplus foundry sand recycling and reuse methods

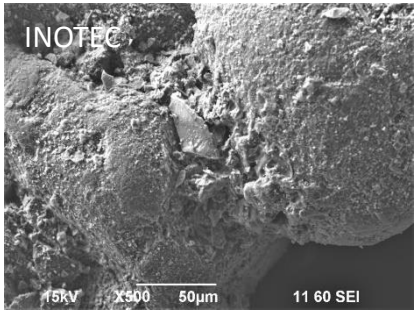
Comparison of mechanical/hydromechanical/ultrasonic technologies and identification of the most effective process for cleaning inorganic sand :

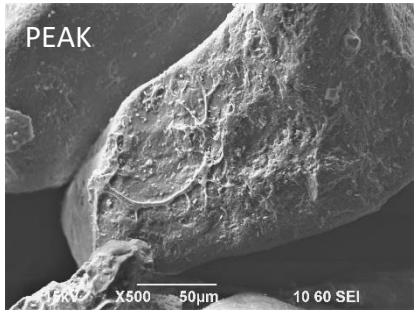
Same treatment time for all technologies

Results SEM expertise : waste sands **before treatment**

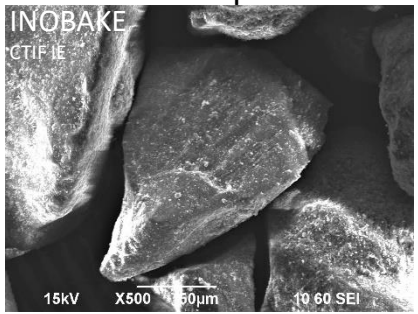


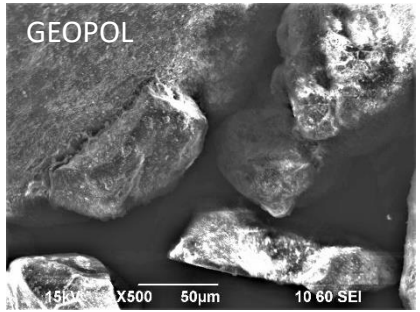


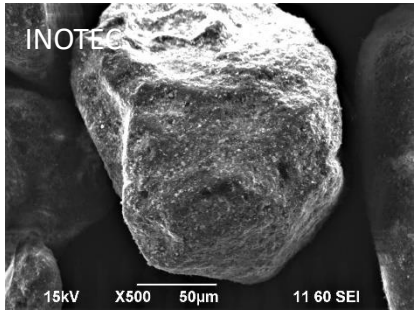


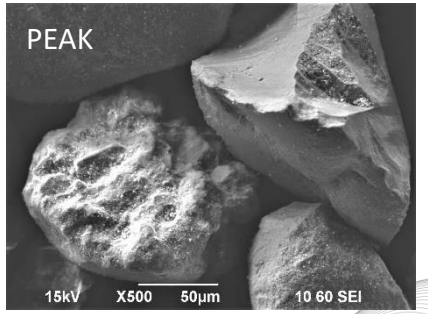


Results SEM expertise : sands **after mechanical treatment**









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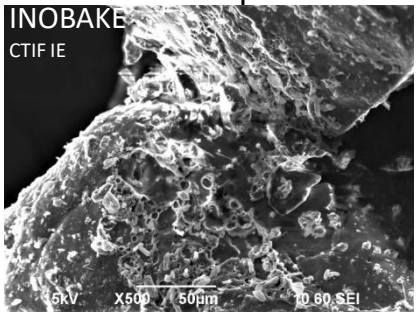
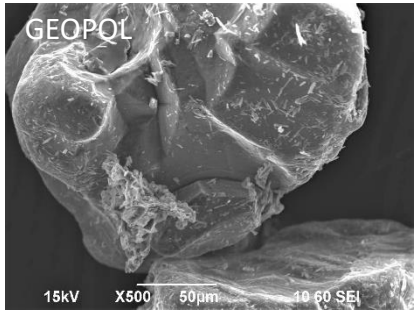
Tested surplus foundry sand recycling and reuse methods

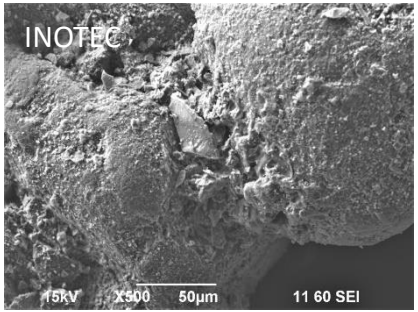
Comparison of mechanical/hydromechanical/ultrasonic technologies and identification of the most effective process for cleaning inorganic sand :

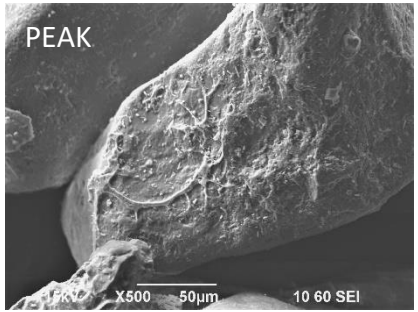
Same treatment time for all technologies

Results SEM expertise : waste sands **before treatment**

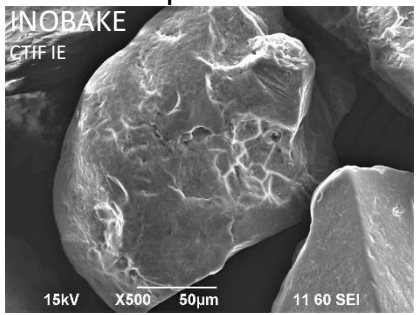


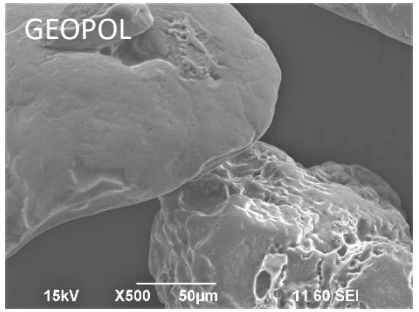


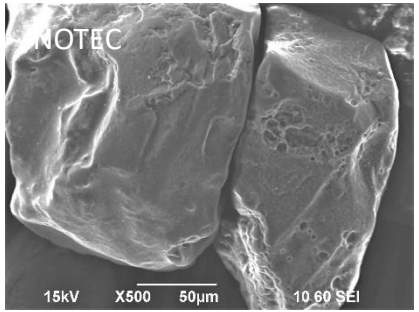


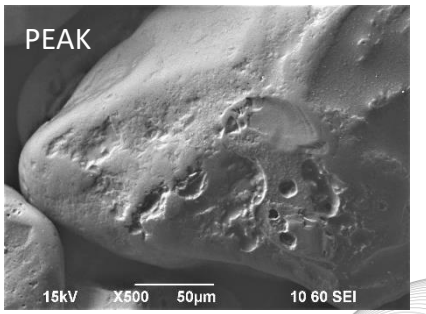


Results SEM expertise : sands **after hydromechanical treatment**









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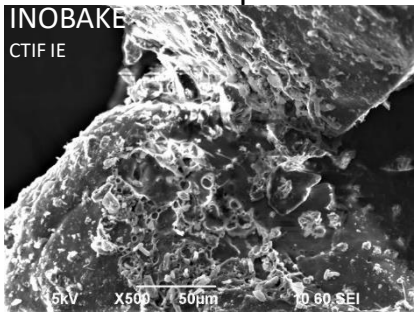
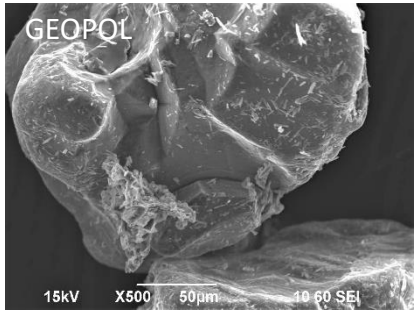
Tested surplus foundry sand recycling and reuse methods

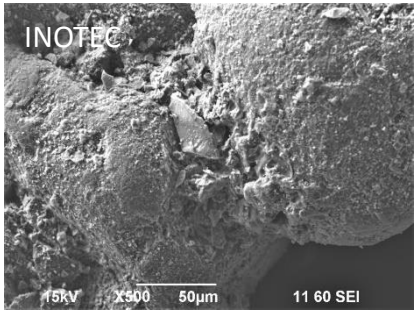
Comparison of mechanical/hydromechanical/ultrasonic technologies and identification of the most effective process for cleaning inorganic sand :

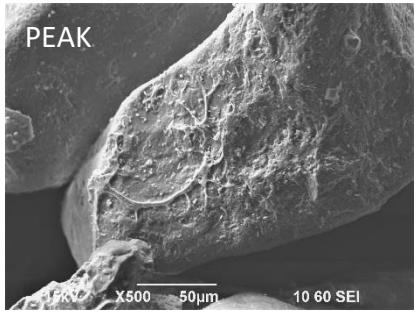
Same treatment time for all technologies

Results SEM expertise : waste sands **before treatment**

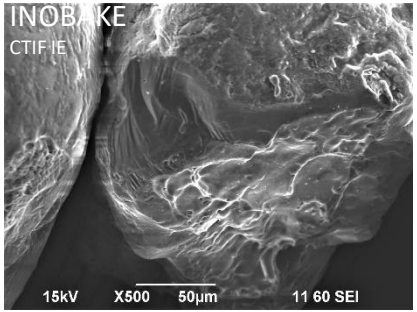


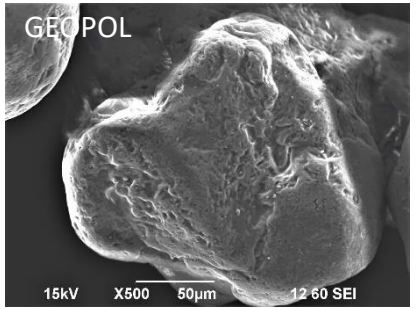


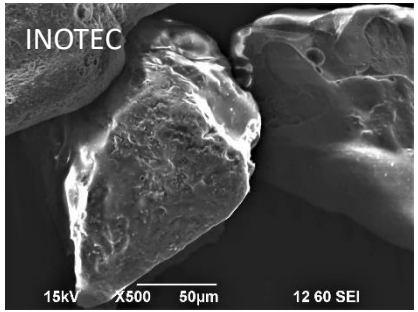


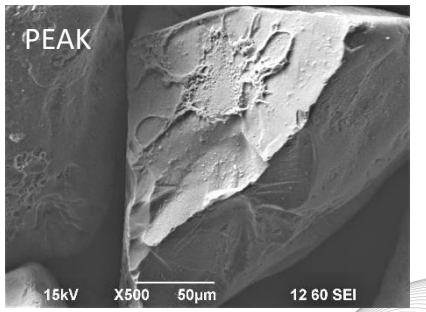


Results SEM expertise : sands **after ultrasonic treatment**









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Tested surplus foundry sand recycling and reuse methods

Core strength test and service life : comparison between the best cleaned treated sand (hydromechanical) and new reference sand (BE01)

Sand preparation: 2.5% resin + 0.30% hardener

Equipment and tools used to produce cores (standardized test pieces)

Source : CTIF

LIFE17 ENV/FI/000173 Green Foundry LIFE
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Tested surplus foundry sand recycling and reuse methods

Core strength test and service life : comparison between the best cleaned treated sand (hydromechanical) and new reference sand (BE01)

Test pieces removing

Measurement of flexural strength of test pieces

Source : CTIF

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Tested surplus foundry sand recycling and reuse methods

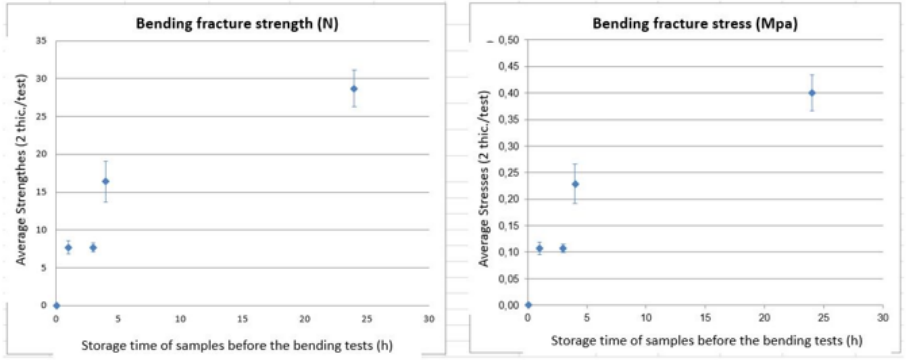
Results :

The strength of the cores made with the hydromechanically treated ”INOBAKE” sand and the service life of the prepared sand are similar to those obtained with the new reference sand BE01.

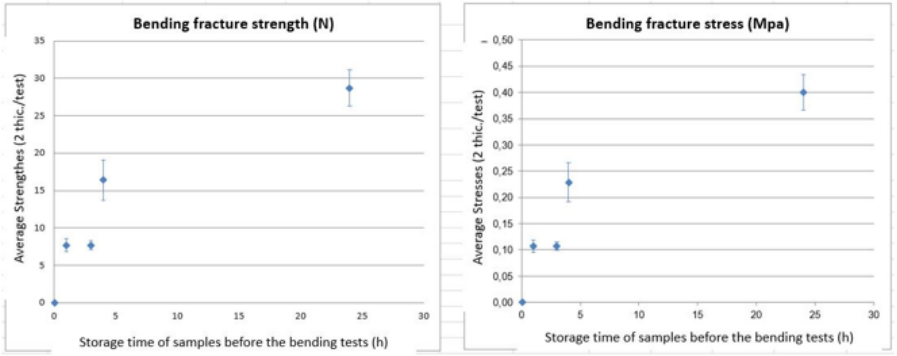
Conclusion :

This confirms that the hydromechanical treatment of inorganic sand waste is particularly effective for the reuse of treated sand in moulding or core making (and certainly in ultrasonic because the analyses results were equivalent).

With 100% of new sand BE01 : bending fracture stress = 0.400 Mpa



With 100% of CTIF IE sand hydromechanically treated: bending fracture stress = 0.405 Mpa



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Tested surplus foundry sand recycling and reuse methods

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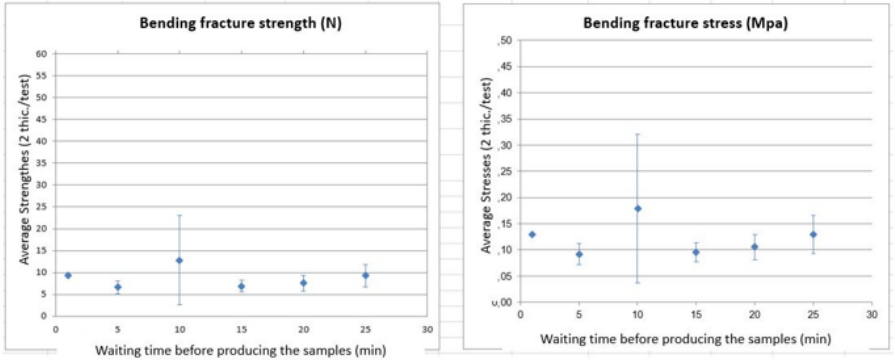
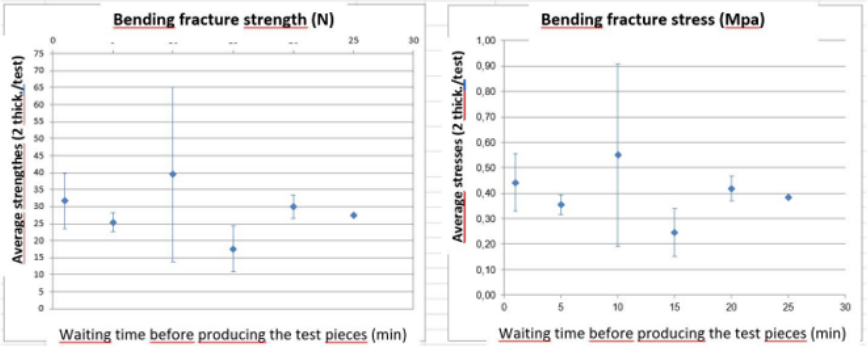
With 100% of new sand BE01 : life of the prepared sand



Comment: at T=30mn, hardening of the prepared sand and plugging of the machine's shooting head (unfilled test pieces)

With 100% hydromechanically treated CTIF IE sand: life of the prepared sand



Comment: at T=30mn, hardening of the prepared sand and plugging of the machine's shooting head (unfilled test pieces)

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Tested surplus foundry sand recycling and reuse methods

Means and resources used by CTIF :

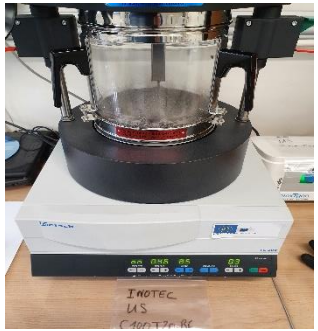
Mechanical pre-treatment of waste sand

Sands characterization

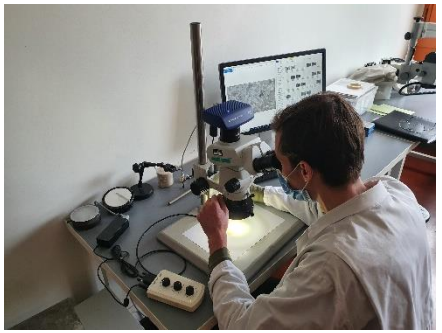
Mechanical treatment

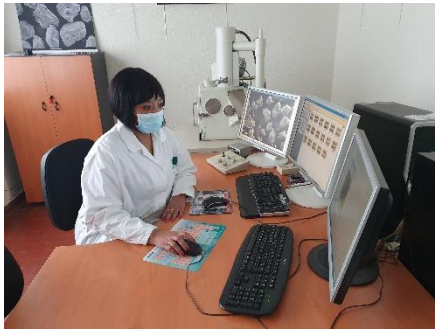
Hydromechanical

Ultrasonic treatment



Drying and dusting





Optical microscope and SEM expertise

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Leaching tests and identifying reuse options

Work carried out by CTIF :

- Leaching tests on inorganic sands waste,
- Leaching tests on treated inorganic sands (the least well and the best cleaned),

- Tables summarizing the results obtained in relation to the reference documents transmitted by the project partners (Spain, Finland, France, Italy, Poland).

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leaching tests and identifying reuse options

Summary table of documents submitted by partners :

Acceptance limit values in inert waste storage center (all countries)

Country	Germany	Spain	Filand	France	Italy	Poland
Reference document		Decree of 01.12.2015	Decree 843/2017	Decree of 12.12.2014	Decree of 02.05.1998	WAS Pollut 2016 TCLP*
Setting	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/litre	Limit values mg/kgMS
As		0,5	0,5	0,5	0,05	0,5
Ba			20	20	1	20
Cd		0,04	0,04	0,04	0,005	0,04
Cr		0,5	0,5	0,5	0,05	0,5
Cu		2	2	2	0,05	2
Hg		0,01	0,01	0,01	0,001	0,01
Mo		0,5	0,5	0,5		0,5
Ni		0,4	0,4	0,4	0,01	0,4
Pb			0,5	0,5	0,05	0,5
Sb		0,06	0,3	0,06		0,06
Se		0,1	0,4	0,1	0,01	0,1
Zn		4	4	4	3	4
Chloride		800	800	800	100	800
Fluoride		10	10	10	1,5	10
Sulphate		6000	1200	1000	250	1000
Phenolic compounds		1	5	1		1
DOC / eluate		500	500	500	30	500
Soluble fraction				4000		4000
DOC / raw				30000		30000
BTEX (sum)		< 6		6		6
TEX (sum)			25			
Benzene (LOQ 0,01 et 0,05 mg/kg dm)			0,02			
PCB-7 (sum)			1	1		1
Petroleum hydrocarbons C10-C40			300	500		500
Sum 16 EPA-PAH, excl. LOQ			30	50		1
Nitrates					50	
Cyanides					0,05	
Be					0,01	
Co					0,25	
V			2		0,25	
Asbestos					30	
Naphthalene			5			

* Water Air Soil Pollut (2016 : 227) - Toxicity Characteristics Leaching Procedure

MAJ du 14.01.2022

Source : CTIF

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leaching tests and identifying reuse options

Summary table of documents submitted by partners :

Acceptance limit values for sand reuse in geo-construction (Finland)

Finland	Reuse options in geo-contruction						
Channels	Roadway covered[1]	Roadway paved[1]	Field covered[1]	Field paved[1]	Embankment	Floor structure of industrial or storage buildin	Crushed stones and ash[2]
Setting	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS
As	1	2	0,5	1,5	0,5	2	2
Ba	40 à 80*	100	20	60	20	100	80
Cd	0,04	0,06	0,04	0,06	0,04	0,06	0,06
Cr	2,00	10	0,5	5	1	10	5
Cu	10	10	2	10	10	10	10
Hg	0,03	0,03	0,01	0,03	0,03	0,03	0,03
Mo	1,5	6	0,5	6	1	6	2
Ni	2	2	0,4	1,2	1,2	2	2
Pb	0,5	2	0,5	2	0,5	2	1
Sb	0,7	0,7	0,3 à 0,4*	0,7	0,7	0,7	0,7
Se	1	1	0,4	1	1	1	1
Zn	15	15	4	12	15	15	15
Chloride (Cl^-)[3]	3200 à 3600*	11000 à 14000*	800	2400	1800	11000	4700
Fluoride (F^-)[3]	50	150	10	50	30	150	100
Sulphate (SO_4^{2-})[3]	5900 à 6000*	18000 à 20000*	1200	10000	3400	18000	6500
Phenolic compounds[6]	10	10	5	10	10	10	10
Soluble fraction							
DOC / Eluate	500	500	500	500	500	500	500
DOC / raw							
Σ BTEX							
Σ TEX[4]	25	25	25	25	25	10	25
Benzene (LOQ 0,01 et 0,05 mg/kg dm)	0,2	0,2	0,02	0,2	0,06	0,02	0,2
PCB-7 compounds[7]	1	1	1	1	1	1	1
Petroleum hydrocarbons C10-C40	500	500	500	500	500	500	500
PAH compounds[5]	30	30	30	30	30	30	30
Nitrates							
Cyanides							
Be							
Co							
V	2 à 3*	3	2	3	2	3	3
Asbestos							
Naphthalene	5	5	5	5	5	5	5
MAJ du 11.01.2022							
PRJ1700885 Green Foundry Life							

Source : CTIF

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leaching tests and identifying reuse options

Summary table of documents submitted by partners :

Acceptance limit values for sand reuse in road engeneering (France)

France	Reuse options in road ingeneering		
Channels	Alternative material for type 1 use	Alternative material for type 2 use	Alternative material for type 3 use
Setting	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS
As	0,6	0,6	0,6
Ba	25	25	25
Cd	0,05	0,05	0,05
Cr	0,8	0,6	0,6
Cu	3	3	3
Hg	0,01	0,01	0,01
Mo	0,6	0,6	0,6
Ni	4	2	0,5
Pb	0,6	0,6	0,6
Sb	0,7	0,4	0,08
Se	0,1	0,1	0,1
Zn	20	20	5
Chloride (Cl-)	1000	1000	1000**
Fluoride (F-)	60	30	13
Sulphate (SO_4^{2-})	10000	5000	1300**
Phenolic compounds	2	2	1
Soluble fraction			5000**
DOC / Eluate	500	500	500
DOC / raw	30000 / 60000*	30000 / 60000*	30000 / 60000*
Σ BTEX	6	6	6
Σ TEX			
Benzene (LOQ 0,01 et 0,05 mg/kg dm)			
PCB-7 compounds	1	1	1
Petroleum hydrocarbons C10-C40	500	500	500
PAH compounds	50	50	50
Nitrates			
Cyanides			
Be			
Co			
V			
Asbestos			
Naphthalene			
MAJ du 11.01.2022	*A limit value of 60000 mg/kgDM can be accepted, if the TOC/eluate value does not exceed 500 mg/kgDM		
PRJ1700885 Green Foundry Life	**To be compliant, either the chlorides and sulphates VL or the soluble fraction VL must be respected		

Source : CTIF

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leaching tests and identifying reuse options

Results : leaching tests performed on inorganic sand waste

Waste sand samples	Waste sand CTIF IE	Waste sand INOTEC	Waste sand GEOPOL W37-20	Waste sand PEAK W37
Treatment	No	No	No	No
Setting	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS
As	0,01	0,11	0,03	0,02
Ba	< 0,05	0,07	< 0,05	< 0,05
Cd	< 0,002	< 0,002	< 0,002	< 0,002
Cr	< 0,01	0,07	0,03	0,01
Cu	< 0,02	0,05	0,04	0,02
Hg	< 0,0005	< 0,0005	< 0,0005	< 0,0005
Mo	< 0,02	0,03	< 0,02	< 0,02
Ni	< 0,03	< 0,03	< 0,03	< 0,03
Pb	< 0,02	< 0,02	0,02	< 0,02
Sb	< 0,02	0,067	< 0,02	< 0,02
Se	< 0,02	< 0,02	< 0,02	< 0,02
Zn	< 0,10	0,30	< 0,10	< 0,10
Chloride	< 10	< 10	< 10	23
Fluoride	< 2	8,9	76	110
Sulphate	< 10	76	13	20
Phenolic compounds	0,23	< 0,10	< 0,10	< 0,10
DOC (on eluate)	770	40	810	300
Soluble fraction	7000	4930	4160	3080
DOT (on raw)	< 2000	< 2000	< 2000	< 2000
BTEX (sum)	< 0,10	< 0,10	< 0,10	< 0,10
TEX (sum)	< 0,10	< 0,10	< 0,10	< 0,10
Benzene (LOQ 0,01 et 0,05 mg/kg dm)	< 0,02	< 0,02	< 0,02	< 0,02
PCB-7 (sum)	< 0,007	< 0,007	< 0,007	< 0,007
Petroleum hydrocarbons C10-C40	< 20	< 20	< 20	< 20
Sum 16 EPA-PAH, excl. LOQ	< 0,16	< 0,16	< 0,16	0,20
Nitrates				
Cyanides				
Be				
Co				
V				
asbestos				
Naphthalene	< 0,01	< 0,01	< 0,01	< 0,01
MAJ du 14.01.2022	Limit values exceeded for all countries			
PRJ1700885 Green Foundry Life	Exceeding the limit values for Italy			

➔ Not all inorganic sand waste is acceptable in inert waste disposal facilities for all countries

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Results : leaching tests carried out on the least well-cleaned sands

Waste sand samples	Waste sand CTIF IE	Waste sand INOTEC	Waste sand GEOPOL W37-20	Waste sand PEAK W37
Treatment	Mechanical	Mechanical	Mechanical	Mechanical
Setting	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS
As	0,02	0,09	0,03	0,03
Ba	< 0,05	< 0,05	< 0,05	< 0,05
Cd	< 0,002	< 0,002	< 0,002	0,002
Cr	0,20	0,28	0,09	0,10
Cu	0,02	0,02	< 0,02	< 0,02
Hg	< 0,0005	< 0,0005	< 0,0005	< 0,0005
Mo	< 0,02	0,04	< 0,02	0,02
Ni	< 0,03	< 0,03	< 0,03	0,05
Pb	< 0,02	< 0,02	< 0,02	< 0,02
Sb	< 0,02	< 0,02	< 0,02	< 0,02
Se	< 0,02	< 0,02	< 0,02	< 0,02
Zn	< 0,10	< 0,10	< 0,10	< 0,10
Chloride	< 10	< 10	11	14
Fluoride	< 2	14	85	99
Sulphate	< 10	68	14	20
Phenolic compounds	0,20	0,56	0,32	0,19
DOC (on eluate)	590	45	700	240
Soluble fraction	6830	2940	3830	2710
DOT (on raw)	< 2000	< 2000	< 2000	< 2000
BTEX (sum)	< 0,10	< 0,10	< 0,10	< 0,10
TEX (sum)	< 0,10	< 0,10	< 0,10	< 0,10
Benzene (LOQ 0,01 et 0,05 mg/kg dm)	< 0,02	< 0,02	< 0,02	< 0,02
PCB-7 (sum)	< 0,007	< 0,007	< 0,007	< 0,007
Petroleum hydrocarbons C10-C40	< 20	< 20	< 20	< 20
Sum 16 EPA-PAH, excl. LOQ	< 0,16	< 0,16	< 0,16	< 0,16
Nitrates				
Cyanides				
Be				
Co				
V				
asbestos				
Naphthalene	< 0,01	< 0,01	< 0,01	< 0,01
MAJ du 11.01.2022	Limit values exceeded for all countries			
PRJ1700885 Green Foundry Life	Exceeding the limit values for Italy			

Mechanical technology

- ➔ Not all treated inorganic sand samples are acceptable in inert waste disposal facilities for all countries
- ➔ The mechanical technology is not effective in this case.

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Leaching tests and identifying reuse options

Results : leaching tests carried out on the best cleaned sands

Hydromechanical process

➔ Three samples of inorganic sand are acceptable in inert waste landfills in all countries, one sample is not acceptable in Italy and one sample is not acceptable in all countries, but with very low exceedances.

➔ The hydromechanical technology is effective in this case.

Waste sand samples	Waste sand CTIF IE	Waste sand INOTEC	Waste sand GEOPOL W37-20	Waste sand PEAK W37
Treatment	Hydromechanical	Hydromechanical	Hydromechanical	Hydromechanical
Setting	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS	Limit values mg/kgMS
As	< 0,01	0,02	< 0,01	< 0,01
Ba	< 0,05	< 0,05	< 0,05	< 0,05
Cd	< 0,002	< 0,002	0,003	< 0,002
Cr	0,03	0,04	0,10	0,08
Cu	0,02	< 0,02	0,02	< 0,02
Hg	< 0,0005	< 0,0005	< 0,0005	< 0,0005
Mo	< 0,02	< 0,02	< 0,02	< 0,02
Ni	< 0,03	< 0,03	< 0,03	< 0,03
Pb	< 0,02	< 0,02	< 0,02	< 0,02
Sb	< 0,02	< 0,02	< 0,02	< 0,02
Se	< 0,02	< 0,02	< 0,02	< 0,02
Zn	< 0,10	< 0,10	< 0,10	< 0,10
Chloride	< 10	< 10	< 10	< 10
Fluoride	< 2	2,3	4,1	7,1
Sulphate	< 10	< 10	< 10	< 10
Phenolic compounds	0,19	0,46	1,10	0,10
DOC (on eluate)	28	34	36	29
Soluble fraction	561	1100	< 500	< 500
DOT (on raw)	< 2000	< 2000	< 2000	< 2000
BTEX (sum)	< 0,10	< 0,10	< 0,10	< 0,10
TEX (sum)	< 0,10	< 0,10	< 0,10	< 0,10
Benzene (LOQ 0,01 et 0,05 mg/kg dm)	< 0,02	< 0,02	< 0,02	< 0,02
PCB-7 (sum)	< 0,007	< 0,007	< 0,007	< 0,007
Petroleum hydrocarbons C10-C40	< 20	< 20	< 20	< 20
Sum 16 EPA-PAH, excl. LOQ	< 0,16	< 0,16	< 0,16	< 0,16
Nitrates				
Cyanides				
Be				
Co				
V				
asbestos				
Naphthalene	< 0,01	< 0,01	< 0,01	< 0,01
MAJ du 11.01.2022	Limit values exceeded for all countries			
PRJ1700885 Green Foundry Life	Exceeding the limit values for Italy			

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If optimising the treatment of inorganic sands GEOPOL W37-20 and PEAK W37 by hydromechanics was not feasible to improve the results on the previous page, reuse options are however possible.

Regarding the inorganic sand waste and the mechanically treated sands, which are not acceptable in inert waste landfills with several limit values largely exceeded (fluoride, TOC/Eluate and soluble fraction), reuse options in geo-construction (Finland) and road engineering (France) have been identified with higher acceptance limit values.

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leaching tests and identifying reuse options

Process	Options	Accepted in center	Use of the material in geo-contruction (document from Finlande)						
	Samples tested	waste inert	Roadway covered[1)]	Roadway paved[1)]	Field covered[1)]	Field paved[1)]	Embankment	Floor structure of industrial or storage building	Crushed stones and ash[2]
Untreated sands	INOTEC	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	CTIF IE	No	No	No	No	No	No	No	No
	GEOPOL W37-20	No	No	No	No	No	No	No	No
	PEAK W37	No	No	Yes	No	No	No	Yes	No
Mechanical processing	INOTEC	No	Yes	Yes	No	Yes	Yes	Yes	Yes
	CTIF IE	No	No	No	No	No	No	No	No
	GEOPOL W37-20	No	No	No	No	No	No	No	No
	PEAK W37	No	No	Yes	No	No	No	Yes	No
Hydro mechanical processing	INOTEC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	CTIF IE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	GEOPOL W37-20	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	PEAK W37	Yes except in Italie	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Process	Options	Accepted in center	Use of the material in road ingeneering (2019 Cerema guide France)		
	Samples tested	waste inert	Alternative material for type 1 use	Alternative material for type 2 use	Alternative material for type 3 use
Untreated sands	INOTEC	No	Yes	Yes	Yes
	CTIF IE	No	Yes	Yes	Yes
	GEOPOL W37-20	No	No	No	No
	PEAK W37	No	No	No	No
Mechanical processing	INOTEC	No	Yes	Yes	No
	CTIF IE	No	Yes	Yes	Yes
	GEOPOL W37-20	No	No	No	No
	PEAK W37	No	No	No	No
Hydro mechanical processing	INOTEC	Yes	Yes	Yes	Yes
	CTIF IE	Yes	Yes	Yes	Yes
	GEOPOL W37-20	No	Yes	Yes	No
	PEAK W37	Yes except in Italie	Yes	Yes	Yes

MAJ du 12.01.2022

Results of reuse options inorganic sands

In Géo-construction

- 9 Options for sand waste INOTEC and PEAK
- Mechanical treatment not effective (8 options)
- Hydromechanical treatment effective (all options)

In Road ingeneering

- 6 Options for sand waste INOTEC and INOBAKE
- Mechanical treatment not effective (5 options)
- Hydromechanical treatment effective (almost all options)

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General conclusions of the work carried by CTIF

Laboratory expertise has shown that :

- The use of an inorganic sand is possible for the production of small steel parts,
- The contents of carbon, sulphur, nitrogen, hydrogen and oxygen measured on the part samples did not reveal any major problem,
- The inorganic sand would apparently not have a major impact on the occurrence of defects (for the small steel parts tested in this project)

The treatment trials on waste inorganic sands and the technologies comparison has shown that :

- Hydromechanical and ultrasonic technologies are particularly effective in obtaining an inert sand waste after treatment, or in allowing the treated sand to be reused in foundry, geoconstruction or road engineering,
- The hydromechanical and ultrasonic treatment processes need to be tested on an industrial scale to verify whether these emerging technologies would be viable compared to solutions using conventional technologies (mechanical, thermal, thermomechanical, …),
- It would be interesting to develop pilotes capable of treating 400 kg of sand per cycle to check the feasibility and determine the different ratios and the sand treatment cost in €/t, to compare the results obtained with those of conventional installations (with life cycle analysis and carbon impact calculation).

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Thank you for your attention

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