LIFE17 ENV/FI/000173

Green Foundry

1/7/2018-30/6/2022

Action B4.5 Treatment tests of inorganic sand waste

DeB4.5 Feasibility studies of the reuse of inorganic surplus foundry sand in core making and geo-construction

Action B4.6 Options for reuse of inorganic waste

DeB4.6 Reuse options of inorganic waste sand in geo-construction

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1. Introduction

Contrary to what was initially planned at the beginning of the Green Foundry Life project, the process of treating inorganic sand waste with microwaves was not retained, as CTIF found during another project in 2019 that the microwave technology is not efficient to treat inorganic sand.

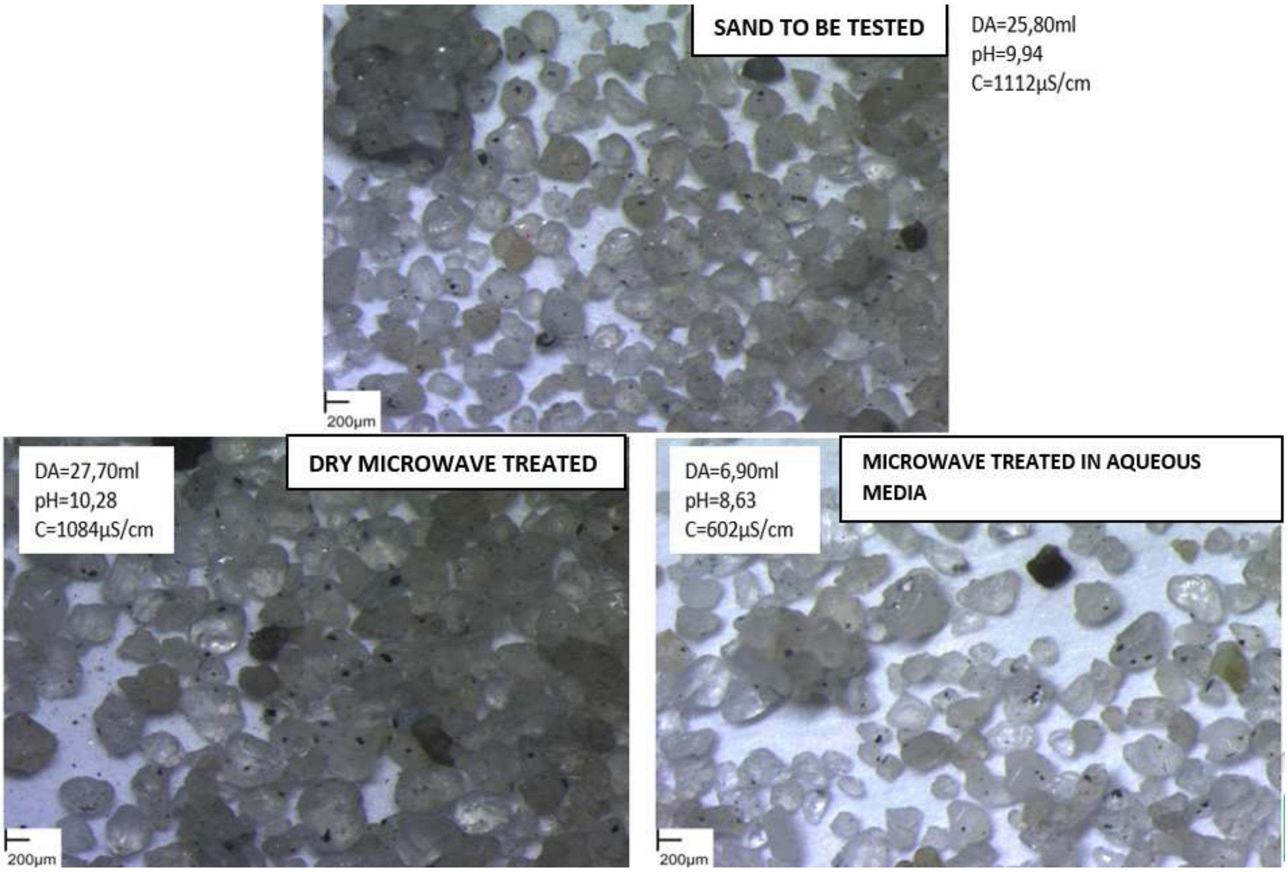
In the case of microwave treatment of inorganic sand, there is an improvement in acidic demands, but this is only due to rinsing operations.

The electrical conductivity values of the treated sand and the optical microscopy images show that:

- The large aggregates are not removed,
- The sand grains are not cleaned,
- The residual gangue remains intact.

Extract from the results of the microwave treatment of an inorganic sand carried out in 2019 in another CTIF's project:

Treatment by microwave of inorganic sand: not effective



The treatment processes selected by CTIF for the Green Foundry Life project are those capable of cleaning inorganic sand waste to obtain a quality of treated sand sufficient for reuse in foundries (moulding, core making), or for external reuse.

The processes using the emerging hydromechanical and ultrasonic technologies being the most efficient were selected for comparison with a conventional mechanical technology currently used in industry (attrition mechanical process).

2. Treatment tests of inorganic sand waste

Once the steel parts have been cast by the different partners of the Green Foundry Life project in order to compare the emissions generated in the foundry between organic and inorganic sand, CTIF carried out several works.

- Mechanical treatment tests,
- Hydromechanical treatment tests,
- Ultrasonic treatment tests,
- Characterisations of sand samples carried out before and after treatment, to observe the impact of the different technologies on inorganic sands, and to select sand batches to be tested in leaching (sand batches before treatment, least treated sand batches and best treated sand batches).

Four batches of inorganic sand waste produced by the partners were tested:

- A batch of inorganic sand waste marked "GEOPOL W37-20",
- A batch of inorganic sand waste marked "PEAK W37",
- A batch of inorganic sand waste marked "INOTEC",
- A batch of inorganic sand waste marked "CTIF IE".

After the pre-treatment of the sand waste transmitted by the project partners, the sands to be treated were characterized and compared with the new reference sand (silica sand BE01).

Illustration of the pre-treatment of sand waste to be treated

Sand grains reduction

2 mm screening, then rejections are reduced

Homogenisation of the batch of sand to be treated

Conditioning and labelling of the 4 batches

Table 4: summary of the characterization of the sands to be treated

Laboratory Inspections on the sand samples	Ref SN BE01	INOTEC before T	CTIF IE before T	W37-20 before T	W37 before T
Fineness index	46	49	46	46	46
Distribution 50-70-100 (%)	95,03	85,27	89,71	86,21	86,90
Distribution 200-270-bottom (%)	0,18	1,30	1,10	0,64	0,42
Residual aggregates (% sieve 6+12+20)	0,00	0,24	0,28	0,46	0,30
Theoretical specific surface (cm2/g)	159	169	157	161	159
Breakage of sand grains observed under the optical microscope (high/low/not)	No	Low	Low	Low	Low
Aggregates observed under optical microscope (yes/no)	No	Yes	Yes	Yes	Yes
Presence of fines (no/low/significant)	Low	Significant	Significant	Significant	Significant
Grain shape observed under the light microscope (general trend: spherical/angular)	Spherical	Sph+Ang	Sph+Ang	Sph+Ang	Sph+Ang
Appearance of grains observed under the optical microscope (general trend: smooth/rough)	Smooth	Smooth+Rou	Smooth+Rou	Smooth+Rou	Smooth+Rou
Amount of black grains (general tendency: no/low/significant)	No	Low	Low	Low	Low
Quantity of light-coloured grains with black spots (general tendency: not/low/significant)	No	Significant	Significant	Significant	Significant
Amount of light-coloured, unstained grains (general trend: no/low/significant)	Significant	No	No	No	No
Electrical conductivity of sand (µS/cm)	500 - 520	907	1357	1045	957
pH of the sand	8,30 - 8,40	10,07	10,36	9,70	9,79
Acid demand of sand (ml HCl)	1,2 - 2,0	28	38,1	16,2	15,5
Samples retained for leaching test		X	X	X	X
UPDATED on November 26th 2021					

EDS analyses carried out to identify the elements present in the sands to be treated:

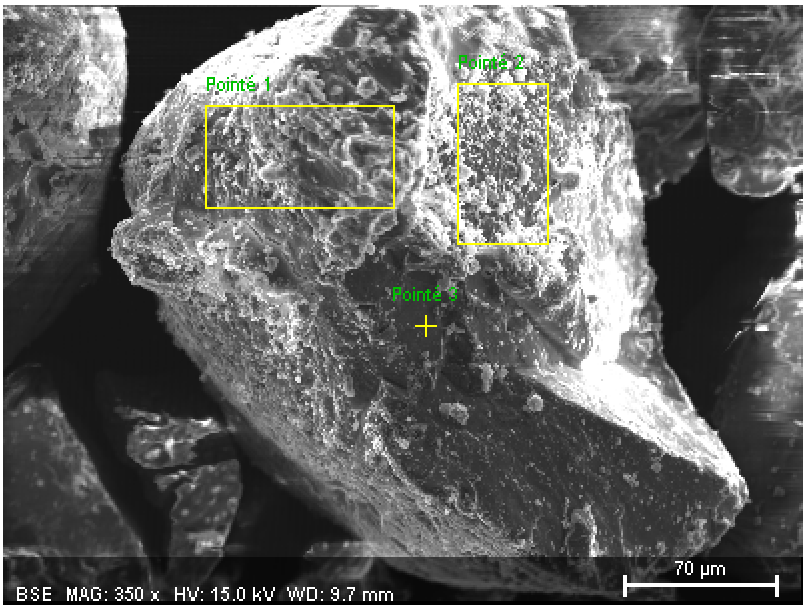
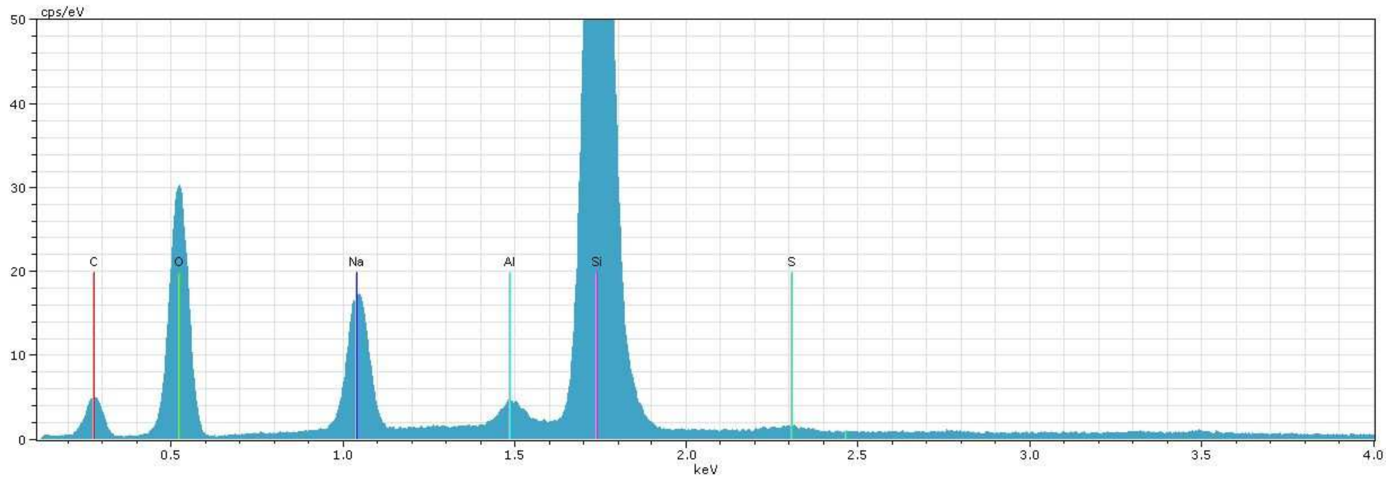
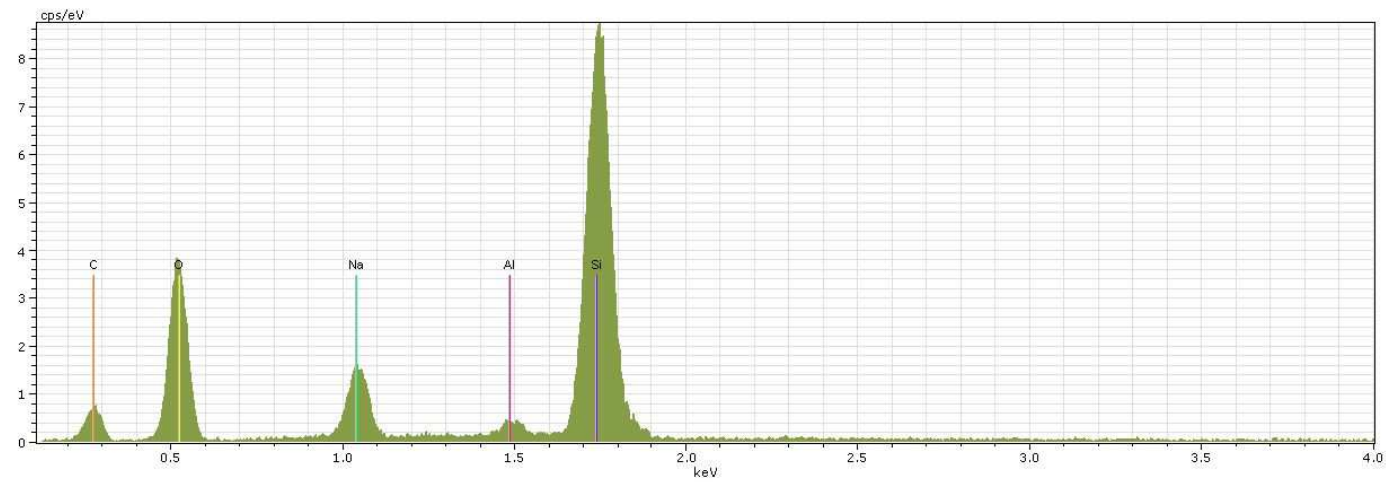


Photo of the sand to be treated, marked CTIF IE, with the analysis zones " marked 1, marked 2, marked 3 ".

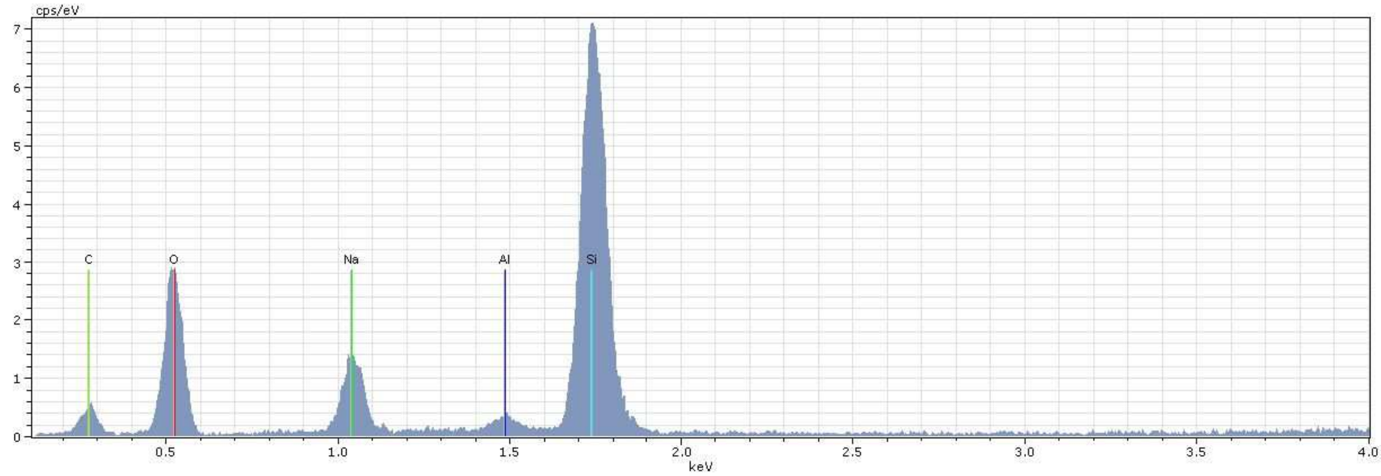


EDS analysis results: CTIF IE photo to be processed "marked 1"



EDS analysis results: CTIF IE photo to be treated "marked 2"

EDS analyses carried out to identify the elements present in the sands to be treated: cont'd



EDS analysis results: CTIF IE photo to be treated "marked 3"

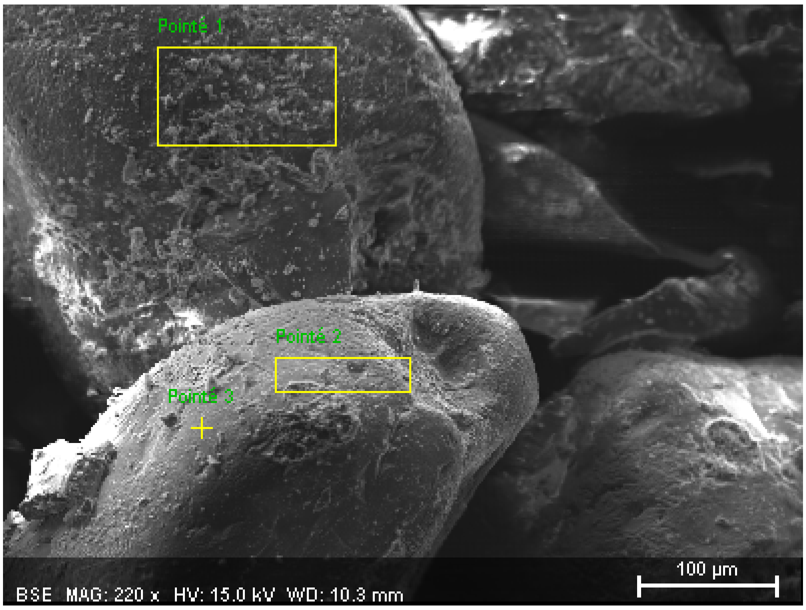
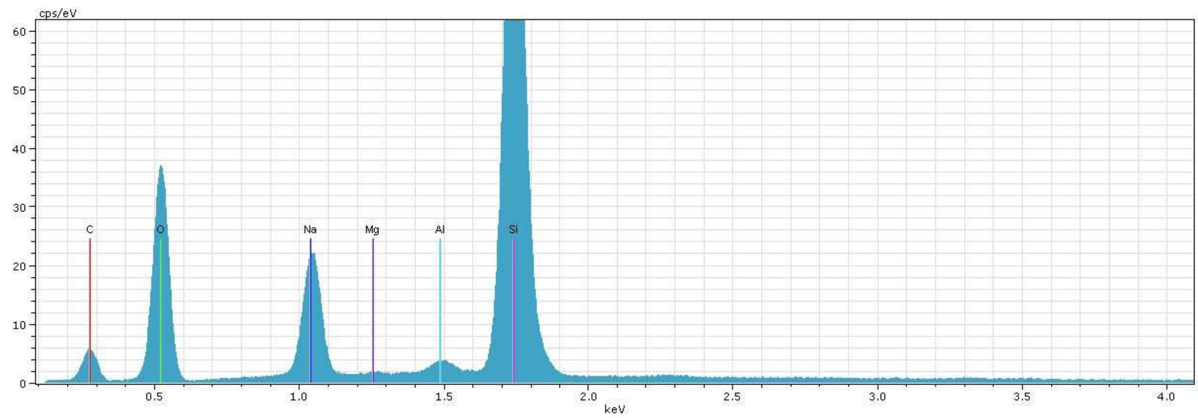
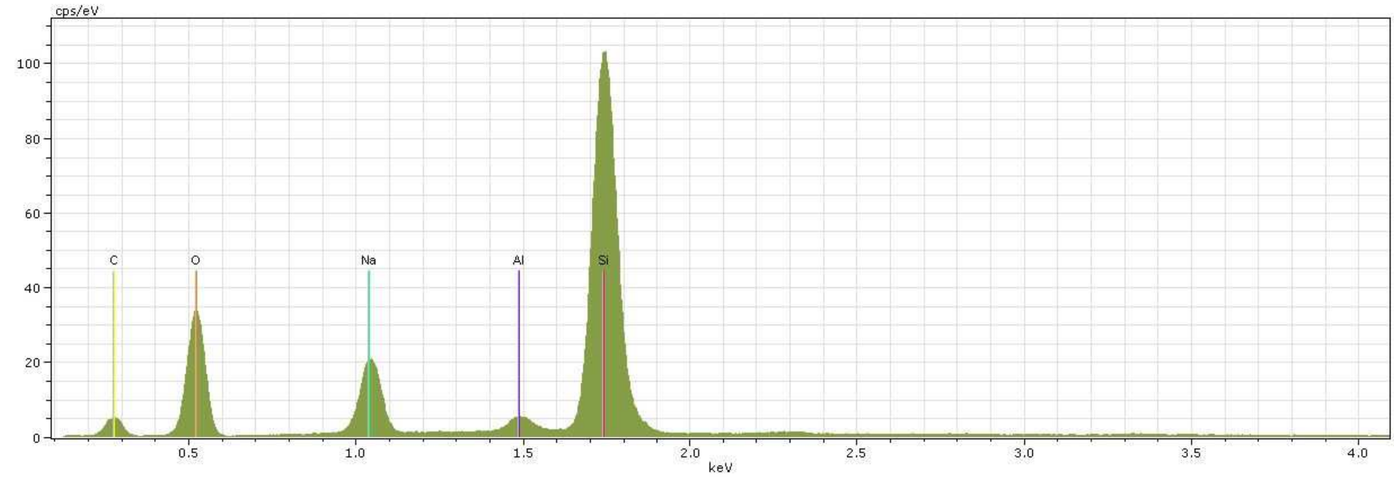


Photo of the sand to be treated, marked INOTEC, with the analysis zones " marked 1, marked 2, marked 3 ".

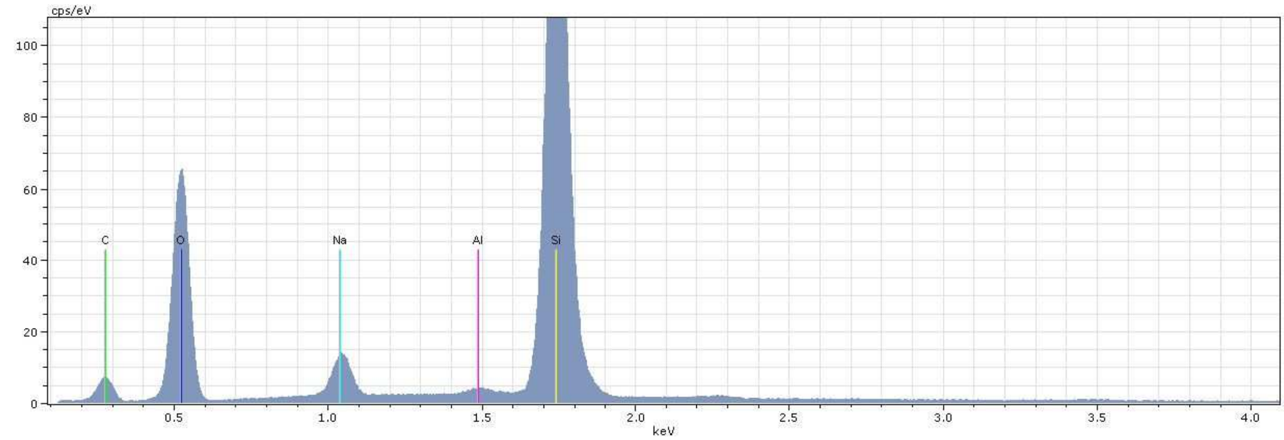


EDS analysis results: INOTEC photo to be treated "marked 1"

EDS analyses carried out to identify the elements present in the sands to be treated: Cont'd



EDS analysis results: INOTEC photo to be treated "marked 2"



EDS analysis results: INOTEC photo to be treated "marked 3"

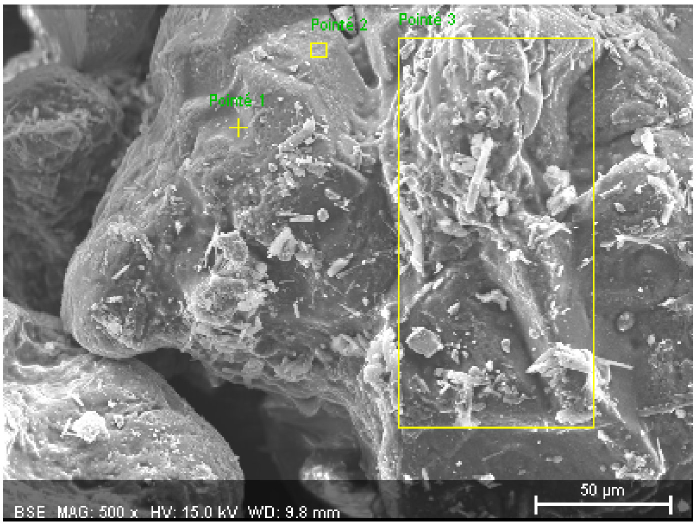
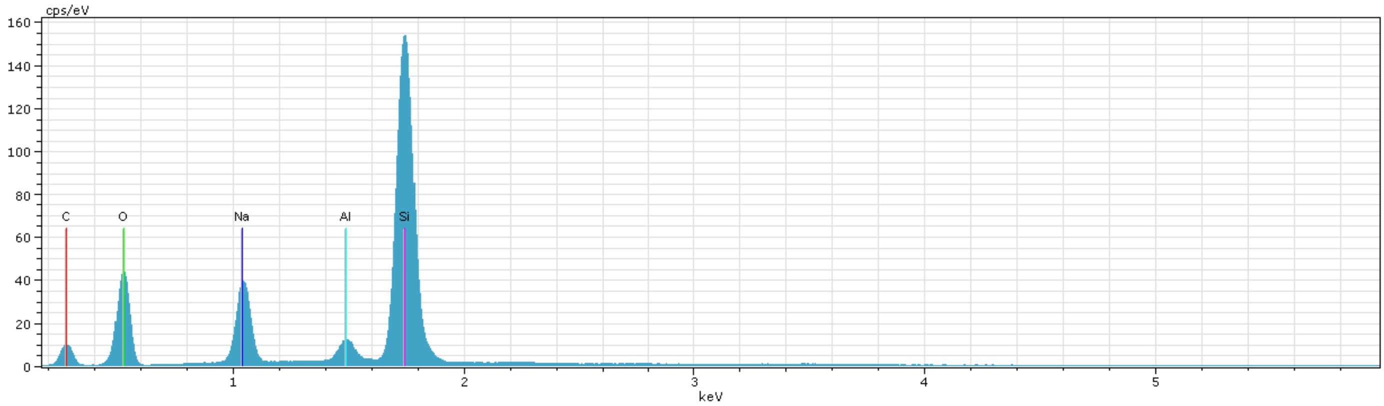
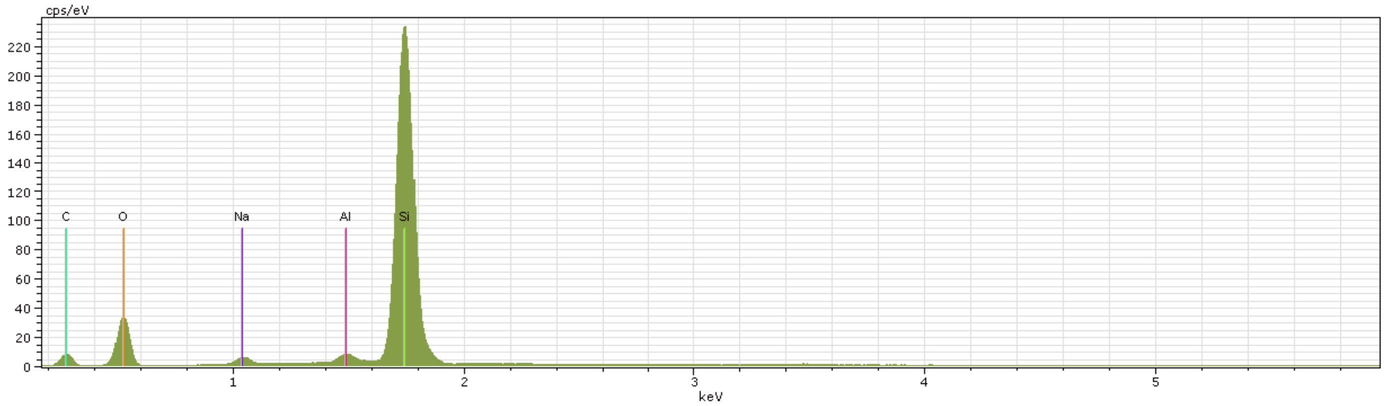


Photo of the sand to be treated marked GEOPOL W37-20, with the analysis zones " marked 1, marked 2, marked 3 ".

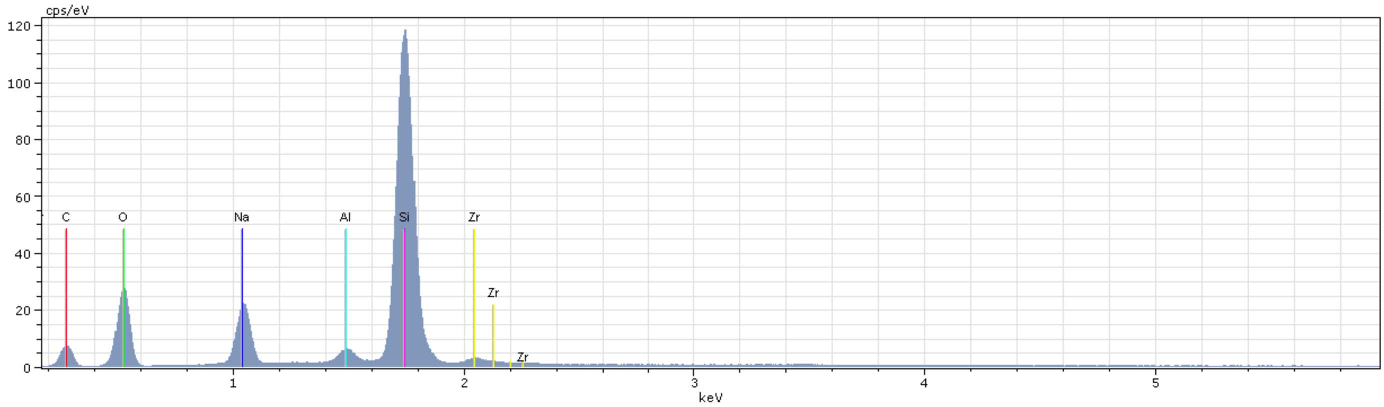
EDS analyses carried out to identify the elements present in the sands to be treated: Cont'd



EDS analysis results: Geopol W37-20 photo to be treated "marked 1"



EDS analysis results: Geopol W37-20 photo to be treated "marked 2"



EDS analysis results: Geopol W37-20 photo to be treated "marked 3"

EDS analyses carried out to identify the elements present in the sands to be treated: Cont'd

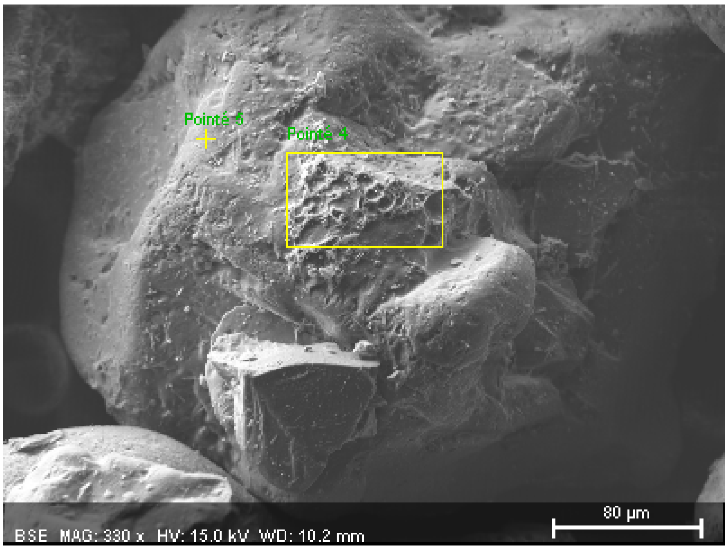
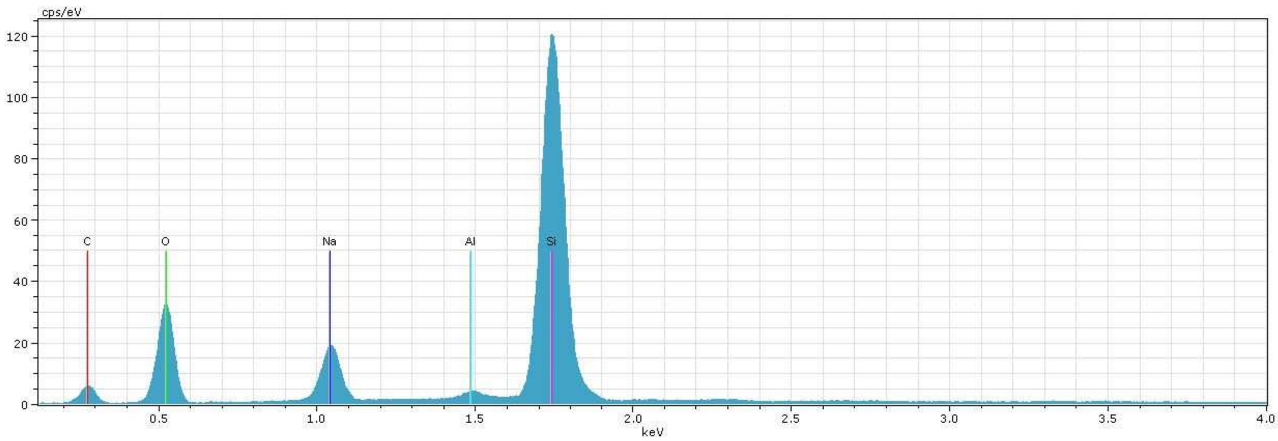
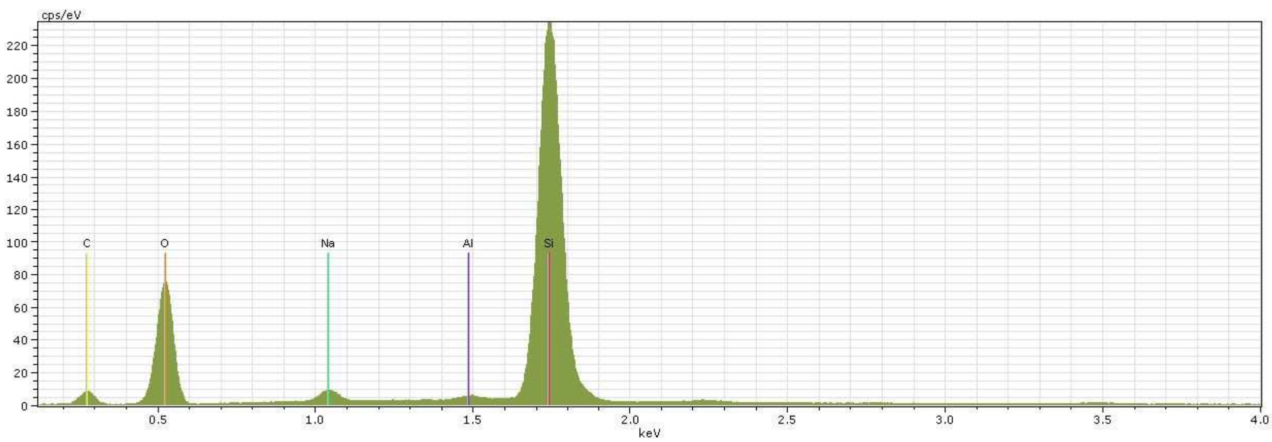


Photo of the sand to be treated marked PEAK W37, with the analysis zones " marked 4, marked 5 ".



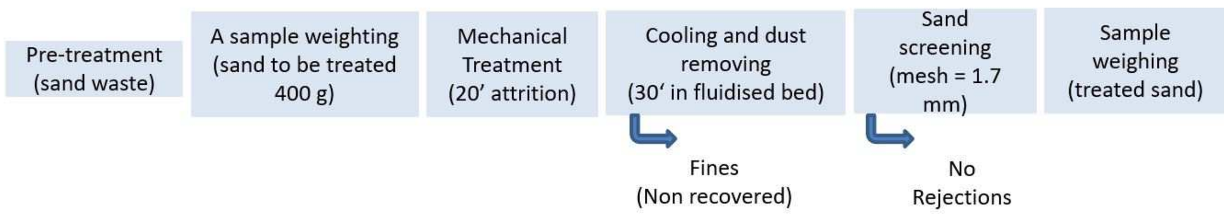
EDS analysis results: PEAK W37 photo to be treated "marked 4"



EDS analysis results: PEAK W37 photo to be treated "marked 5"

2.1. Description of the processes and treatments implemented at the CTIF's platform

Mechanical treatment process



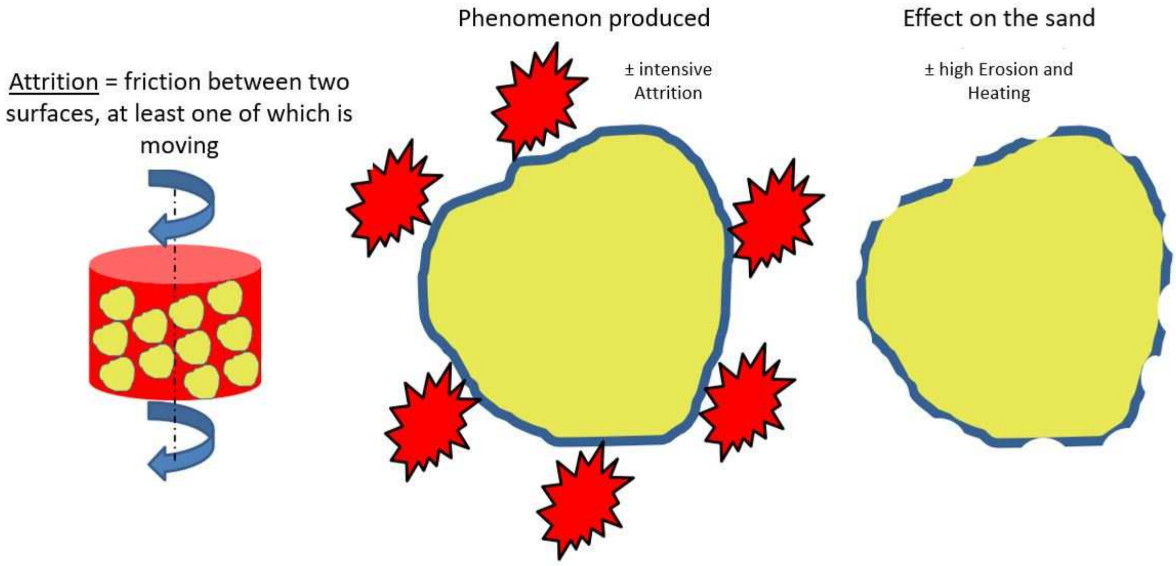


Illustration of the mechanical treatment process


Samples weighing before treatment


Mechanical Treatment (20')


For example sand PEAK W37 after treatment


Cooling and dust removing (30')


Sand screening after treatment (>1.7 mm)

Weighing of the sample of treated Sand

Hydromechanical treatment process

Principle of the hydromechanical treatment

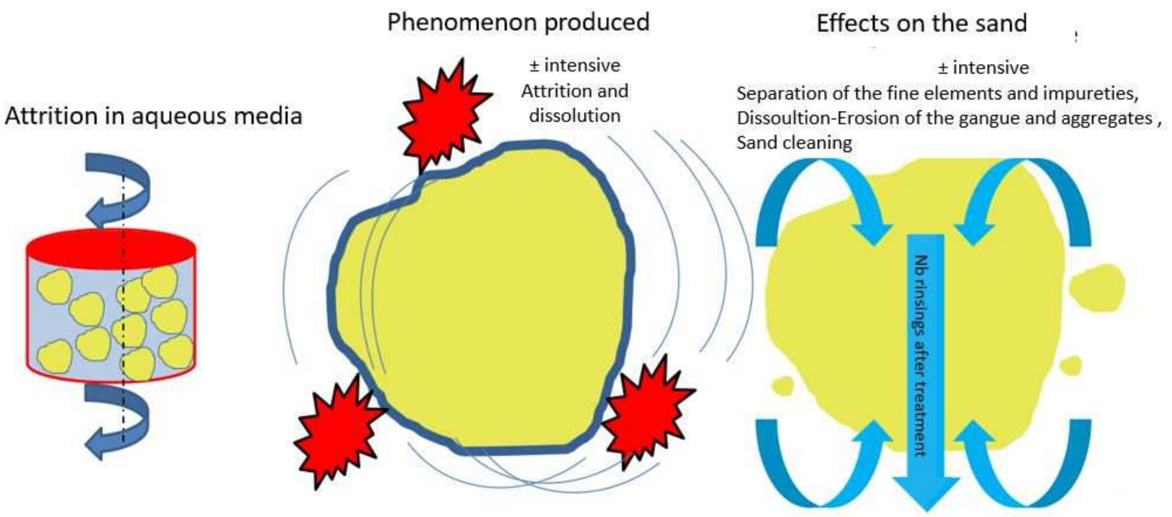


Illustration of the hydromechanical treatment process

Samples weighing before treatment

Sand moistening before treatment

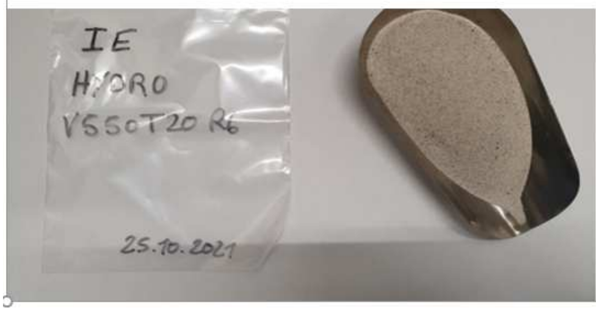
Hydromechanical treatment (20’)

Sand before draining and rinsing (6)

Sand CTIF IE after rinsing

Drying and dust removing (30’)

Screening and weighing after treatment



Ultrasonic Treatment process

Principle of ultrasound treatment

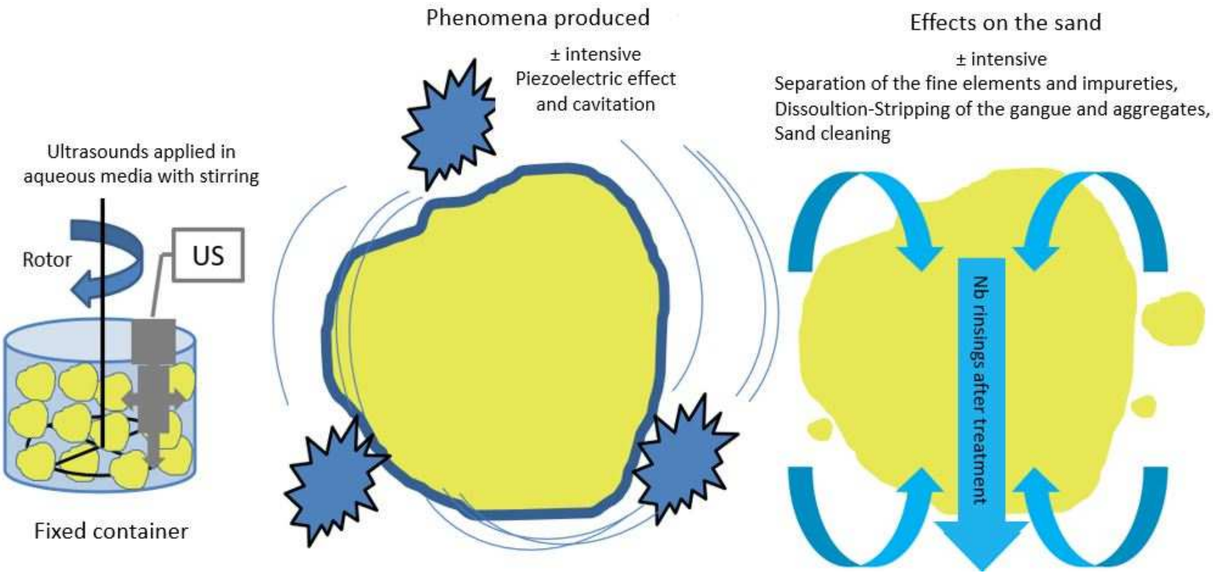
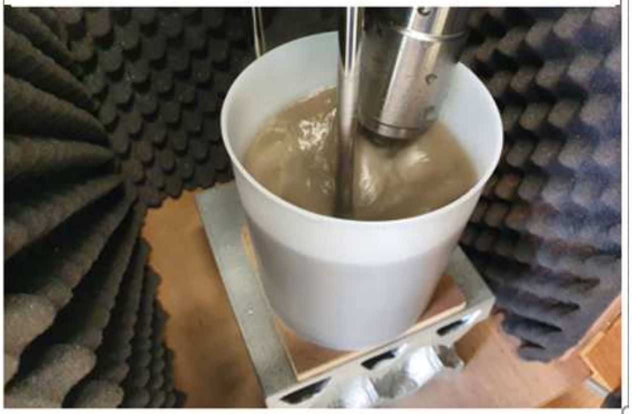


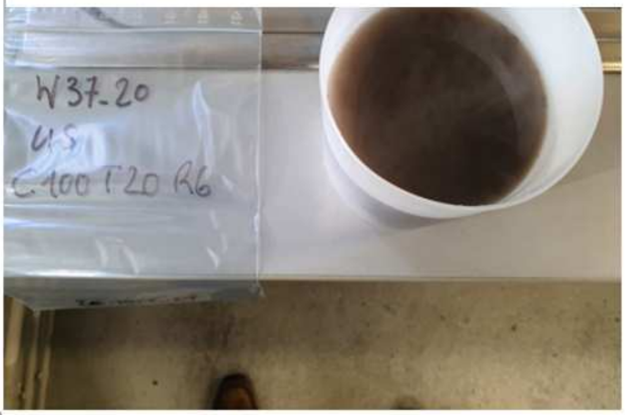
Illustration of the ultrasound treatment process

Weighing of the samples before treatment

Sand moistering and US treatment (20’)



Sand GEOPOL W37-20 after treatment



Sand GEOPOL W37-20 after rinsing (6)

Drying and dust removing (30’)

Sand screening and weighing after treatment

2.2. Summary of the mechanical treatment tests

Table 5: results of the sand characterization after mechanical treatment

Laboratory checks on the sand samples	Ref SN BE01	INOTEC	CTIF IE	GEOPOL W37-20	PEAK W37
Fineness index	46	50	49	52	55
Distribution 50-70-100 (%)	95,03	92,00	94,68	90,27	90,75
Distribution 200-270-bottom (%)	0,18	0,92	1,04	1,89	2,28
Absence of residual aggregate (%)	0,00	0,00	0,00	0,08	0,04
Theoretical specific surface (cm2/g)	159	176	170	184	195
Breakage of sand grains observed under the light microscope (high/low/no)	no	low	low	significant	significant
Aggregate removal observed under optical microscope (yes/no)	no	yes	yes	yes	yes
Amount of fines produced by the treatment (no/low/significant)	no	significant	significant	significant	significant
Grain shape observed under light microscope (general trend: spherical/angular)	Spherical	Sph+Ang	Sph+Ang	Sph+Ang	Sph+Ang
Appearance of grains observed under the light microscope (general trend: smooth/rough)	smooth	smooth+Rug	smooth	smooth	smooth
Amount of black grains (general tendency: not/low/significant)	no	significant	low	low	low
Quantity of light-coloured grains with black spots (general tendency: not/low/significant)	no	significant	significant	significant	significant
Amount of light-coloured unstained grains (general trend: not/low/significant)	significant	no	low	low	low
Electrical conductivity of treated sand (µS/cm)	500 - 520	863	1262	997	842
pH of the treated sand	8,30 - 8,40	10,01	10,17	9,57	9,44
Acid demand of treated sand (ml HCL)	1,2 - 2,0	27,5	35,9	20,9	17,1
Samples retained for leaching test		X	X	X	X
Updated on 26/11/2021					

Initial findings: (see illustrations on pages 21 to 46)

- Grain breakage for the GEOPOL W37-20 and PEAK W37 sands,
- The production of fines is significant in all cases,
- For all the treated sand samples, conductivity, pH and acid demands are not in conformity with the new sand reference BE01,
- All sand samples are not well cleaned.

Explanations:

In order to compare the effects of the mechanical treatment with the hydromechanical and ultrasonic treatments, the settings of the mechanical module were set at V550T20 + 30 min of dedusting.

- To reduce grain breakage in GEOPOL W37-20 and PEAK W37 sands, the rotation speed of the module and the treatment time should be adjusted (e.g. set to V550T15 or V500T20),
- The 30 minute dedusting time was not sufficient to reduce the fines content,
- The mechanical treatment does not clean the inorganic sand well: the production of fines is high (dry attrition phenomenon), and a large quantity of residual gangue remains stuck to the surface of the grains (temperature rise phenomenon).

Note: after mechanical treatment, no clear unstained grain is found in INOTEC sand: this difference in behaviour compared to other sands is perhaps due to the nature, composition and/or quality of the binder and additives used for this process.

2.3. Summary of the hydromechanical treatment tests

Table 6: results of the sand characterization after hydromechanical treatment

Laboratory checks on the sand samples	Ref SN BE01	INOTEC	CTIF IE	GEOPOL W37-20	PEAK W37
Fineness index	46	49	47	48	49
Distribution 50-70-100 (%)	95,03	92,64	95,42	94,68	93,94
Distribution 200-270-bottom (%)	0,18	0,14	0,04	0,00	0,06
Absence of residual aggregate (%)	0,00	0,04	0,00	0,04	0,08
Theoretical specific surface (cm2/g)	159	172	160	169	172
Breakage of sand grains under the light microscope (significant/low/no)	no	low	low	low	low
Aggregate removal observed under optical microscope (yes/no)	no	yes	yes	yes	yes
Amount of fines produced by the treatment (no/low/significant)	no	low	low	low	low
Grain shape observed under the optical microscope (general trend: spherical/angular)	Spherical	Sph+Ang	Sph+Ang	Sph+Ang	Sph+Ang
Appearance of grains under the optical microscope (general trend: smooth/rough)	smooth	smooth	smooth	smooth	smooth
Amount of black grains (general trend: no/low/significant)	no	low	low	low	low
Quantity of light-coloured grains with black spots (general trend: no/low/significant)	no	significant	low	low	low
Amount of clear unstained grains (general trend: no/low/significant)	significant	significant	significant	significant	significant
Electrical conductivity of treated sand (µS/cm)	500 - 520	523	516	507	511
pH of treated sand	8,30 - 8,40	8,78	8,73	8,72	8,45
Acid demand of treated sand (ml HCl)	1,2 - 2,0	5,8	2,2	0,6	1,5
Samples retained for leaching test		X	X	X	X
Updated on 26/11/2021					

<u>Initial findings</u>: (see illustrations on pages 21 to 46)

- No breakage of the sand grains in all cases,
- All the parameters checked are in conformity with the reference sand BE01,
- The sand is well cleaned in all cases,
- Only the INOTEC sand has a slightly higher acid demand.

<u>Explanations</u> :

- The phenomena produced and the effects generated by the treatment are particularly effective in cleaning inorganic sands,
- The slightly high acid demand for INOTEC sand can be reduced by optimising the settings of the treatment module (rotation speed, treatment time, number of rinses).

2.4. Summary of the ultrasonic treatment tests

Table 7: results of the characterisation of the sands after ultrasonic treatment

Laboratory checks on the sand samples	Ref SN BE01	InoEC	CTIF IE	GEOPOL W37-20	PEAK W37
Fineness index	46	50	47	49	50
Distribution 50-70-100 (%)	95,03	93,02	96,10	94,14	93,98
Distribution 200-270-bottom (%)	0,18	0,18	0,06	0,04	0,10
Absence of residual aggregate (%)	0,00	0,04	0,04	0,06	0,12
Theoretical specific surface (cm2/g)	159	176	162	171	175
Casse grains de sable observée au microscope optique (significant/low/no)	no	low	low	low	low
Sand grain breakage observed by optical microscope (significant/low/no)	no	yes	yes	yes	yes
Aggregate removal observed under optical microscope (yes/no)	no	low	low	low	low
Amount of fines produced by the treatment (no/low/significant)	Spherical	Sph+Ang	Sph+Ang	Sph+Ang	Sph+Ang
Appearance of grains under the optical microscope (general trend: smooth/rough)	smooth	smooth	smooth	smooth	smooth
Amount of black grains (general trend: no/low/significant)	no	low	low	low	low
Quantity of light-coloured grains with black spots (general trend: no/low/significant)	no	significant	low	low	low
Quantity of clear unstained grains (general trend: no/low/significant)	significant	low	significant	significant	significant
Electrical conductivity of treated sand (µS/cm)	500 - 520	525	521	515	518
pH of treated sand	8,30 - 8,40	8,76	8,77	8,79	8,58
Acid demand of treated sand (ml HCL)	1,2 - 2,0	7,5	4,5	1,5	1,6
Samples retained for leaching test					
Updated on 26/11/2021					

<u>Initial findings</u>: (see illustrations on pages 21 to 46)

- No breakage of the sand grains in all cases,
- All the parameters checked are in conformity with the reference sand BE01,
- The sand is well cleaned in all cases,
- Only the INOTEC sand has a slightly high acid demand and a low quantity of clear unstained grains.
- The acid demand of the CTIF IE sand is also a little high.

<u>Explanations:</u>

- The phenomena produced and the effects generated by the treatment are particularly effective in cleaning inorganic sands (with, however, poorer characterisation results of the treated sands, compared to the hydromechanical treatment process),
- The acidic demands that are still somewhat high for INOTEC and CTIF IE sands can be reduced by optimising the settings of the treatment module (treatment time and rinses).

Illustration related to the summaries of inorganic sand treatment tests

Photo optical microscope CTIF's sand IE to be treated: overview

Photo optical microscope INOTEC sand to be treated: overview

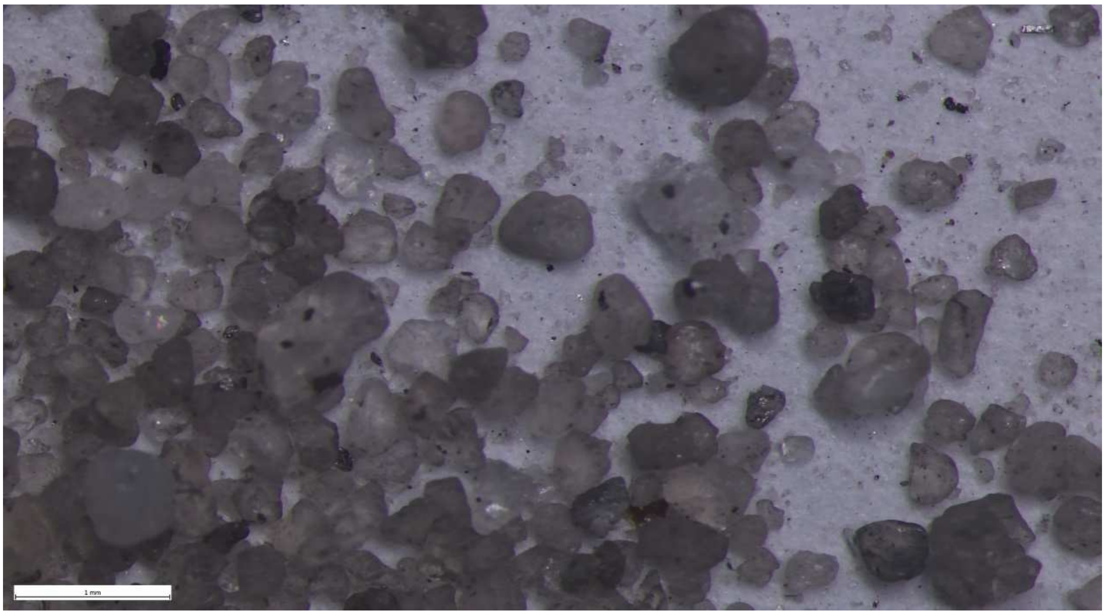


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo - optical microscope GEOPOL W37-20 sand to be treated: overview

Photo - optical microscope PEAK W37 sand to be treated: overview

Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo - optical microscope sand new reference BE01: overview

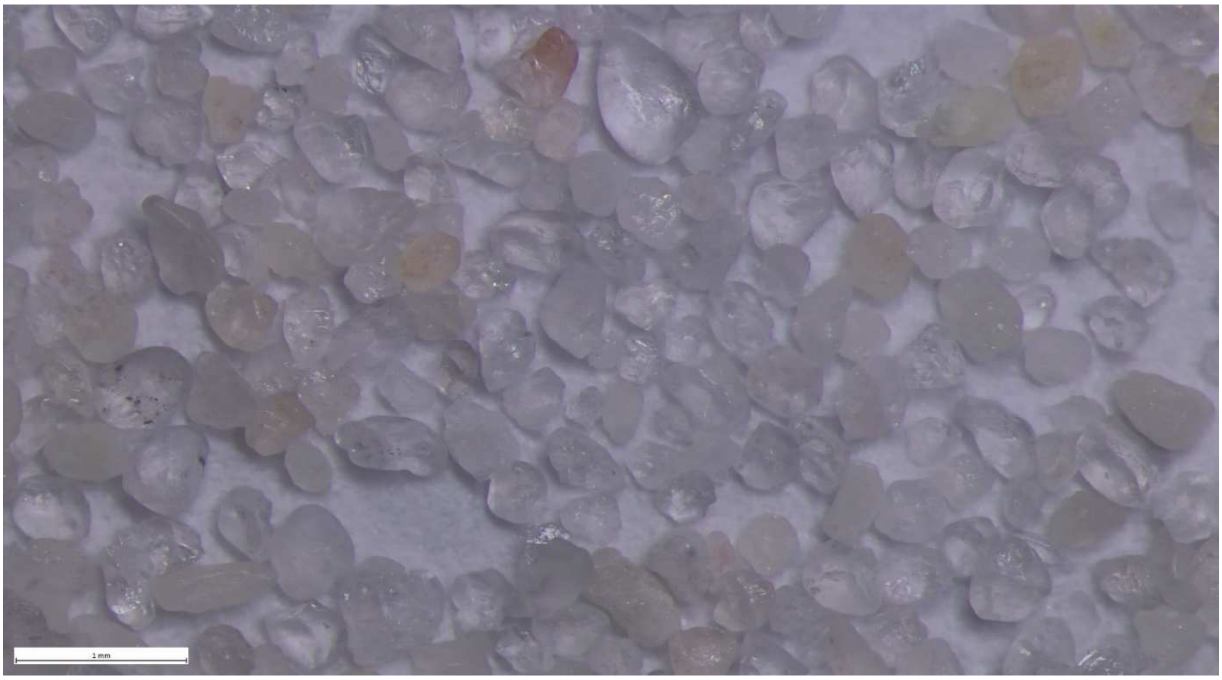


Photo - MEB new sand reference BE01: appearance of the grains

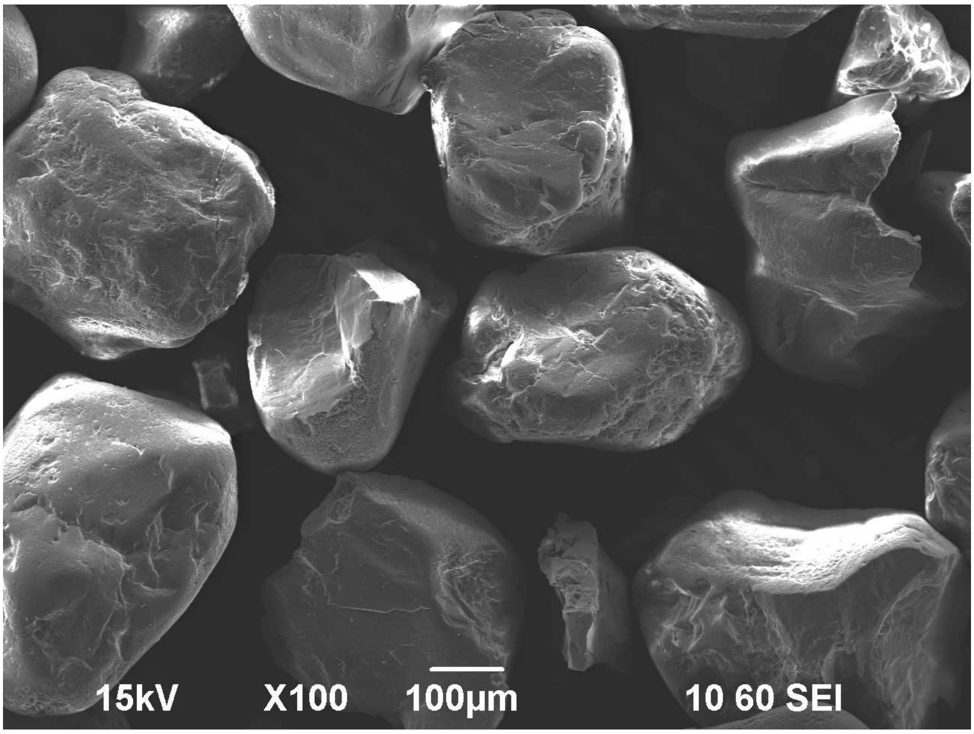


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo MEB new sand reference BE01: appearance of a broken grain (extraction and cleaning conditions)

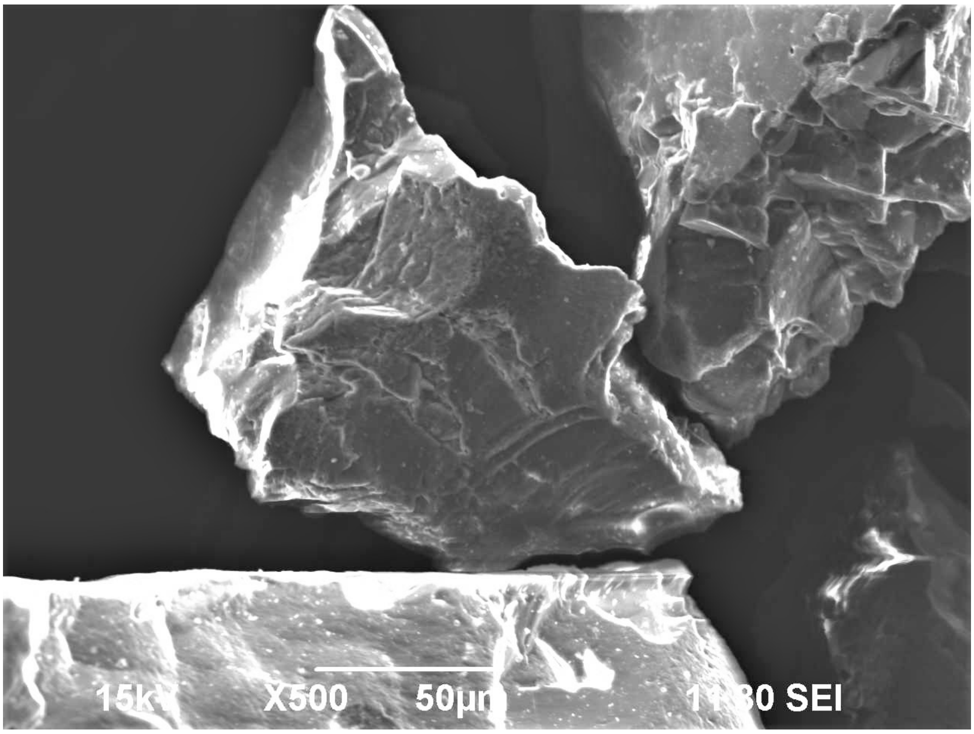


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo - optical microscope sand CTIF IE mechanically treated: overview

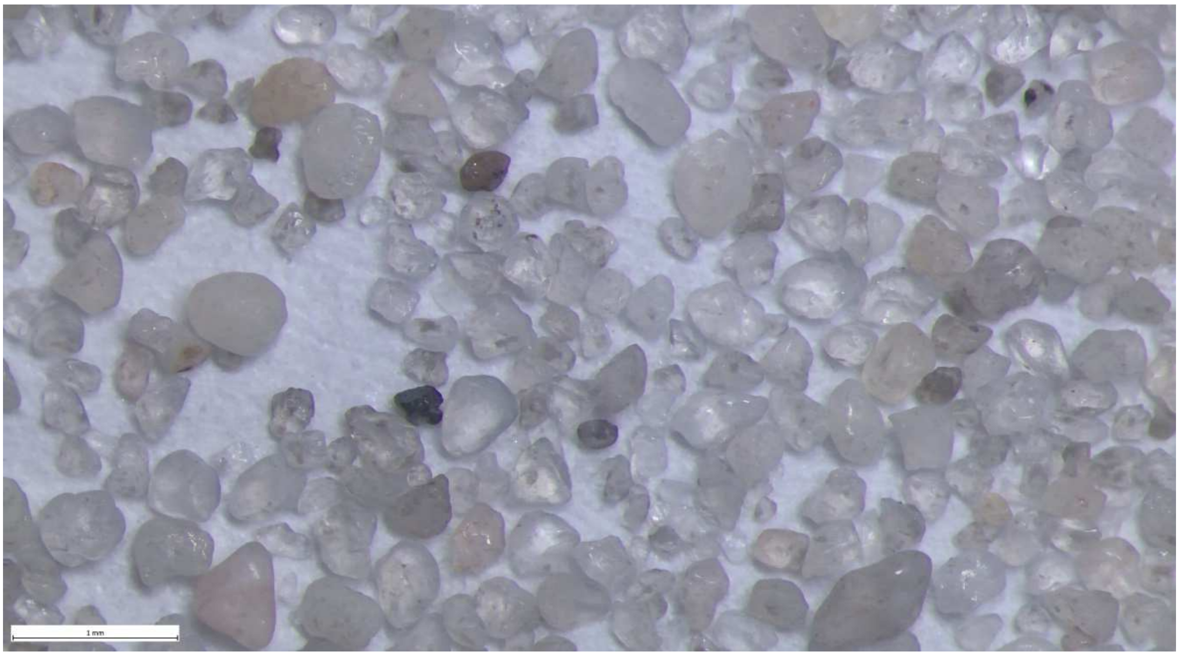


Photo - optical microscope sand INOTEC mechanically treated: overview

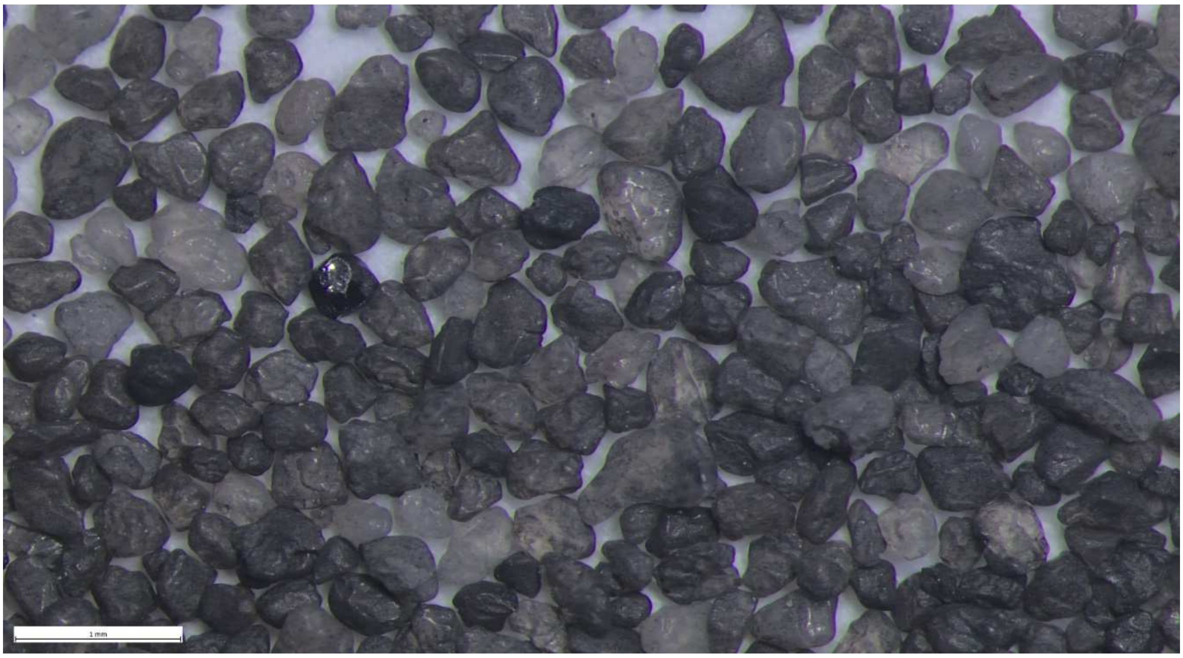


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo - optical microscope Geopol W37-20 mechanically treated sand: overview

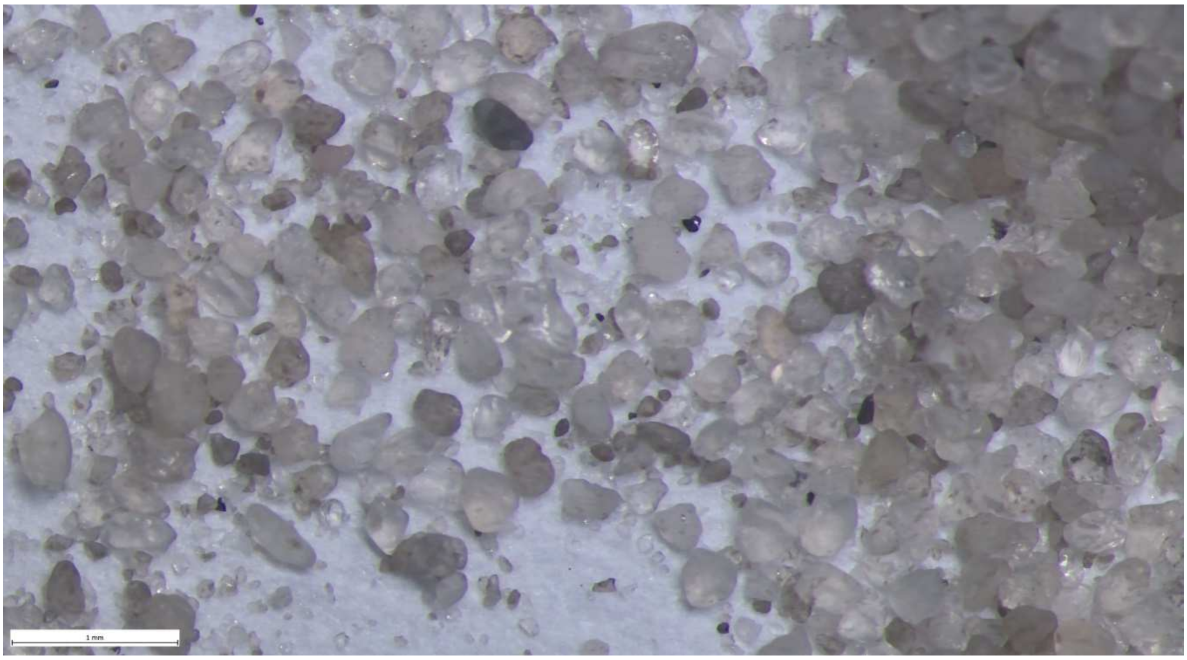


Photo - Optical microscope PEAK W37 sand mechanically treated: overview

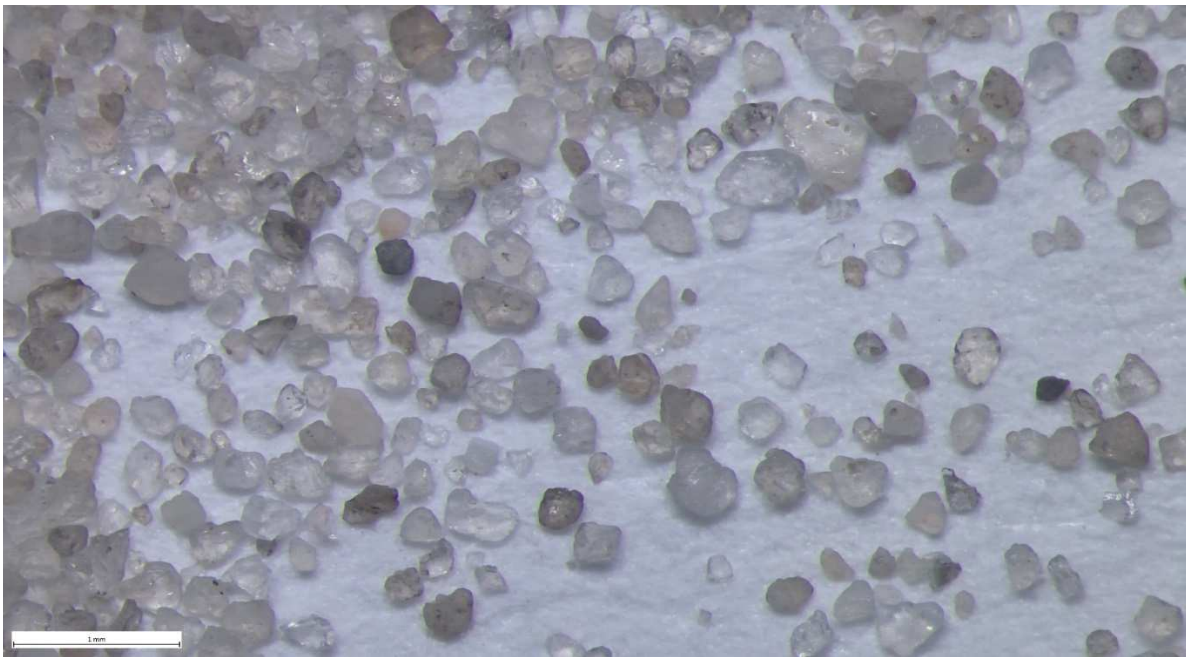


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Optical microscope photo of hydromechanically treated CTIF IE sand: overview

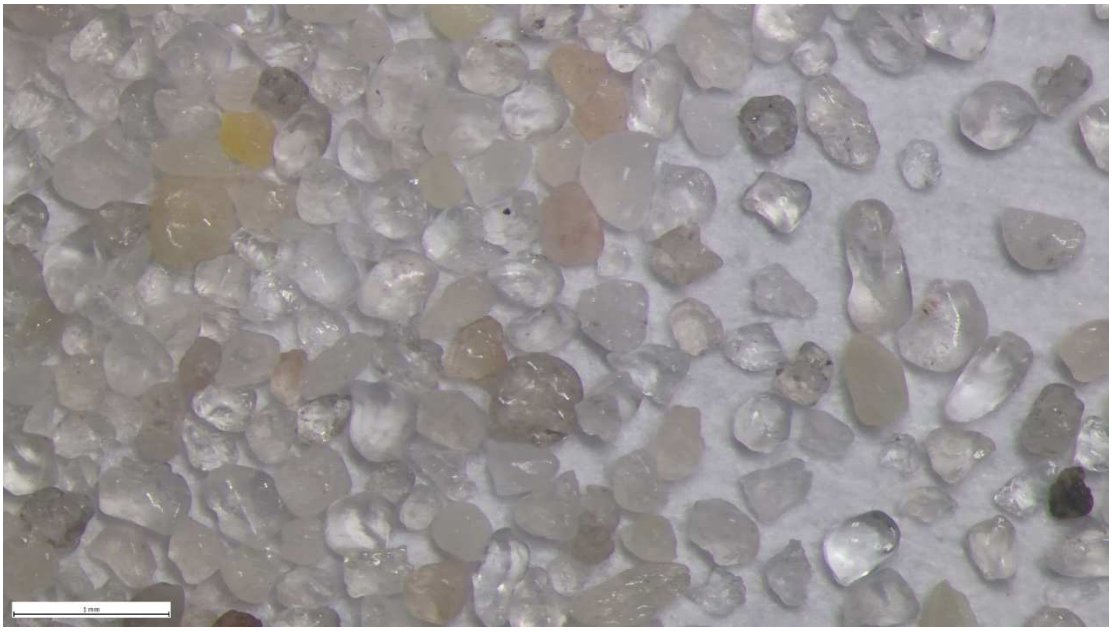


Photo optical microscope of hydromechanically treated INOTEC sand: general view

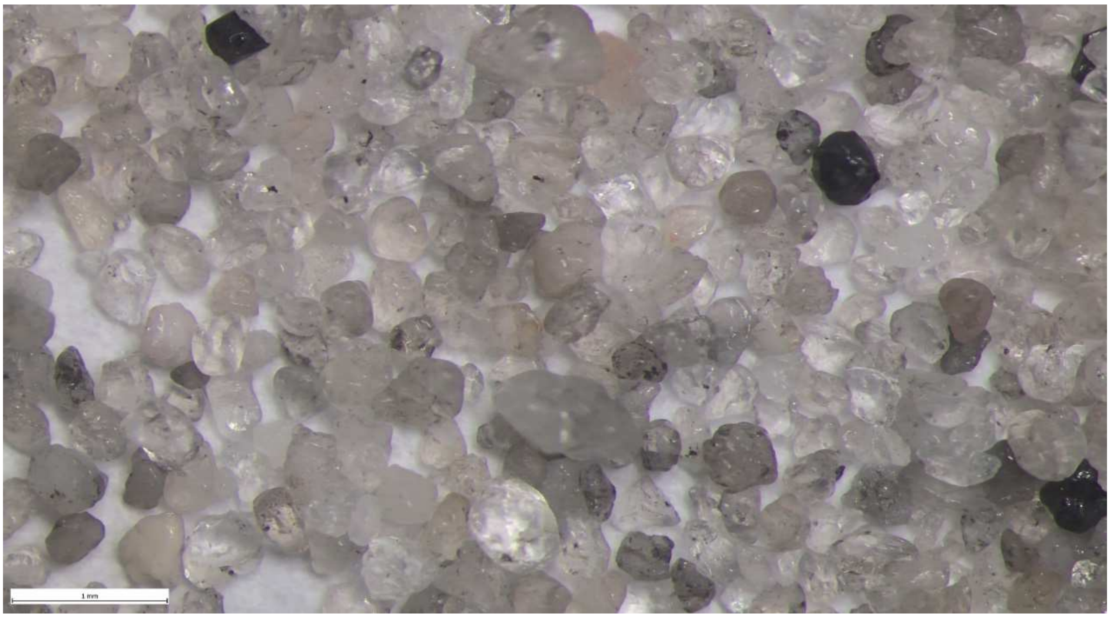
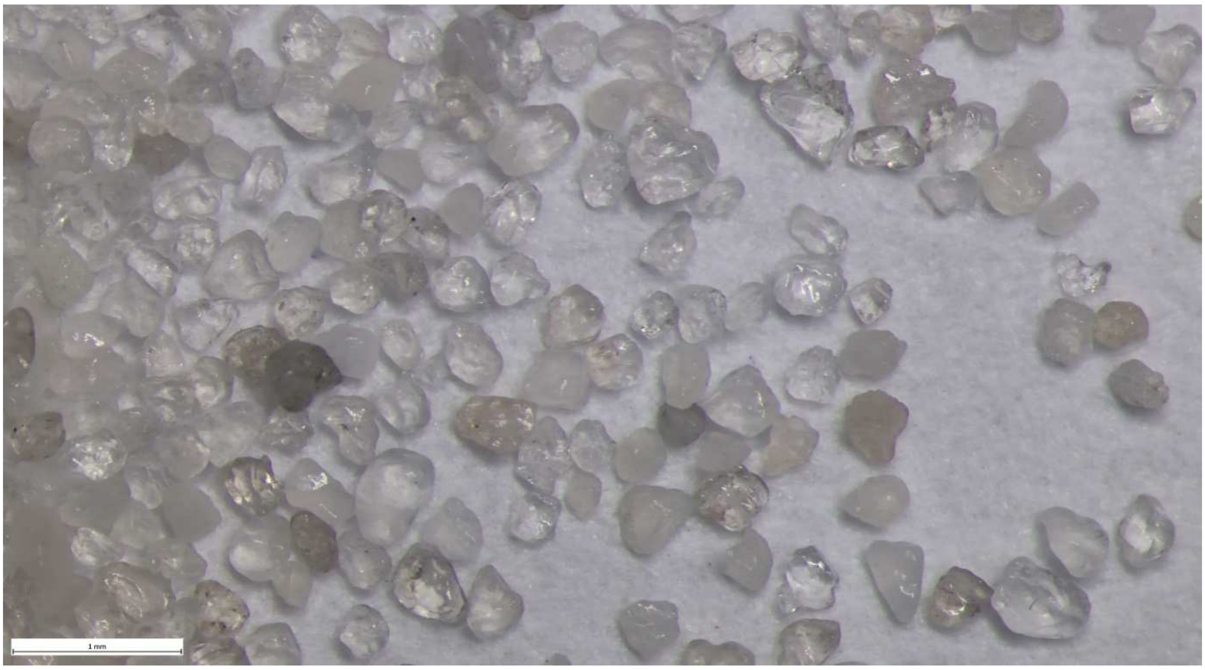


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo - optical microscope of sand GEOPOL W37-20 hydromechanically treated: overview



Optical microscope photo of hydromechanically treated PEAK W37 sand: overview

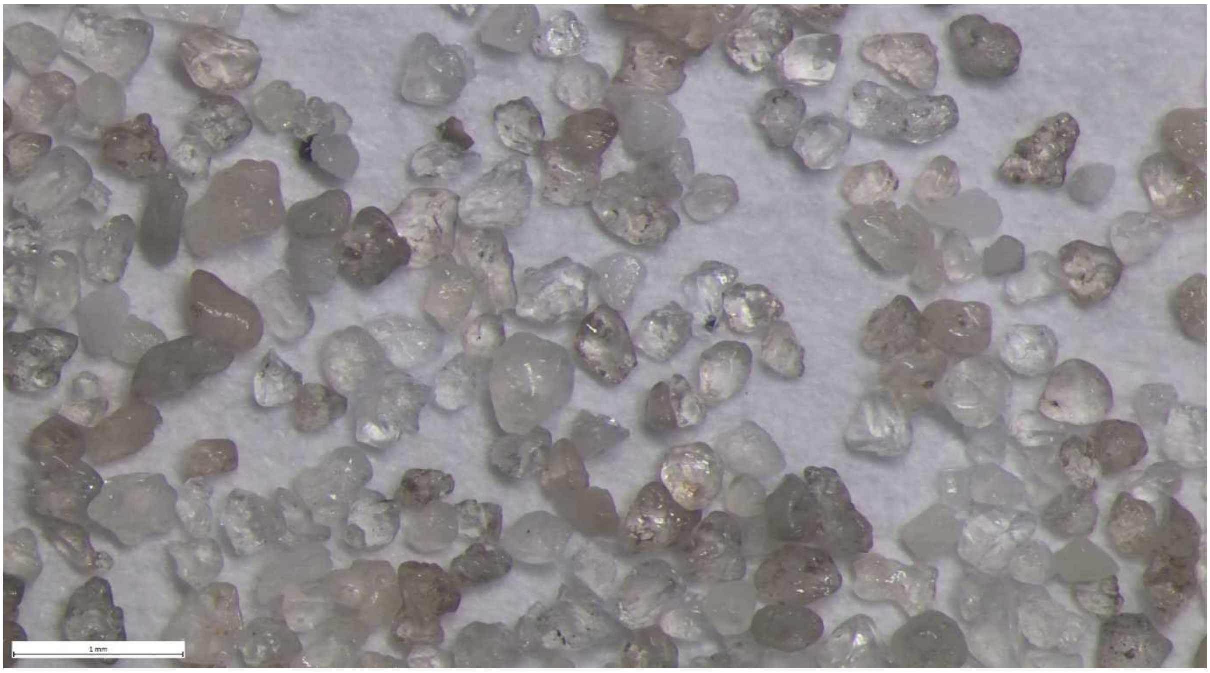


Photo - optical microscope ultrasonically treated CTIF IE sand: overview

Photo - Optical microscope Ultrasonically treated INOTEC sand: overview

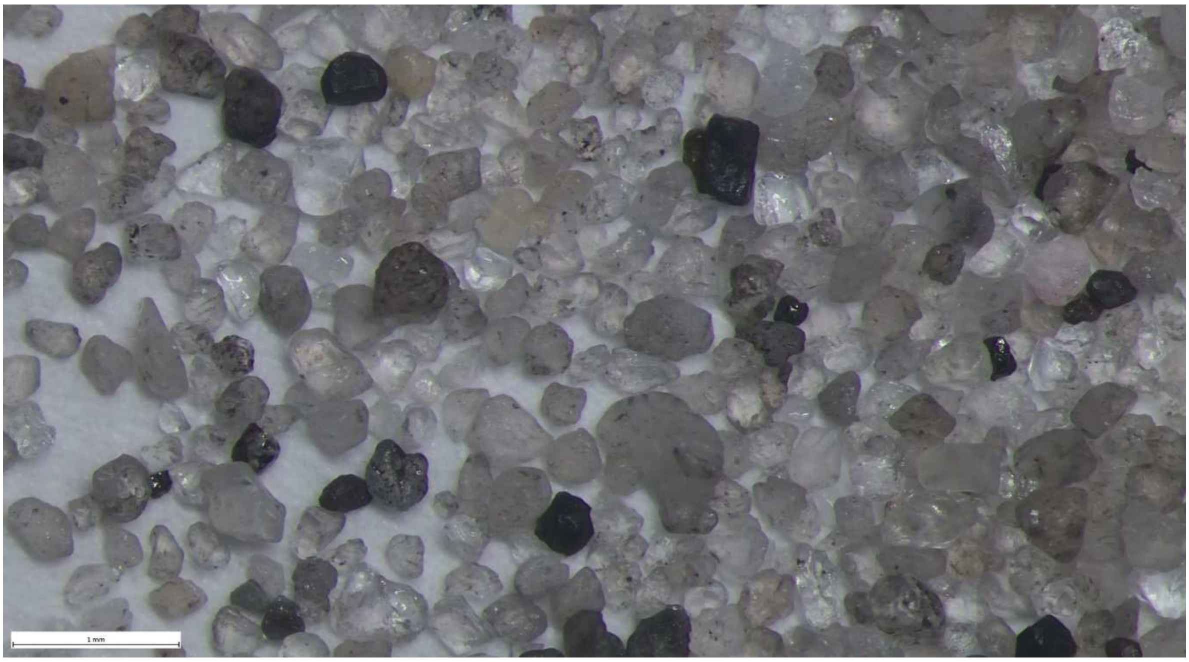


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo - Optical microscope Ultrasonically treated GEOPOL W37-20 sand: overview

Photo - Optical microscope Ultrasonically treated PEAK W37 sand: overview

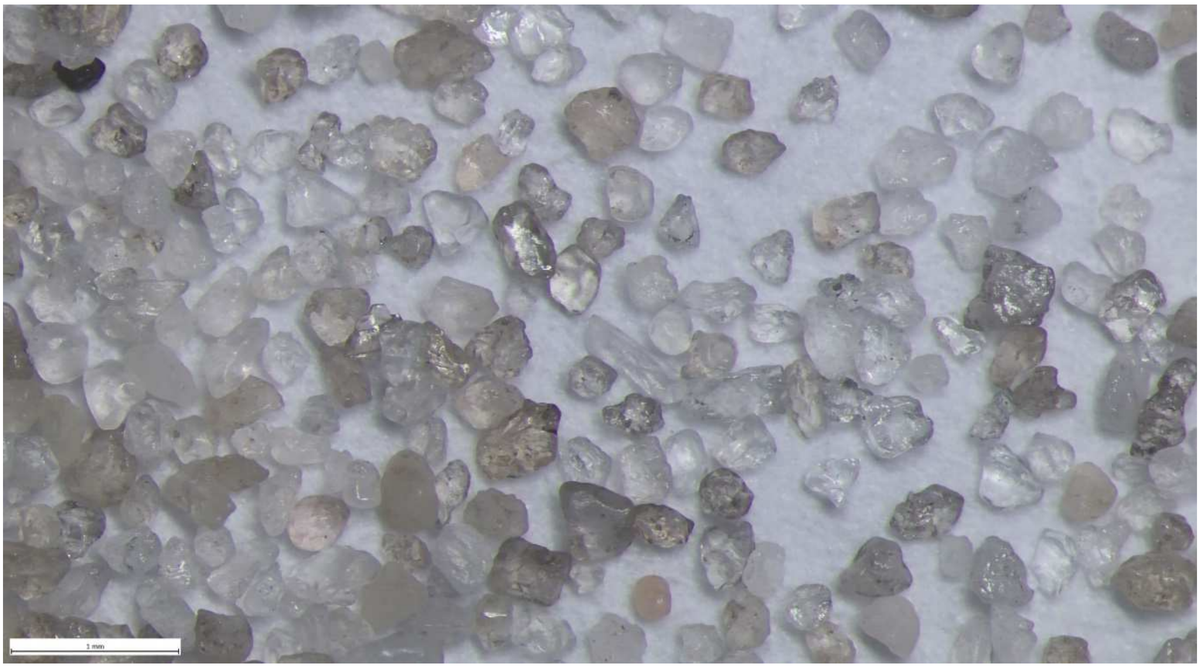


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo - SEM sand CTIF IE to be treated: overview

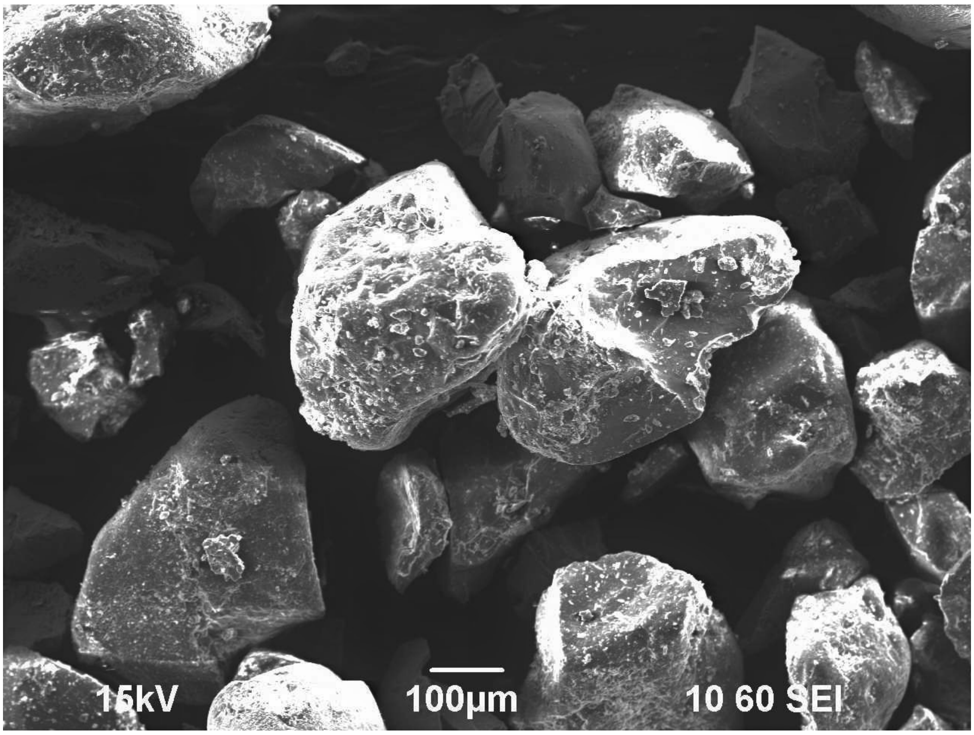


Photo SEM sand INOTEC to be treated: overview

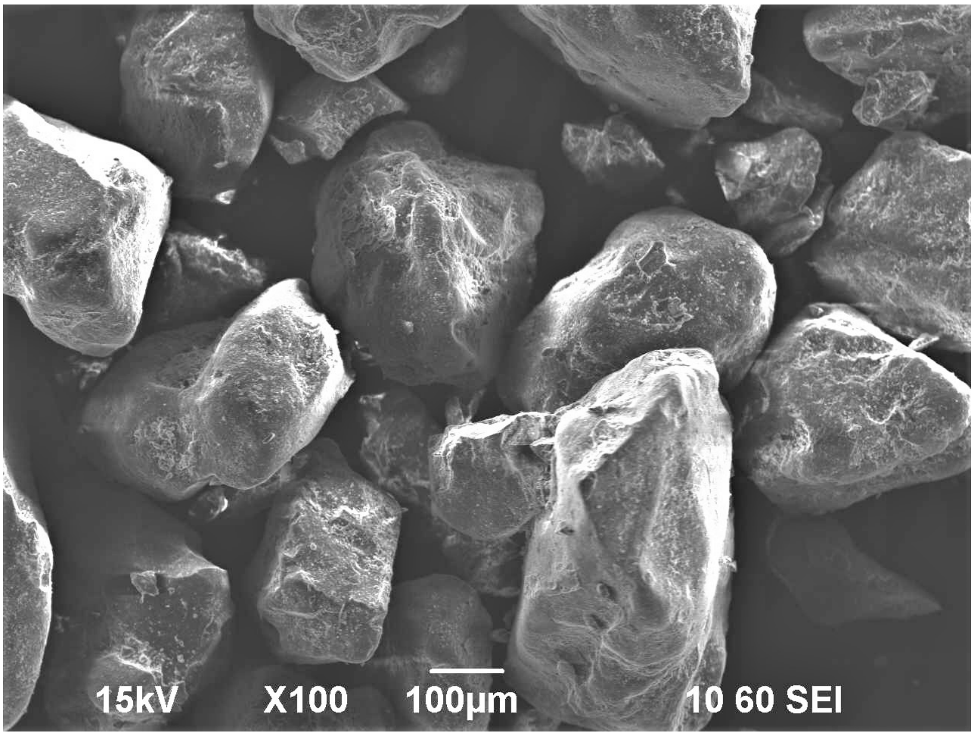


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo MEB sand GEOPOL W37-20 to be treated: overview

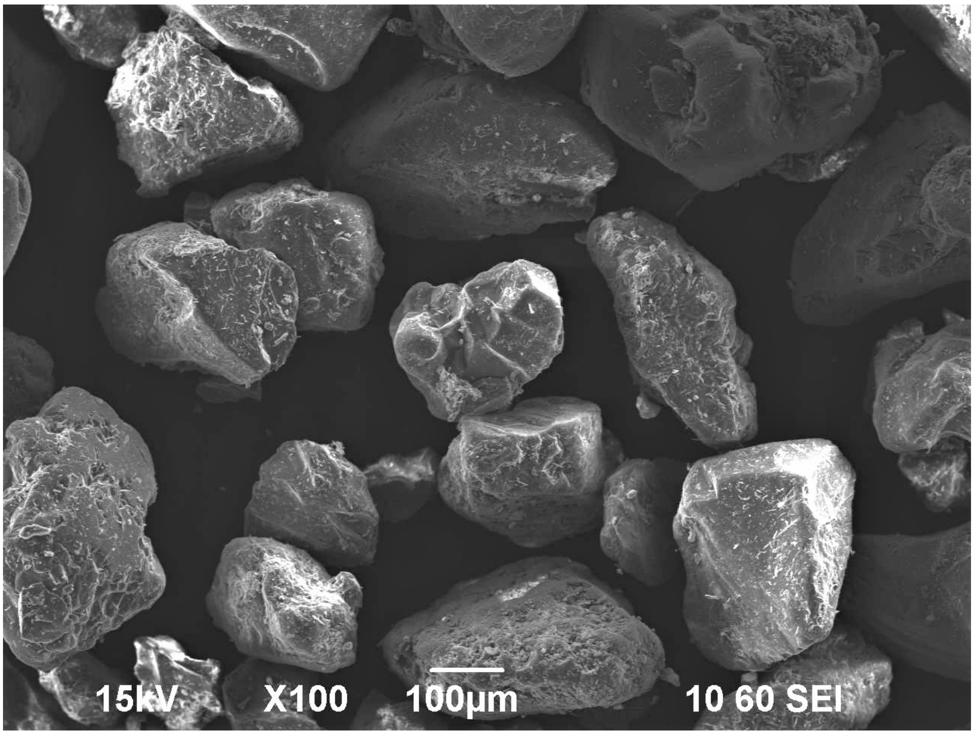


Photo MEB sand PEAK W37 to be treated: overview

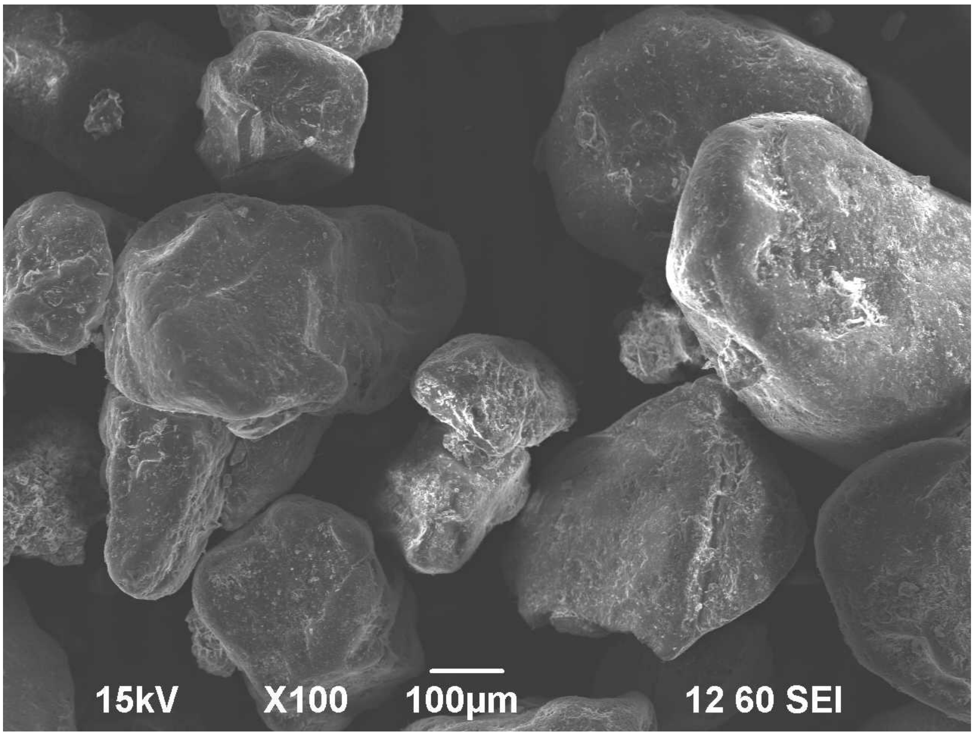


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo MEB sand CTIF IE mechanically treated: overview

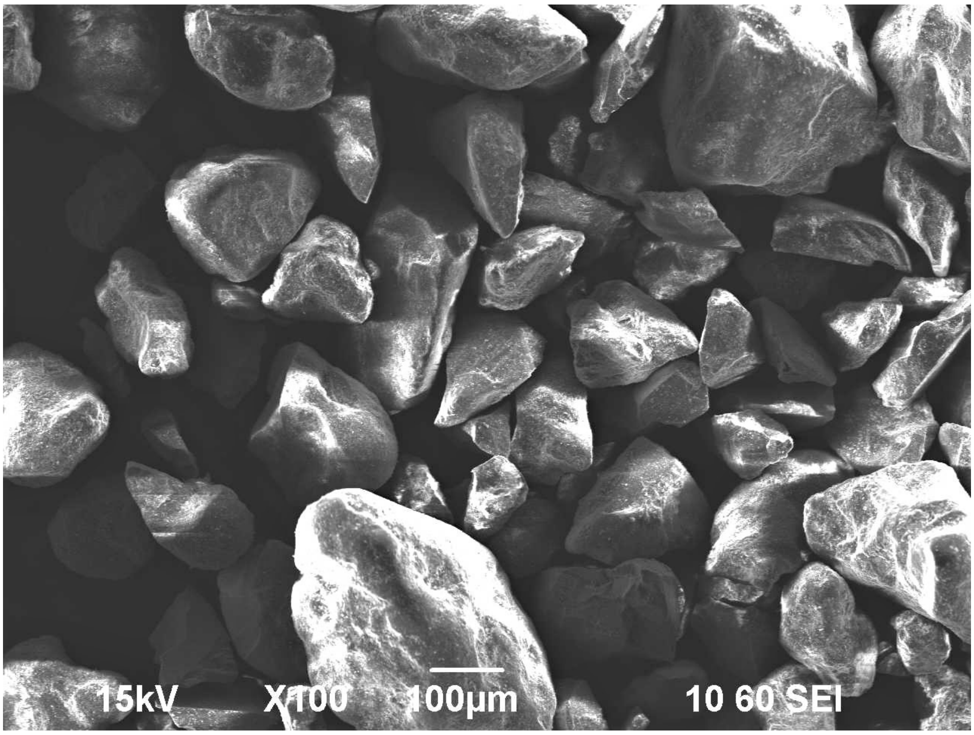


Photo MEB sand INOTEC mechanically treated: overview

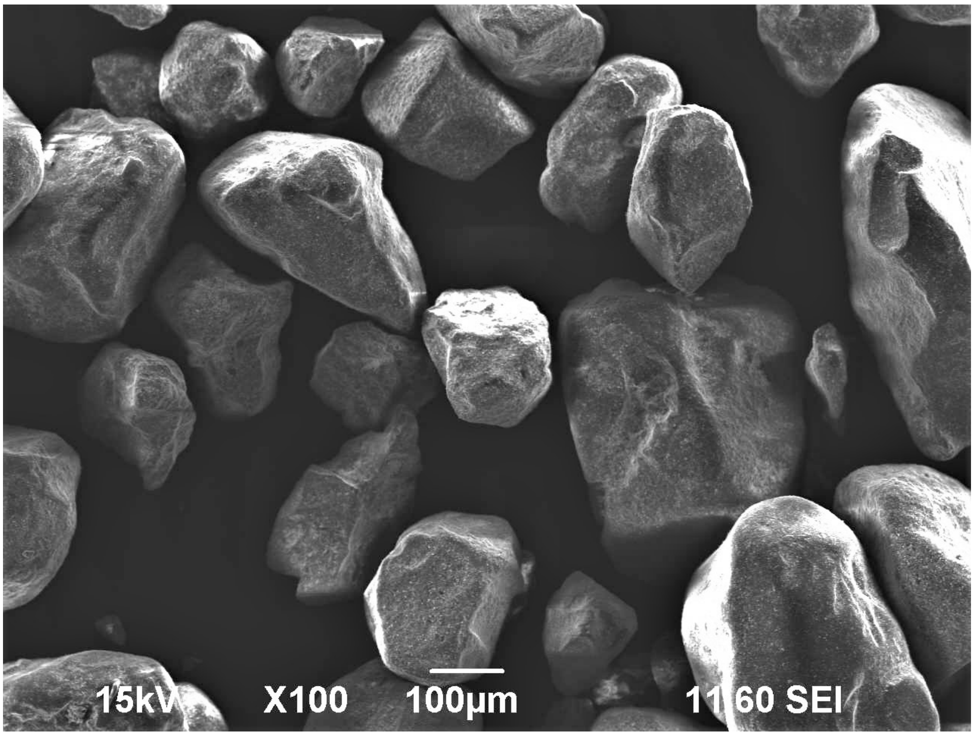


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo MEB sand GEOPOL W37-20 mechanically treated: overview

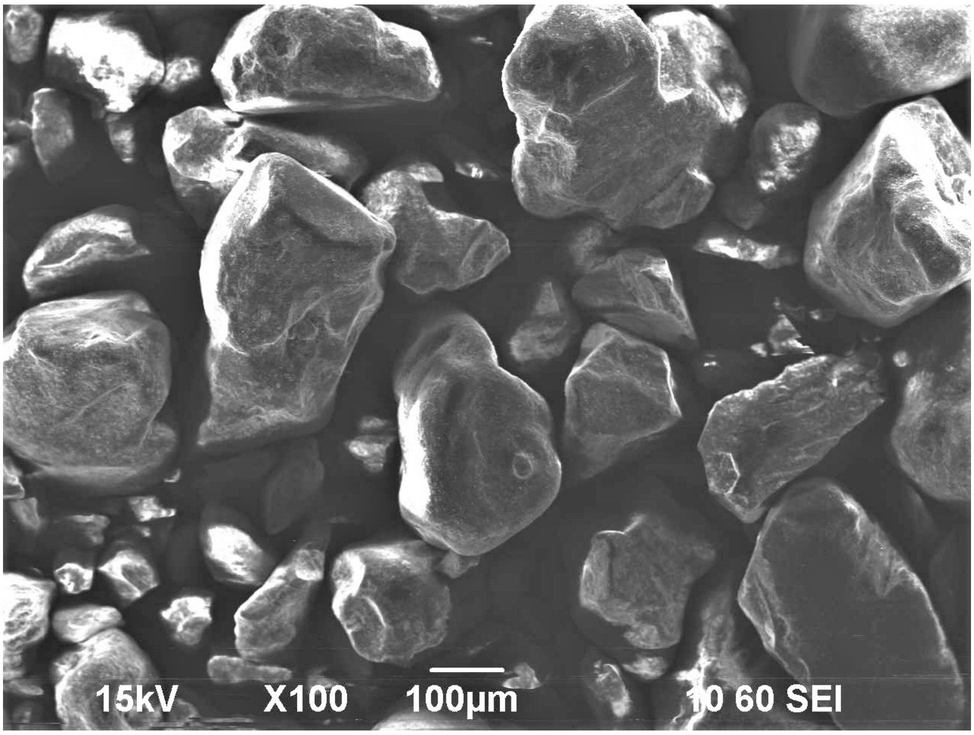


Photo MEB sand PEAK W37 mechanically treated: overview

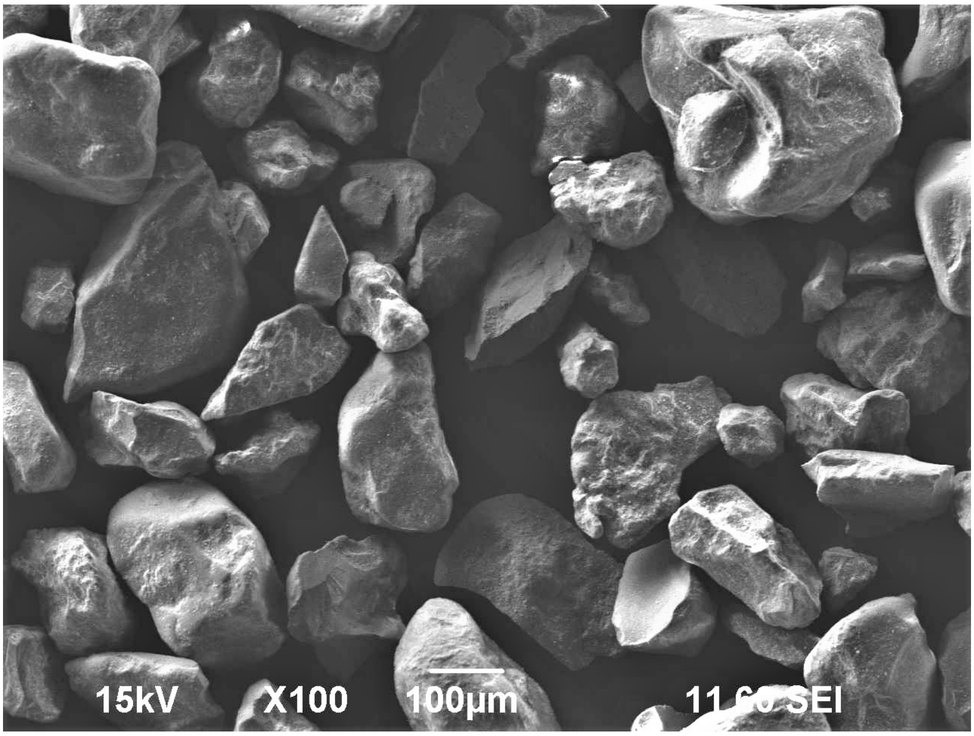


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

Photo SEM sand CTIF IE treated by the hydromechanical process: overview

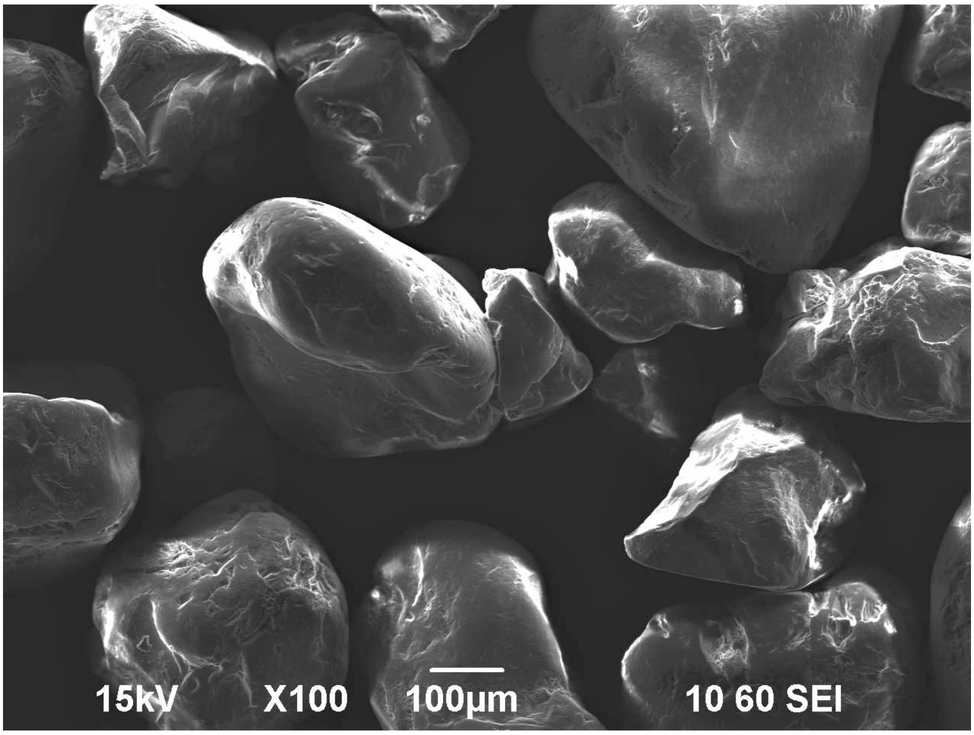


Photo MEB sand INOTEC treated by the hydromechanical process: overview

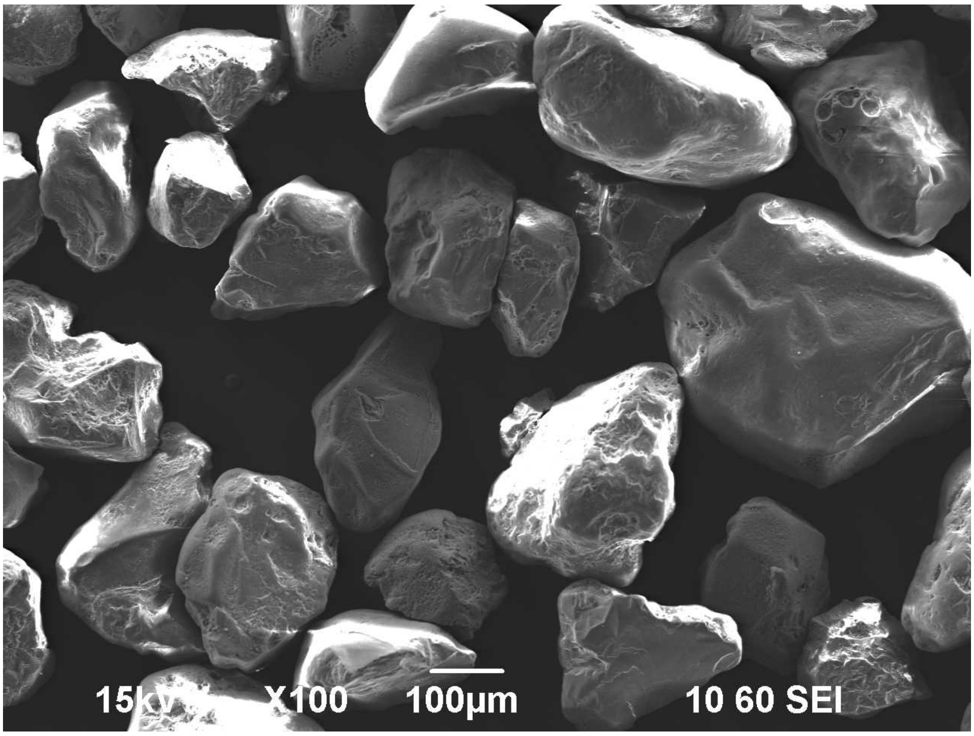


Photo MEB sand GEOPOL W37-20 treated by the hydromechanical process: overview

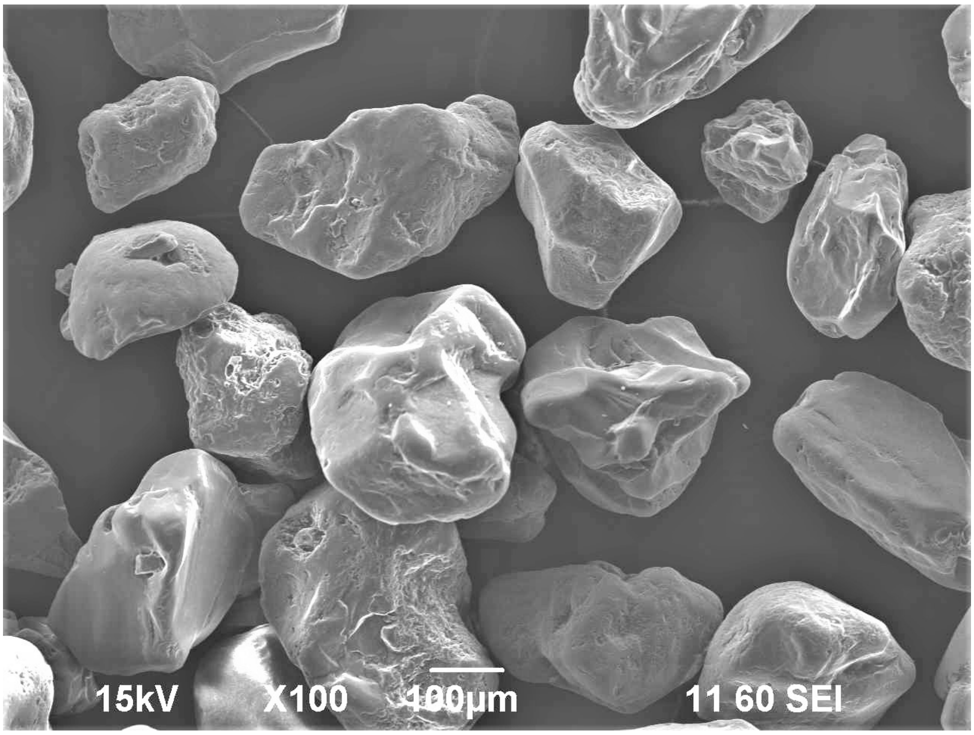


Photo MEB sand PEAK W37 treated by the hydromechanical process: overview

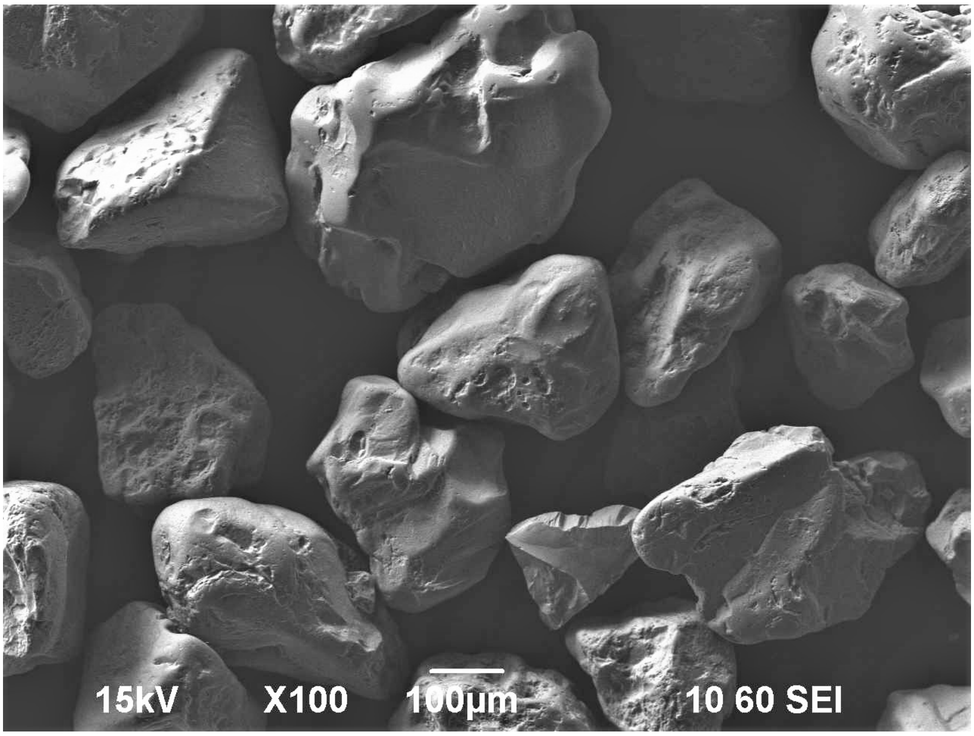
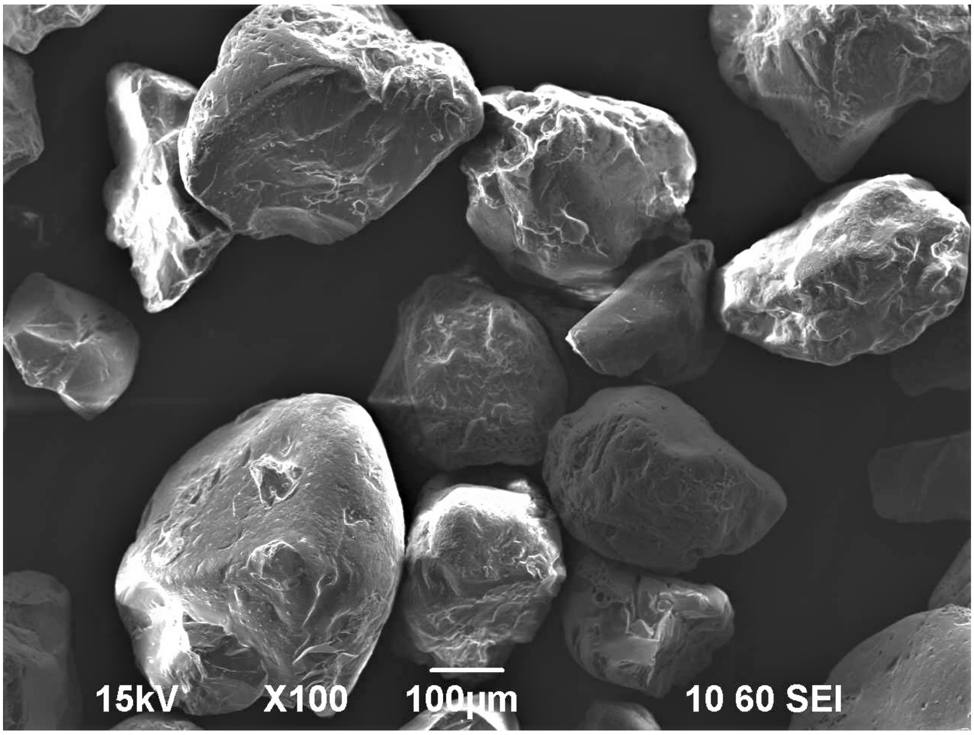


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo of ultrasonically treated CTIF IE sand: general view



SEM photo of INOTEC ultrasonically treated sand: general view

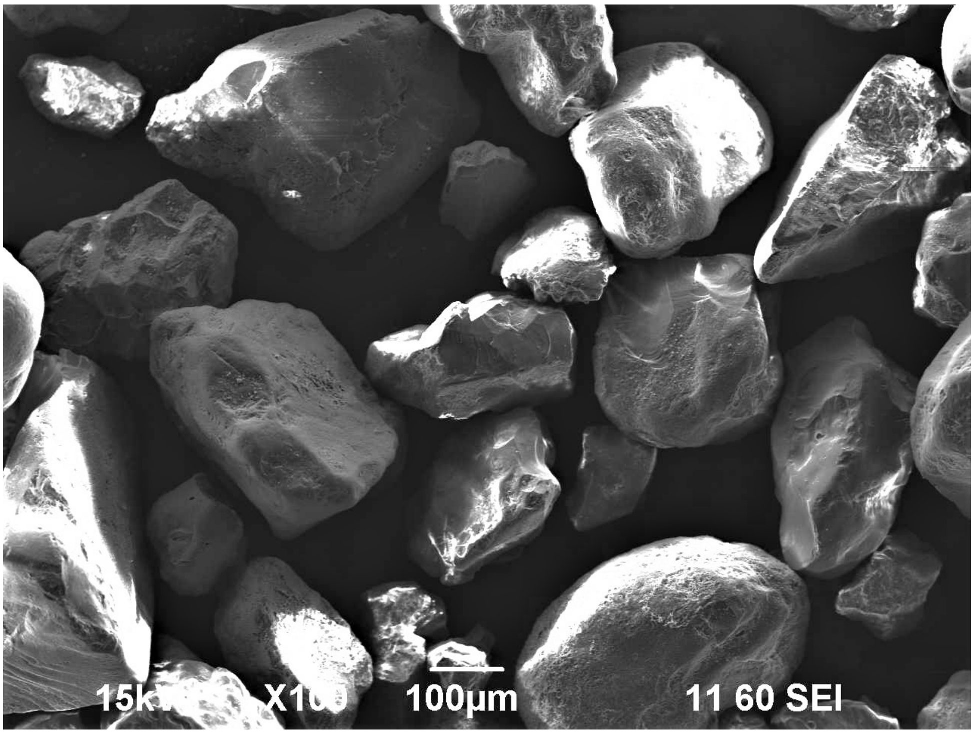
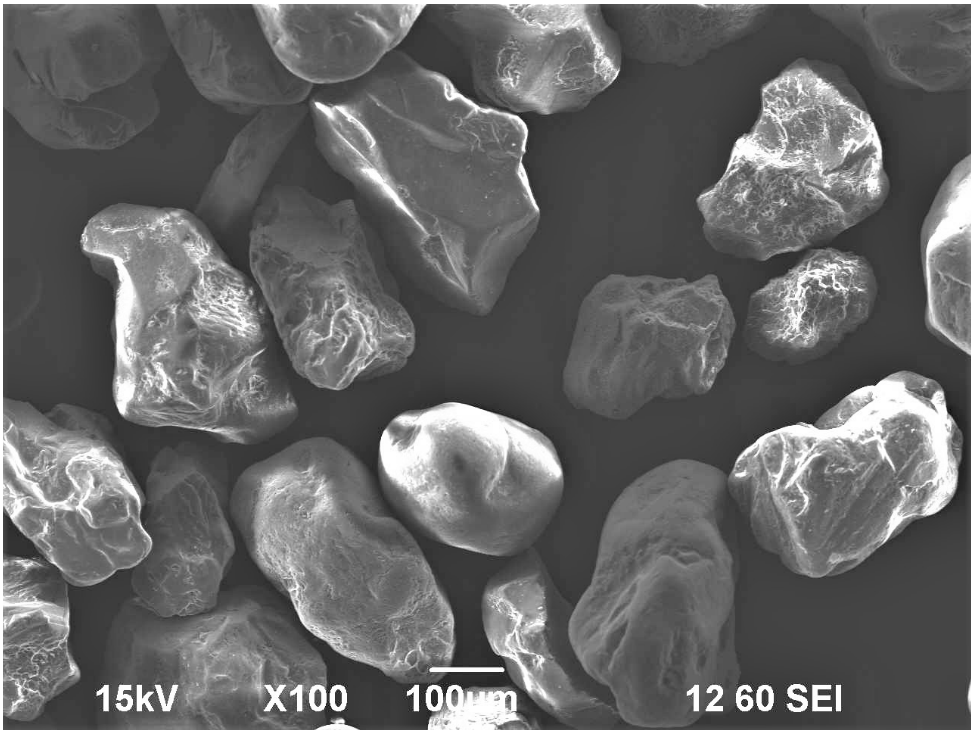


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM Photo - sand GEOPOL W37-20 ultrasonically treated: overview



SEM photo - sand PEAK W37 ultrasonically treated: overview

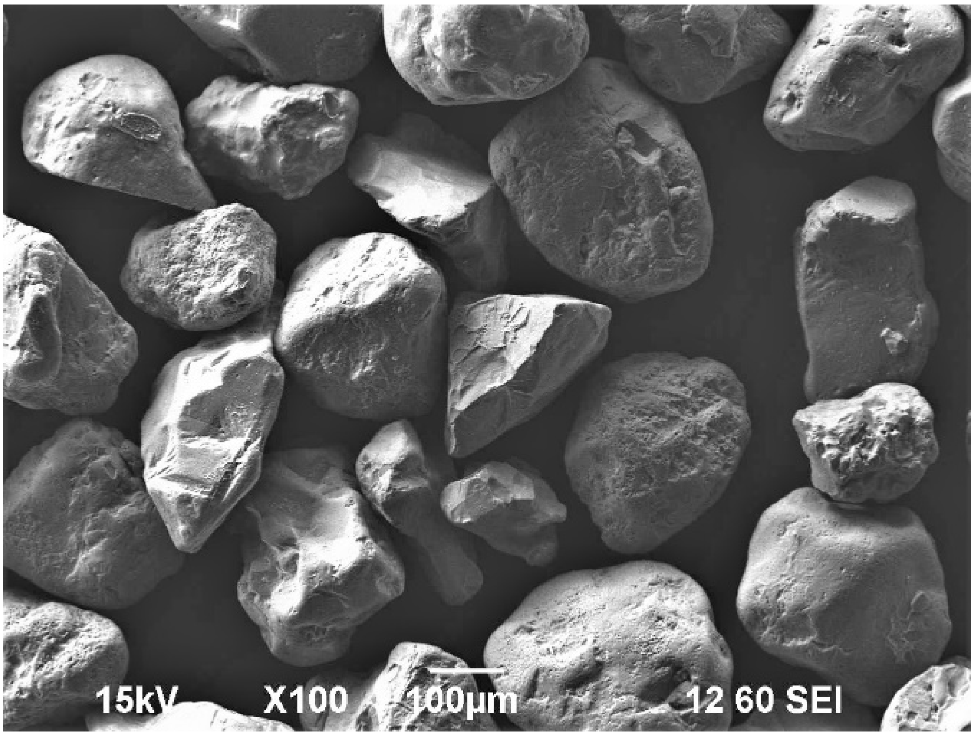
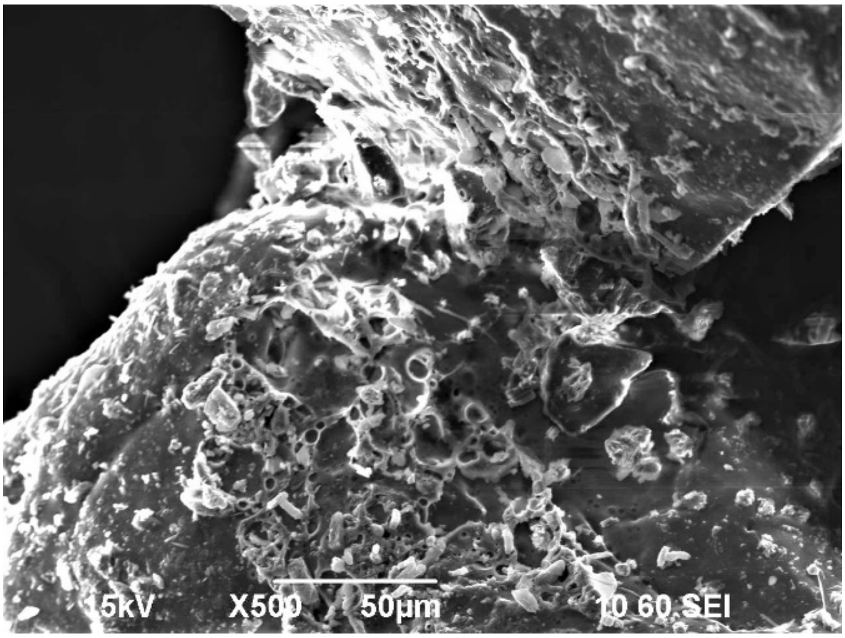


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo of CTIF IE sand to be treated: view of a chemical bridging and appearance of the residual gangue



SEM photo of INOTEC sand to be treated: view of a chemical bridging and appearance of the residual gangue

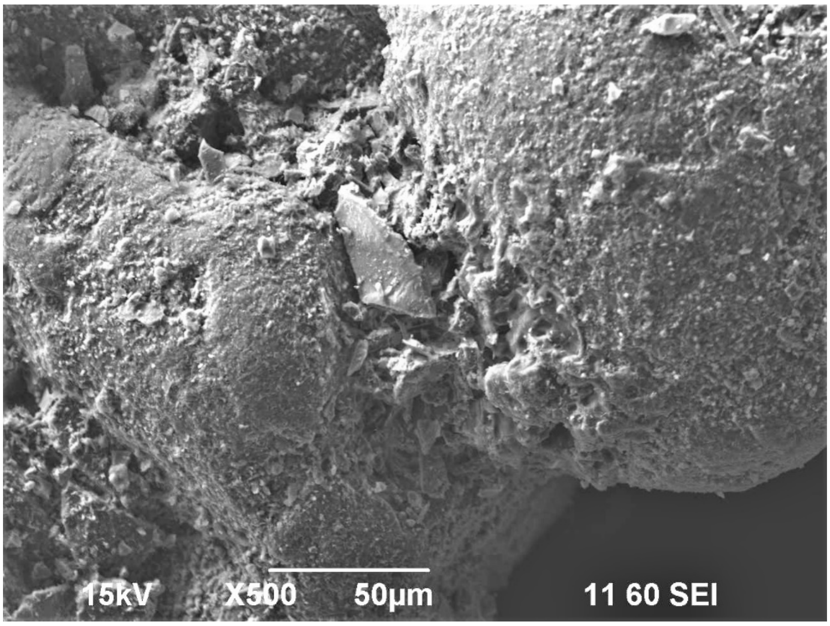
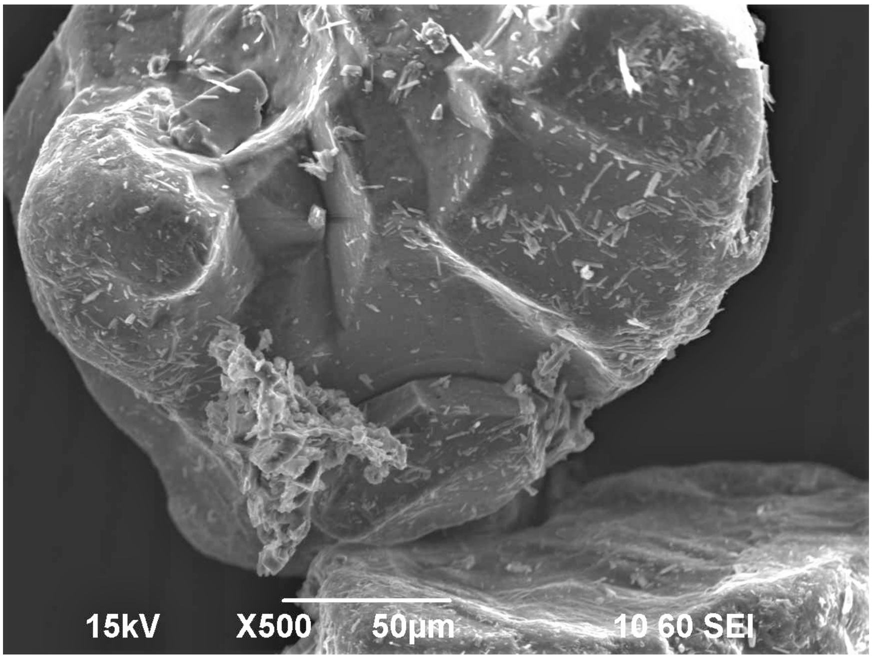


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo of GEOPOL W37-20 sand to be treated: view of chemical bridging and appearance of the residual gangue



SEM photo of PEAK W37 sand to be treated: view of a chemical bridging and appearance of the residual gangue

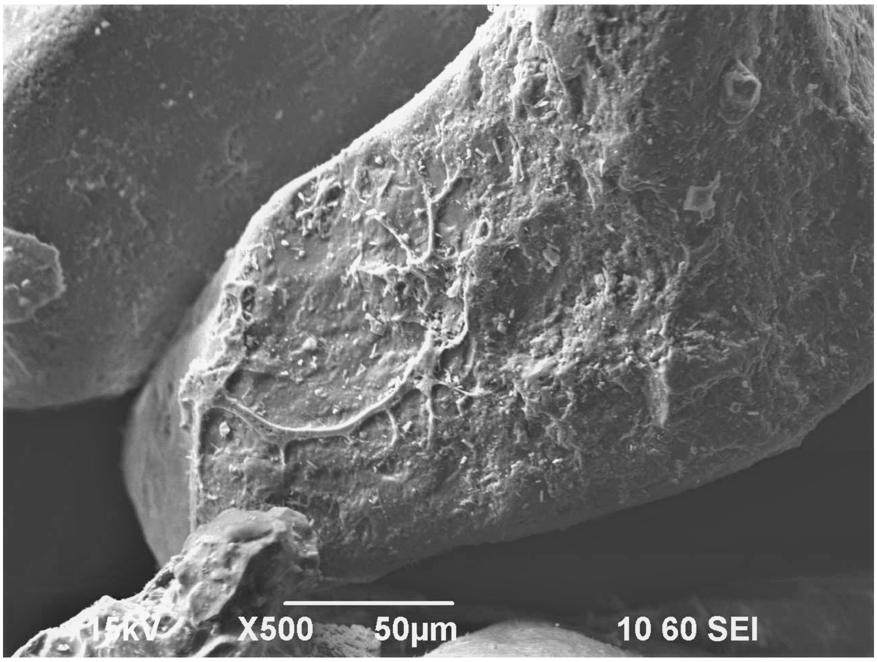
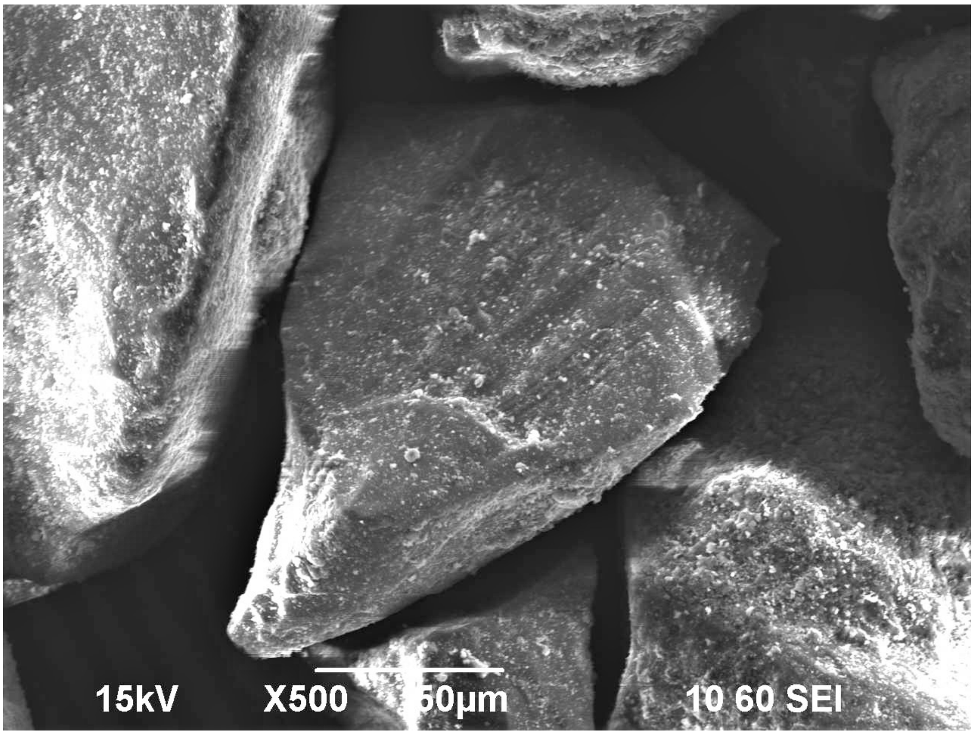


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo of mechanically treated CTIF IE sand: appearance of grains and residual gangue



SEM photo of mechanically treated INOTEC sand: appearance of grains and residual gangue

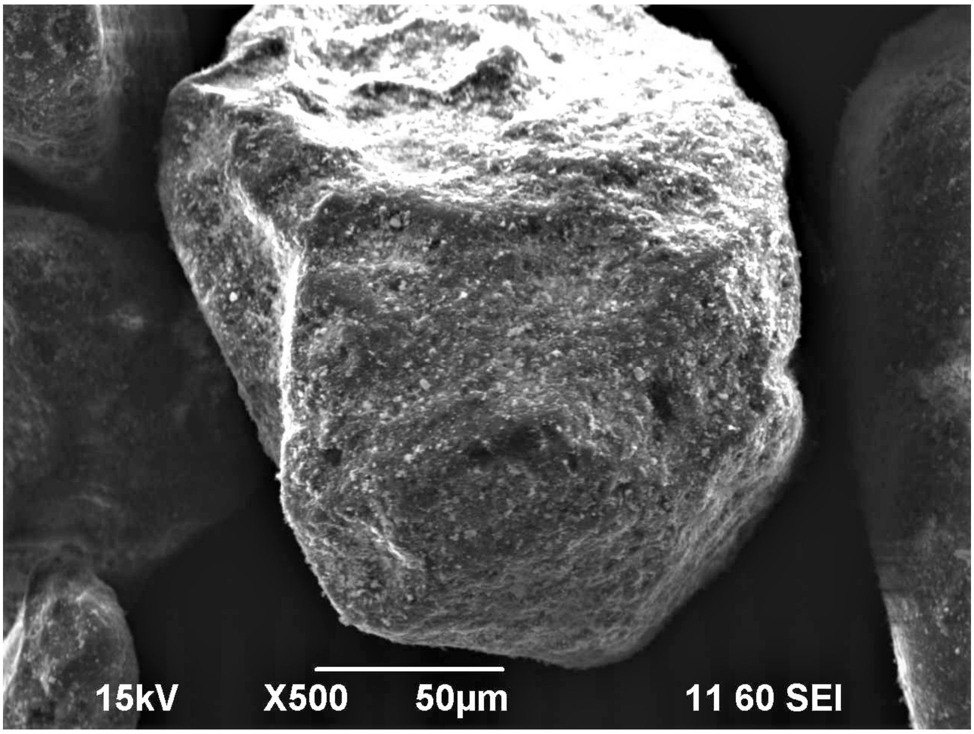
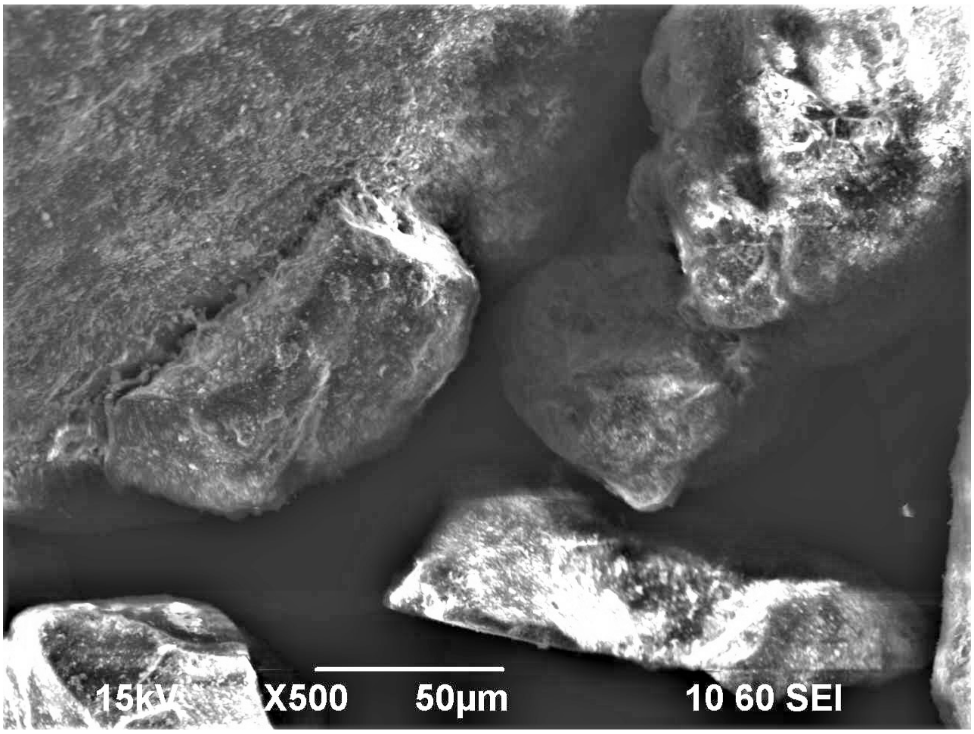


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo of mechanically treated GEOPOL W37-20 sand: appearance of grains and residual guangue



SEM photo of mechanically treated PEAK W37 sand: appearance of grains and residual gangue

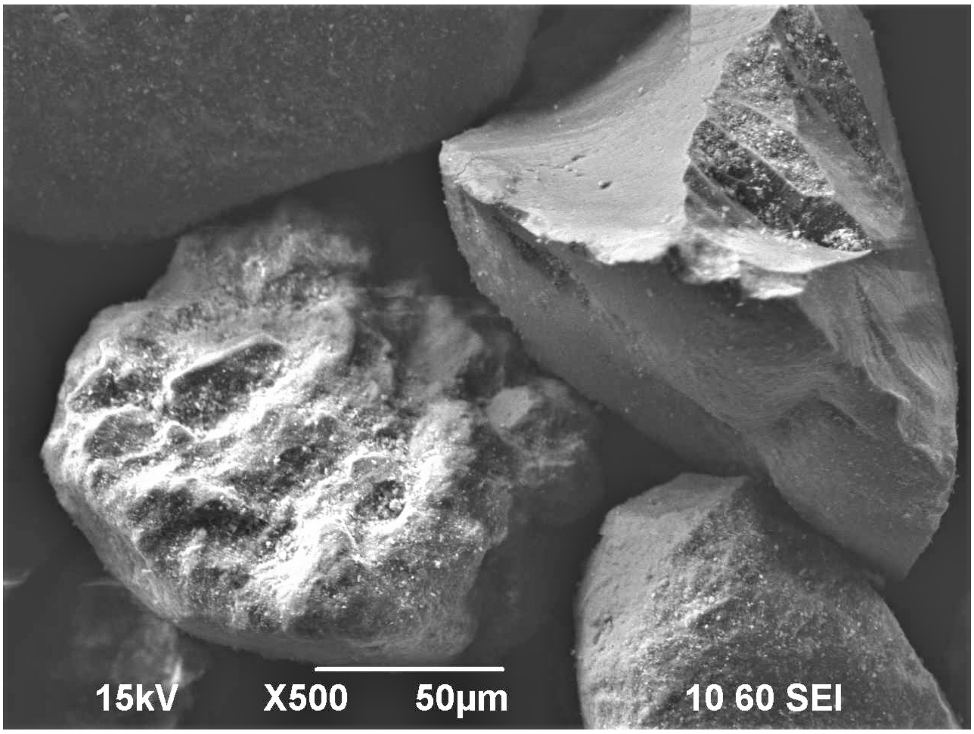
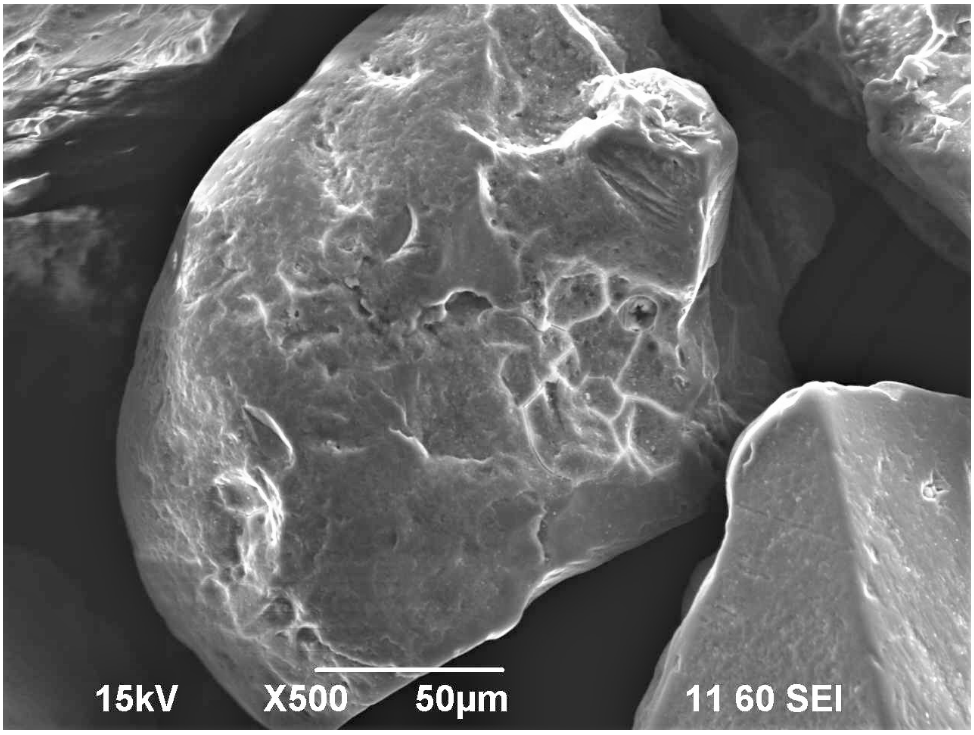


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo of hydromechanically treated CTIF IE sand: grain appearance



SEM photo of hydromechanically treated INOTEC sand: appearance of the grains

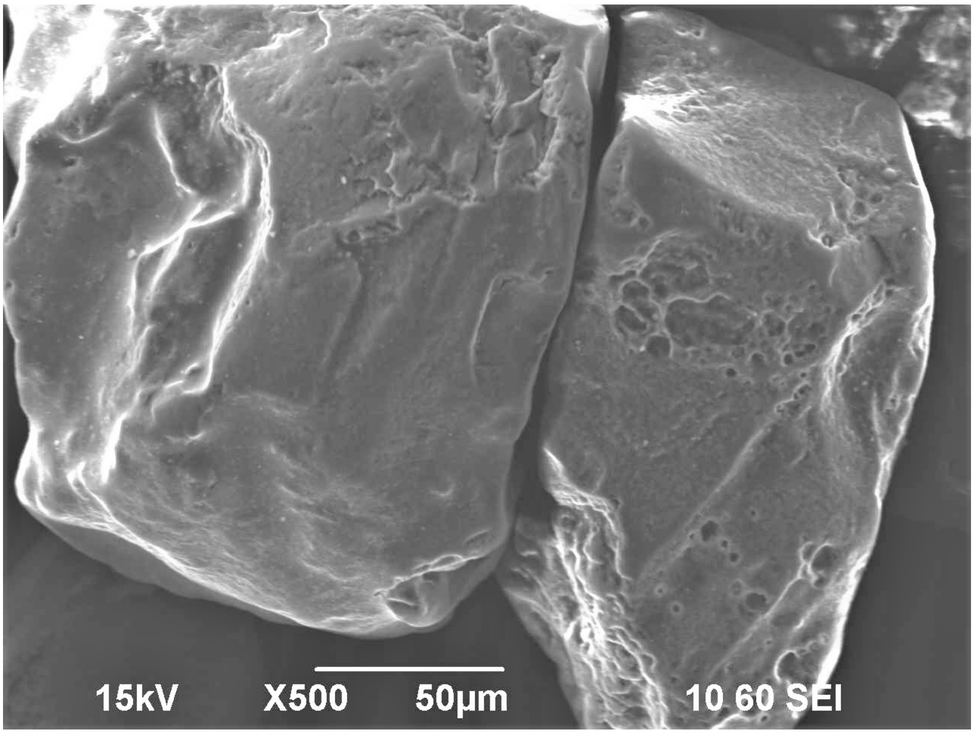
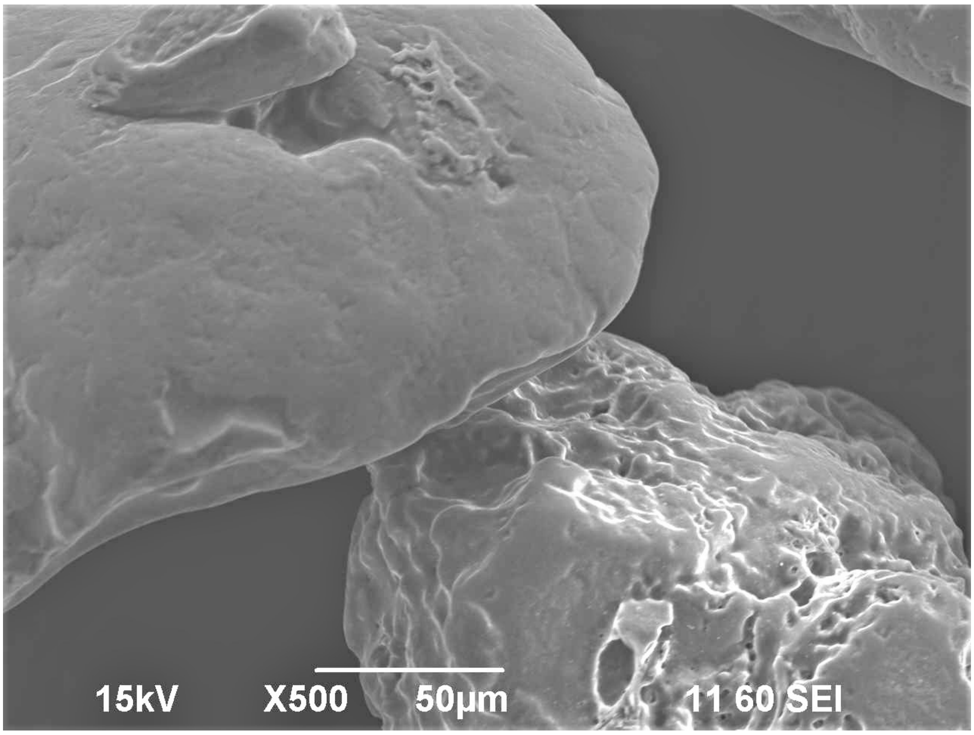


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo GEOPOL W37-20 sand treated by hydromechanical process: grain aspect



SEM photo of hydromechanically treated PEAK W37 sand: grain appearance

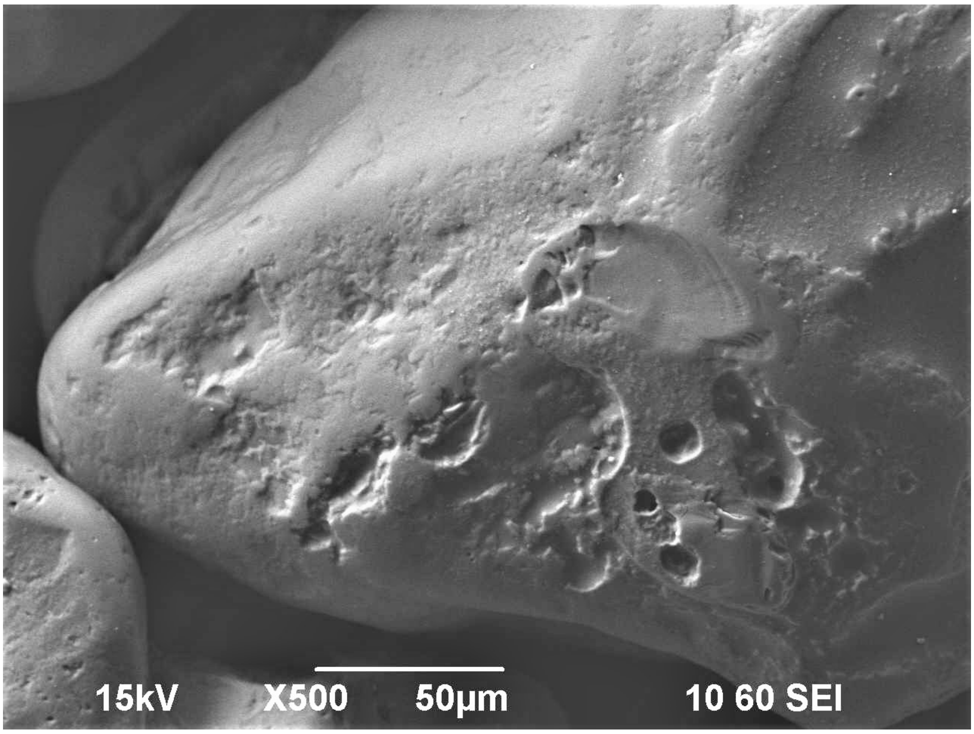
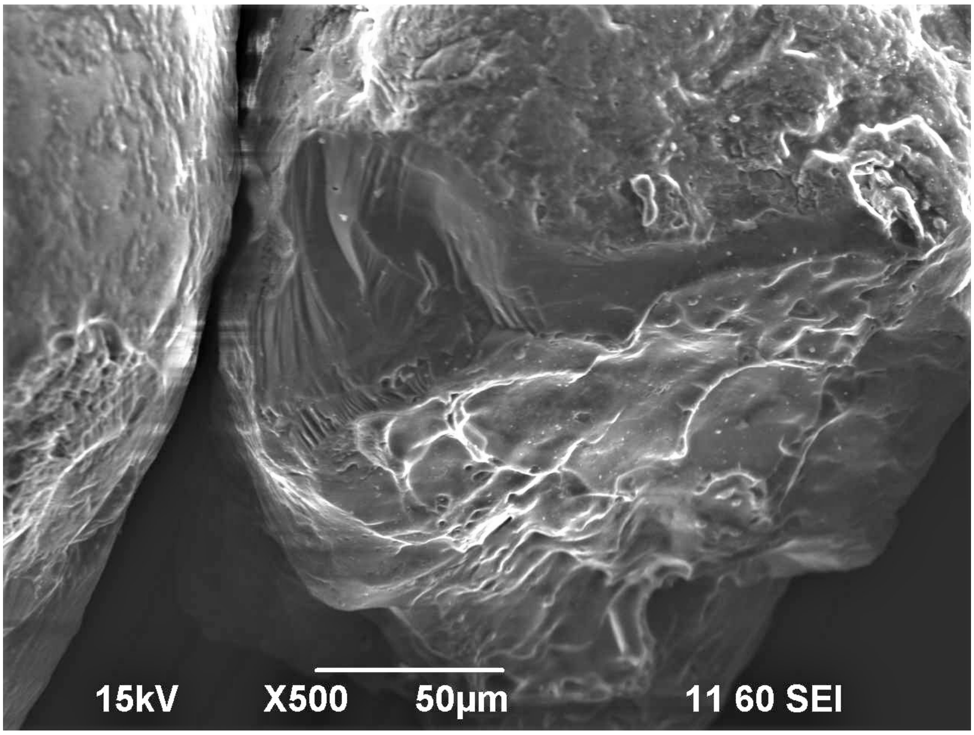


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo of ultrasonically treated CTIF IE sand: grain appearance



SEM photo of INOTEC sand treated by ultrasound: appearance of the grains

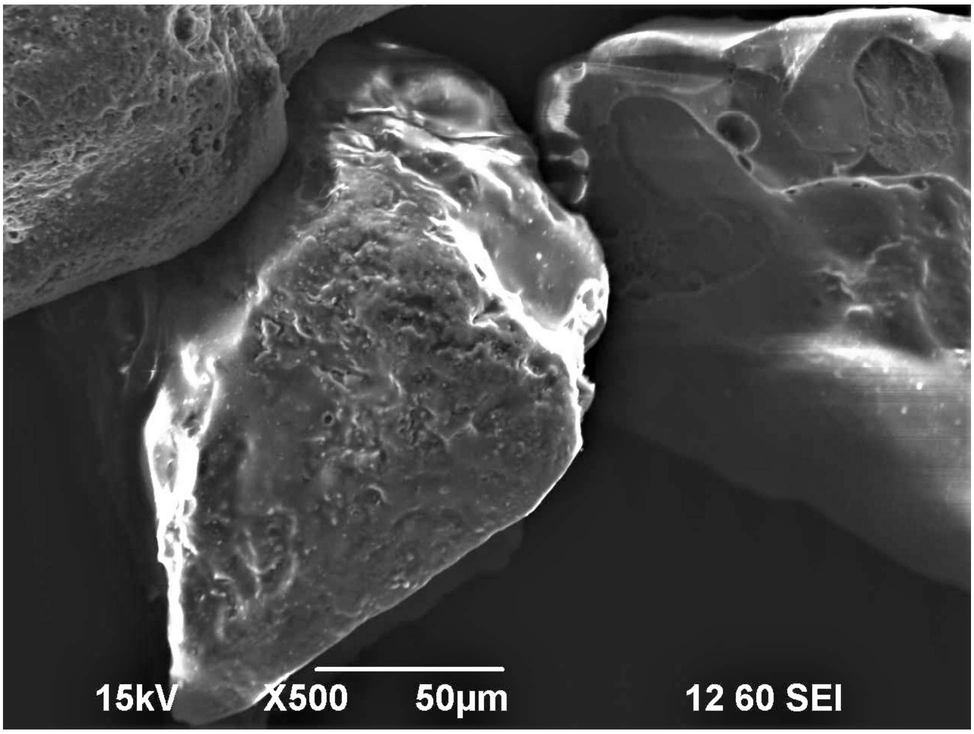
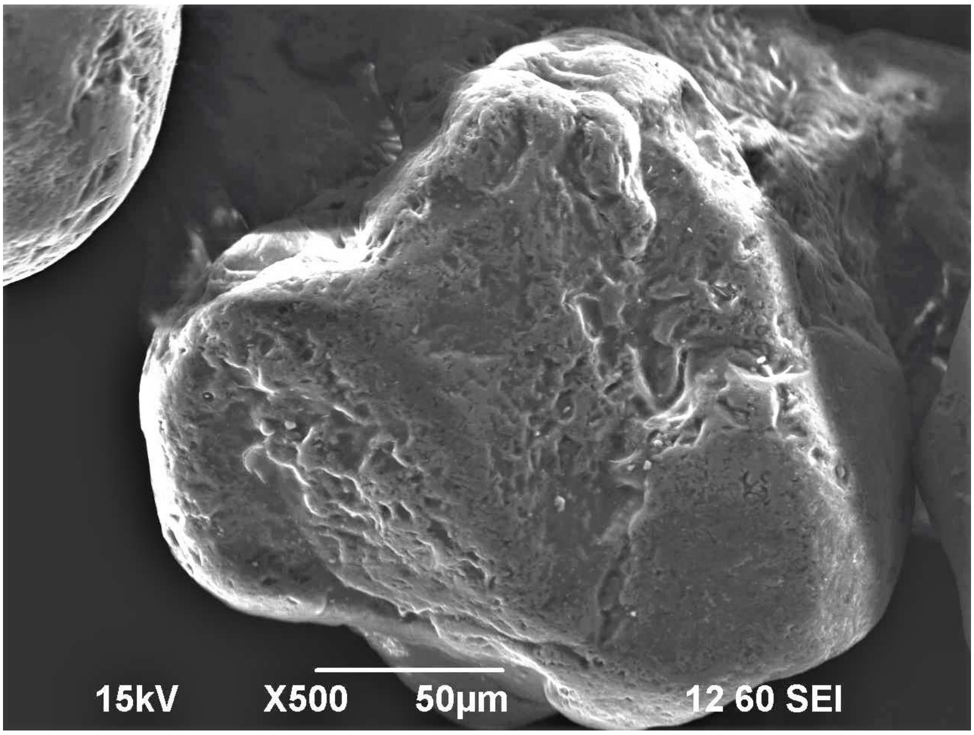
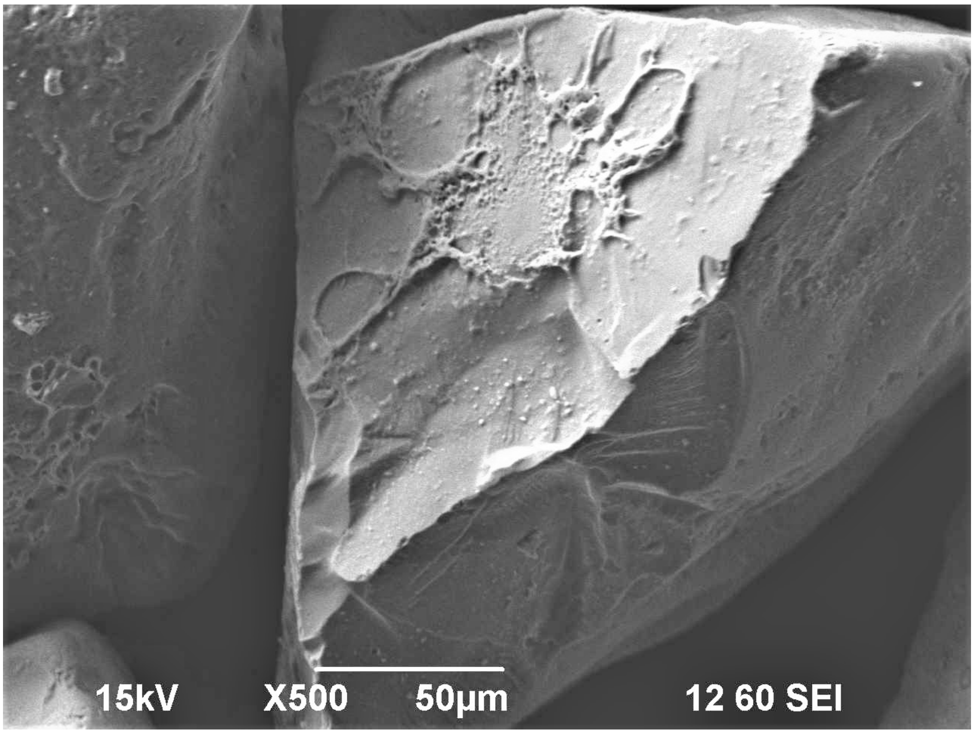


Illustration related to the summaries of the inorganic sand treatment tests (cont'd)

SEM photo GEOPOL W37-20 sand treated by ultrasound: appearance of the grains



SEM photo of ultrasonically treated PEAK W37 sand: grain appearance



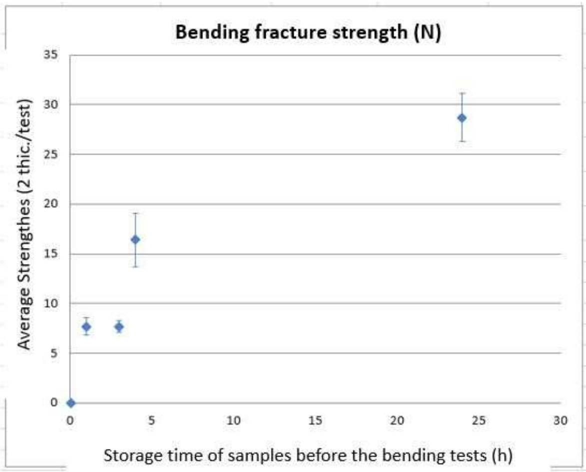
2.5. Reuse test of treated sand and comparison with new reference sand BE01

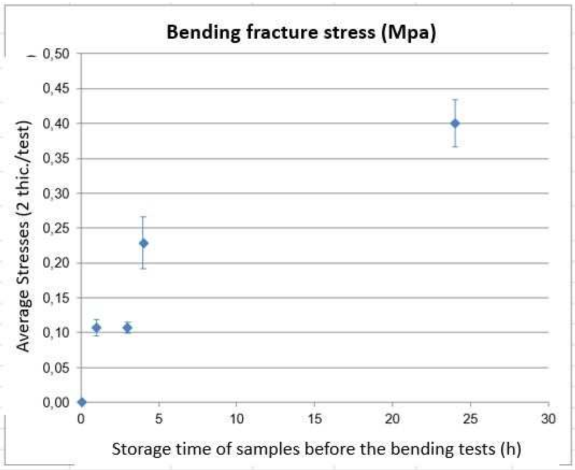
In order to verify whether the treated sand can produce quality cores without major service life problems, a 7 kg batch of sand marked "CTIF IE" was treated with the hydromechanical process that gave the best results.

Bending test pieces were made to measure the strength of the cores and to determine the service life of the sand prepared with 100% treated sand, compared to 100% new sand.

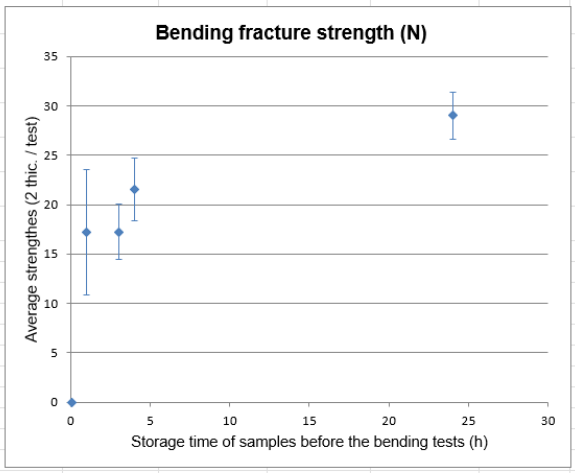
<u>Comparison of cores made with treated sand, compared to new sand cores:</u>

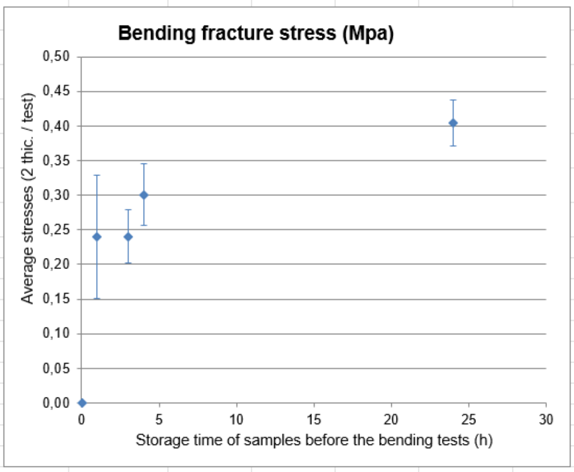
With 100% of new sand BE01 : bending fracture stress = 0.400 Mpa





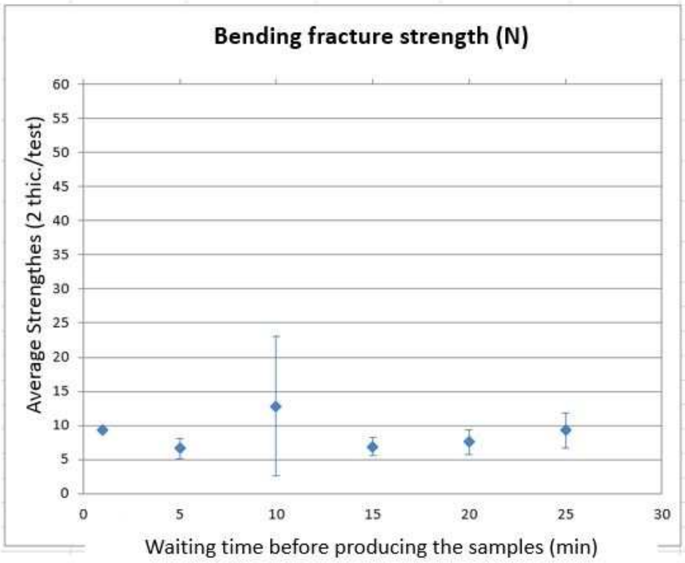
With 100% of CTIF IE sand hydromechanically treated: bending fracture stress = 0.405 Mpa

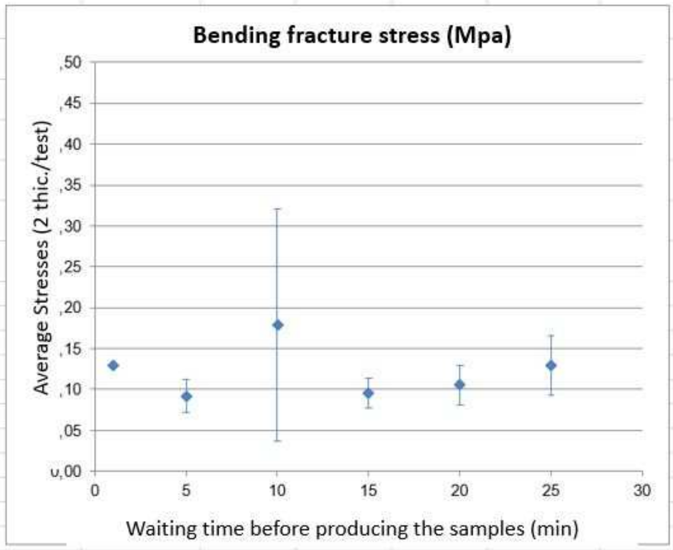




Comparison of cores made with treated sand, compared to new sand cores: Cont'd

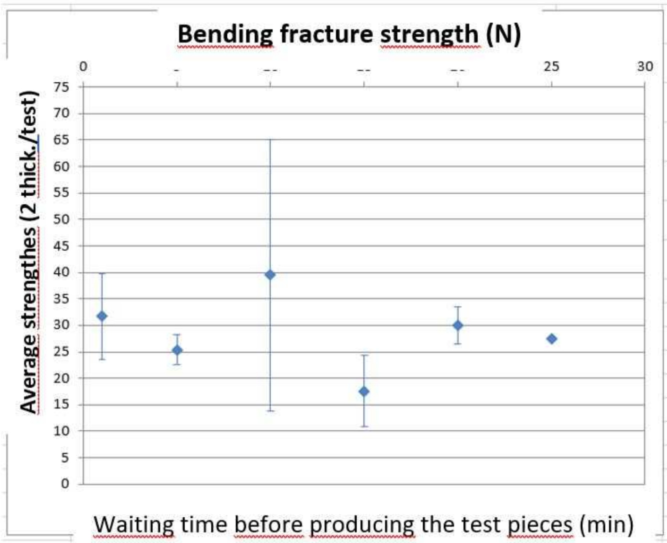
With 100% of new sand BE01 : life of the prepared sand

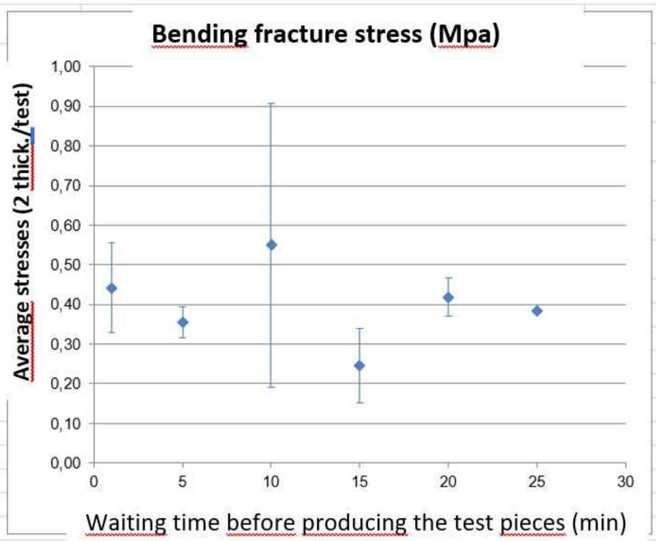




Comment: at T=30mn, hardening of the prepared sand and plugging of the machine's shooting head (unfilled test pieces)

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)

Conclusion: The strength of the cores made with the hydromechanically treated "CTIF IE" sand and the service life of the prepared sand are similar to those obtained with the new reference sand BE01.

This confirms that the hydromechanical treatment of inorganic sand waste is particularly effective for the reuse of treated sand in moulding or core making.

Illustration of bending tests and life tests

Sand preparation: 2.5% resin + 0.30% hardener

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

Illustration of bending tests and life tests: cont'd

Test pieces removing

Measurement of flexural strength of test pieces

3. Options for reusing inorganic sand waste in geo-construction

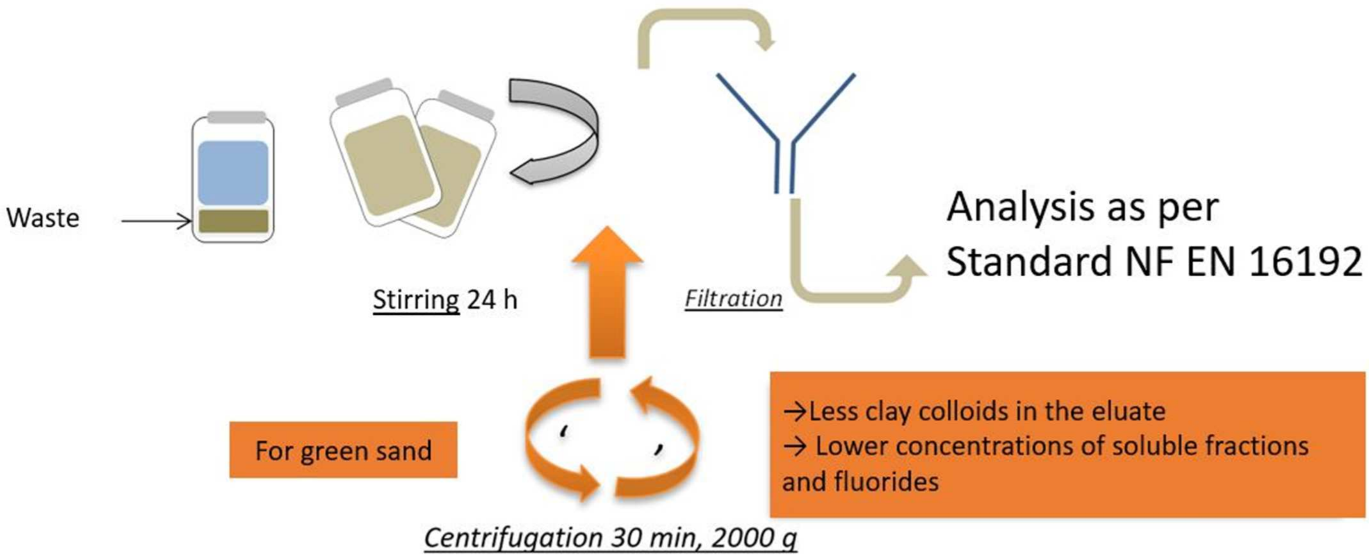
Once the steel parts have been cast by the different partners of the Green Foundry Life project in order to compare the emissions generated in the foundry between organic and inorganic sand, CTIF carried out several works for phase B4.6.

- Leaching tests on inorganic sand waste,
- Leaching tests on treated sands,
- A synthesis of the results obtained in relation to the reference documents of the different countries taking part into this project (Germany, Spain, Finland, France, Italy, Poland).

4. Details of the works performed

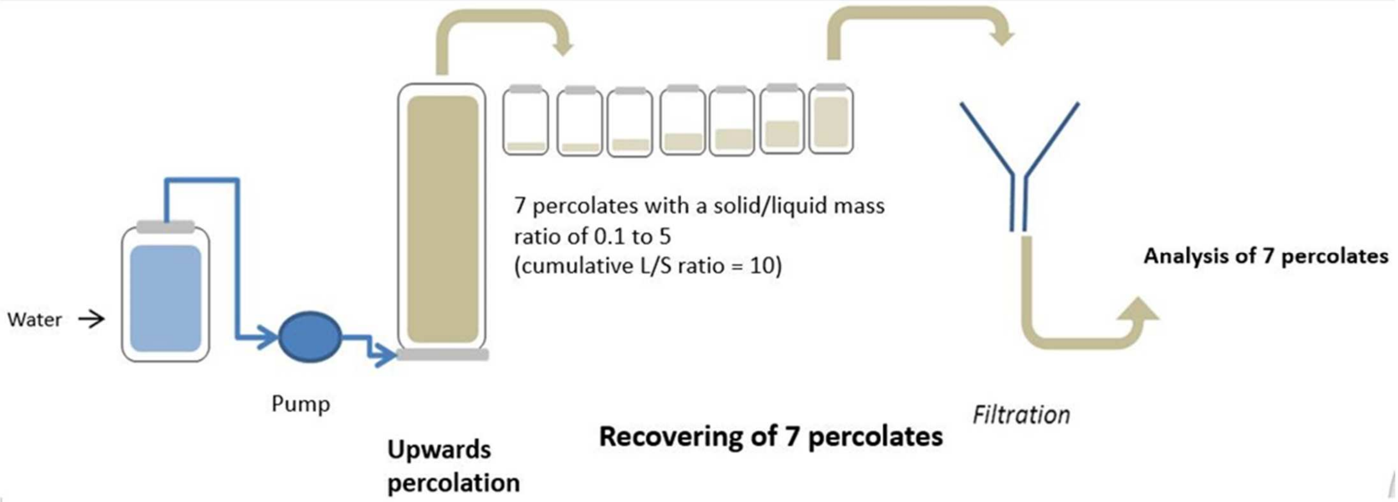
4.1. Leaching tests performed on sand samples

Principle of the leaching test (level 1): reference to standard NF EN 12457-2



Note: Paragraph 5.2.2 provides that there may be filtration difficulties and refers to Appendix E for "fine-textured, humus-rich soil waste".

Principle of the percolation test (level 2): reference to standard NF EN 14405



Note: For green sand, use a specific procedure with calcium chloride (CaCl2) to deactivate the clay and flocculate it.

Limitations related to the leaching test (see the documents submitted by the partners in the appendice)

The table below was produced using the reference documents submitted by the project partners (see documents in the appendice).

Table 8 : Assessment of limit values related to the leaching test (for acceptance of inert waste centres).

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

mg/l x (Volume of solution tested / mass of sand in solution) = mg/kgMS

mg/l x K = mg/kgMS (with K being a function of the leaching ratio L/S which in this case is = 10/2.65).

4.2 Results of leaching tests on sand samples

As announced in the introduction to this report, leaching tests were carried out on 12 sand samples:

- Four samples of inorganic sand to be treated (CTIF IE, GEOPOL W37-20, INOTEC and PEAK W37),

- Four samples of treated inorganic sand, with the lowest results obtained after characterisation (batches from the mechanical treatment process: see paragraphs 2.2, 2.3 and 2.4 of the report DeB4.5 Feasibility studies of the reuse of inorganic surplus foundry sand in core making and geo-construction),

- Four treated inorganic sand samples with the highest results after characterisation (batches from the hydromechanical treatment process: see paragraphs 2.2, 2.3 and 2.4 of the report DeB4.5 Feasibility studies of the reuse of inorganic surplus foundry sand in core making and geo-construction).

Table 9: results of leaching tests carried out on the sands to be treated

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			

Observation: The above results show that all inorganic sand samples are not acceptable for landfill for all countries.

<u>Results of leaching tests on sand samples</u>: cont'd

Table 10: results of leaching tests carried out on mechanically treated 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			

<u>Observation:</u> The above results show that not all inorganic sand samples are acceptable for landfill.

Mechanical treatment of inorganic sands is therefore not effective in this case.

<u>Results of leaching tests on sand samples</u>: cont'd

Table 11: results of leaching tests carried out on hydromechanically treated sands

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			

<u>Observation</u>: the above results show that three of the inorganic sand samples would be acceptable in an inert waste landfill for all countries, except for Italy, where the limit values applied are lower (two sands would be accepted instead of three).

- A measured value for fluoride is exceeded for Italy (limit value = 5.7 mg/kgMS),

- A measured value for phenol index is exceeded for all countries (limit value = 1 mg/kgMS).

The hydromechanical treatment of inorganic sands is particularly effective in this case.

The two exceeded values are relatively low, which suggests that all sands could be accepted by optimising this treatment process.

4.3 Synthesis of results and identification of reuse options for inorganic sands

Summary of leaching results

The results obtained during the leaching tests show that the hydromechanically treated inorganic sands INOTEC and CTIF IE are acceptable in landfills in all the partner countries of the project.

Concerning the hydromechanically treated inorganic sand GEOPOL W37-20, the acceptable limit value of the phenol index is slightly exceeded (1.10 mg/kgMS for 1 mg/kgMS max), therefore this sand is not acceptable in landfill in all project partner countries.

The hydromechanically treated inorganic sand PEAK W37 is not acceptable in landfills, only in Italy, because of a slightly exceeded fluoride content (7.1 mg/kgMS for 5.7 mg/kgMS maximum).

If the optimisation of the treatment of inorganic sands GEOPOL W37-20 and PEAK W37 in hydromechanics was not feasible to improve these results, reuse options are however possible.

For all other inorganic sands (to be treated and mechanically treated), these are not acceptable for landfill in all project partner countries, with several limit values largely exceeded (fluoride, TOC/Eluate and soluble fraction).

However, there are options for reuse of these sands.

Identification of reuse options for inorganic sands

According to the documents provided by the project partners, there are several options for the reuse of foundry sands.

For Finland, the seven pathways presented in the "Governmental Decree 843/2017" for a reuse of sands in geo-construction are the following (see the extract from the reference document in the appendice):

- Roadway, covered
- Roadway, paved
- Field covered
- Field paved
- Embankment
- Floor structure of industrial or storage building
- Road constructed of crushed stone and ash

<u>Identifying options for reusing inorganic sands</u>: cont'd

Table 12 : Limit values to be respected for the reuse of sand in geoconstruction

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 building	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							

***Exceptions to the limit values, if the maximum thickness of the executed structure is 0,5 m (mg/kg L/S 10 l/kg)**

Roadway covered : Ba=80, V=3, Cloride (Cl^-)=3600, sulphate(SO_4^{2-})=6000

Roadway paved : Cloride (Cl^-)=14000, sulphate(SO_4^{2-})=20000

Field covered : Sb=0,4

1) The maximum amount of recovered asphalt chippings and crushed asphalt at an earth construction site is 1,000 tonnes

2) The layer thickness of a road constructed of crushed stone and ash is set at the calculated thickness of the filler layer

3) The limit values set for chloride, sulphate and fluoride in Table 1 do not apply to a structure that meets all the following requirements: situated at a distance no greater than 500 m from the sea; the direction of discharge of water draining through the structure is into the sea; and there are no wells used for domestic water intake between the structure and the sea

4) Toluene, ethylbenzene and xylene (cumulative content)

5) Polyaromatic hydrocarbons: anthracene, acenaphthene, asenaphthylene, bentz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, phenanthrene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, chrysene, naphthalene and pyrene (cumulative content)

6) Phenol, o-cresol, m-cresol, p-cresol and bisphenol-A (cumulative content)

7) Polychlorinated biphenyl congeners 28, 52, 101, 118, 138, 153 and 180 (cumulative content)

<u>Identifying options for reusing inorganic sands</u>: cont'd

For France, the three channels presented in the CEREMA guide "Environmental acceptability of alternative materials in road techniques - Foundry sands", in the case of reuse of sands as alternative materials in road techniques are the following:

- Usage of type 1 : see guide CEREMA on web site www.cerema.fr ,
- Usage of type 2 : see guide CEREMA,
- Usage of type 3 : see guide CEREMA,

Table 13: Limit values to be respected for the reuse of sand in road technology

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		

<u>Identifying options for reusing inorganic sands</u>: cont'd

Based on the values measured during the leaching tests carried out on the inorganic sands, CTIF IE, INOTEC, GEOPOL W37-20 and PEAK W37, and taking into account the limit values provided by the project partners (see tables 8 to 13 in previous pages), table 14 below summarizes all the possible reuses in geo-construction and road techniques for all the samples tested.

Table 14: Possible reuse options for inorganic sands tested during the project

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
MAJ du 12.01.2022									

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					

<u>Conclusion</u> :

The above results show that the waste from the inorganic sand "INOTEC" can be reused in all geo-construction and road engineering options. The waste from the inorganic sand "PEAK" is only reusable for two geo-construction options, and the waste from the inorganic sand "INOBAKE" (CTIF IE) can be reused for all road engineering options.

After mechanical treatment of these inorganic sand wastes, there are fewer options for reuse in geo-construction and road engineering. This shows that the mechanical treatment is inefficient.

Instead of cleaning the sand grains, the mechanical treatment has "released" pollutants captured by the new sand during the steel manufacturing process (these pollutants are contained in the residual gangue and in the fine elements of the sand).

The presence of these pollutants in too large quantities is the cause of poor leaching results (e.g. fluorides, soluble fraction, DOC, Cr, Ni).

On the contrary, it appears that all the options of reuse in geo-construction and road techniques are possible for inorganic sand wastes treated by hydromechanical technology, except for the option of reuse in road technique of type 3 in the case of the "GEOPOL" sand where the phenol index and fluorides are slightly above the acceptance limits in the partner countries.

This shows that hydromechanical technology is effective in treating inorganic sands.

To conclude, at this stage of the development of the different inorganic binders tested during this project, we cannot deduce that such or such process of inorganic sand is the best placed for a reuse in geo-construction or in road techniques, because it is the parameters of production and the industrial history of the sand which have an important impact on the quality of a waste sand.

Indeed, new sand will pick up more or less polluting substances during the production process of the parts used by the foundryman. Thus, the conditions of use of the sand, the metallurgical methods of elaboration, the types of parts produced, the means, the methods and the raw materials used by the foundryman will have a greater or lesser impact on the results of leaching analyses.

Concerning the different inorganic processes, the formulations of the chemical binders will impact the physico-chemical characteristics of the sand so that it behaves during the operations of the manufacturing process of the parts (good fluidity of the sand for core making and moulding, good flexibility of the moulds and cores at de-coring, good mechanical resistance during handling, transport and the operations of assembly and re-moulding, controlled mould/metal reaction, low emissions during casting, etc...).

In general, products developed for inorganic binder processes comply with REACH regulations and contain no or very few SVHC (Substance Very High Convern).

5. Conclusions

The laboratory work carried out during this project made it possible to verify the impact of an inorganic sand on the quality of small steel castings.

It was found that the condition of the casting and finishing surfaces of the parts complied with the NF1370 standard according to BNIF technical recommendation no. 359 (Bureau de Normalisation des Industries de la Fonderie).

The contents of carbon, sulphur, nitrogen, hydrogen and oxygen measured on the part samples did not reveal any major problem.

The structural investigations carried out on the samples taken from the parts also confirmed that inorganic sand would apparently not have a major impact on the occurrence of defects (for the small steel parts tested in this project).

Treatment trials carried out on inorganic sand waste have 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, geo-construction or road engineering.

Nevertheless, these 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).

In this context, it would be interesting to develop a pilot capable of treating 250 kg of sand per cycle to check the feasibility and determine the consumption ratios, the production/maintenance ratios and the sand treatment costs in €/t, and to compare the results obtained with those of conventional installations.

The study of this (these) industrial pilot(s) would also enable a representative life cycle analysis and carbon impact calculation to be carried out, to find out whether the hydromechanical and ultrasonic technologies can be transferred to industry for the treatment of used foundry sand.