

SUPPLEMENTARY MATERIALS

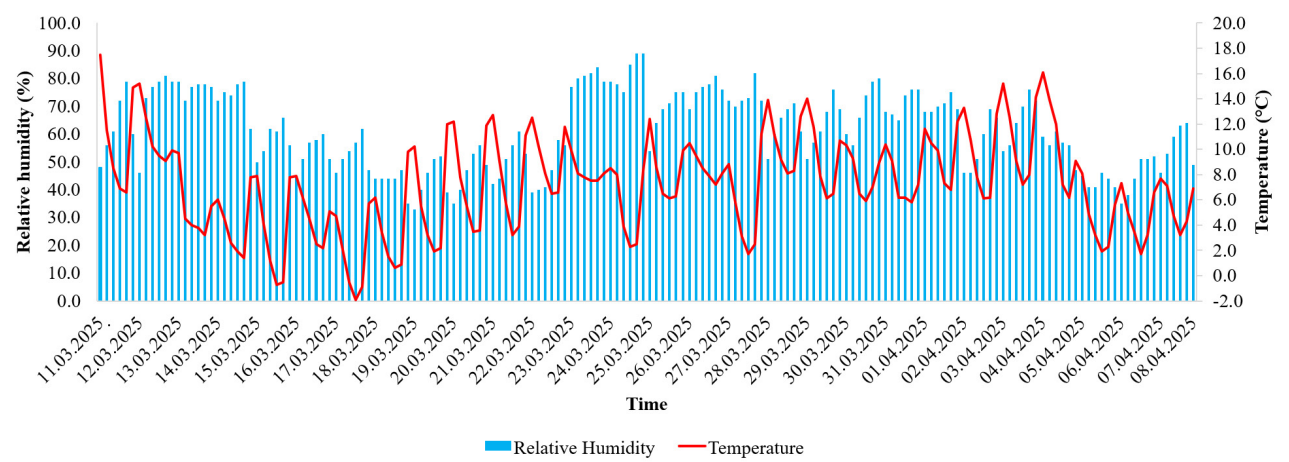
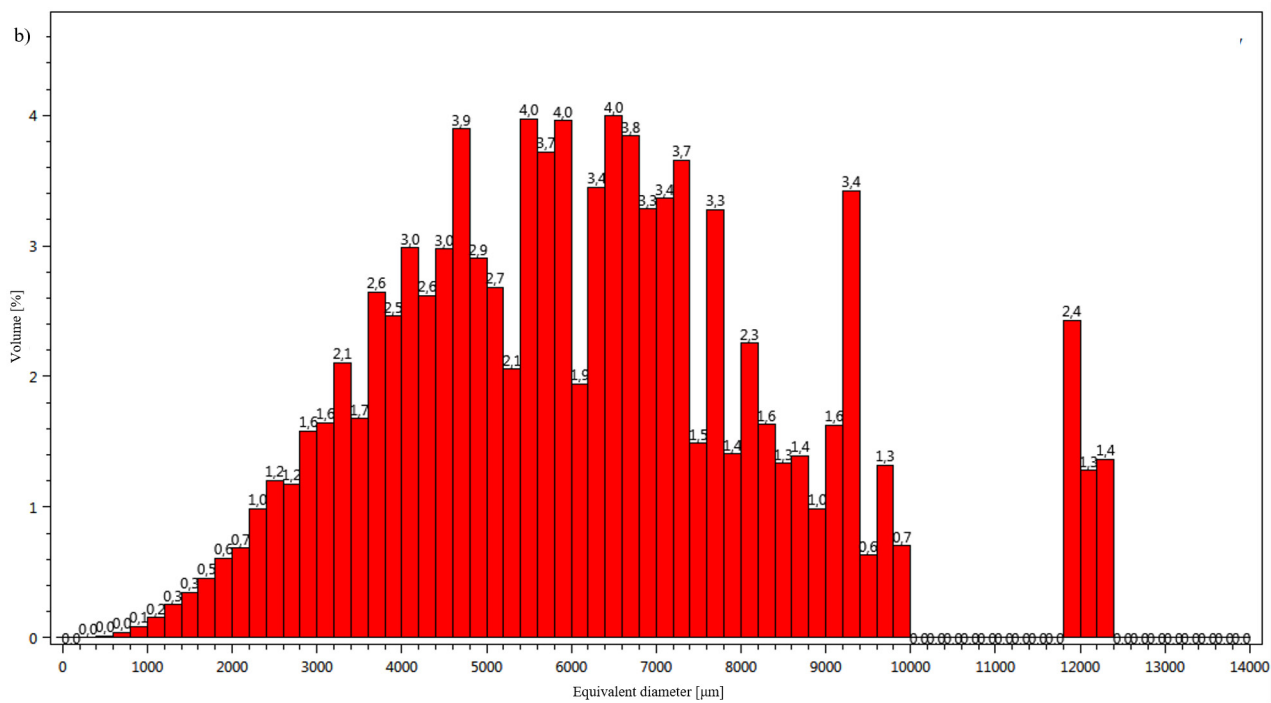
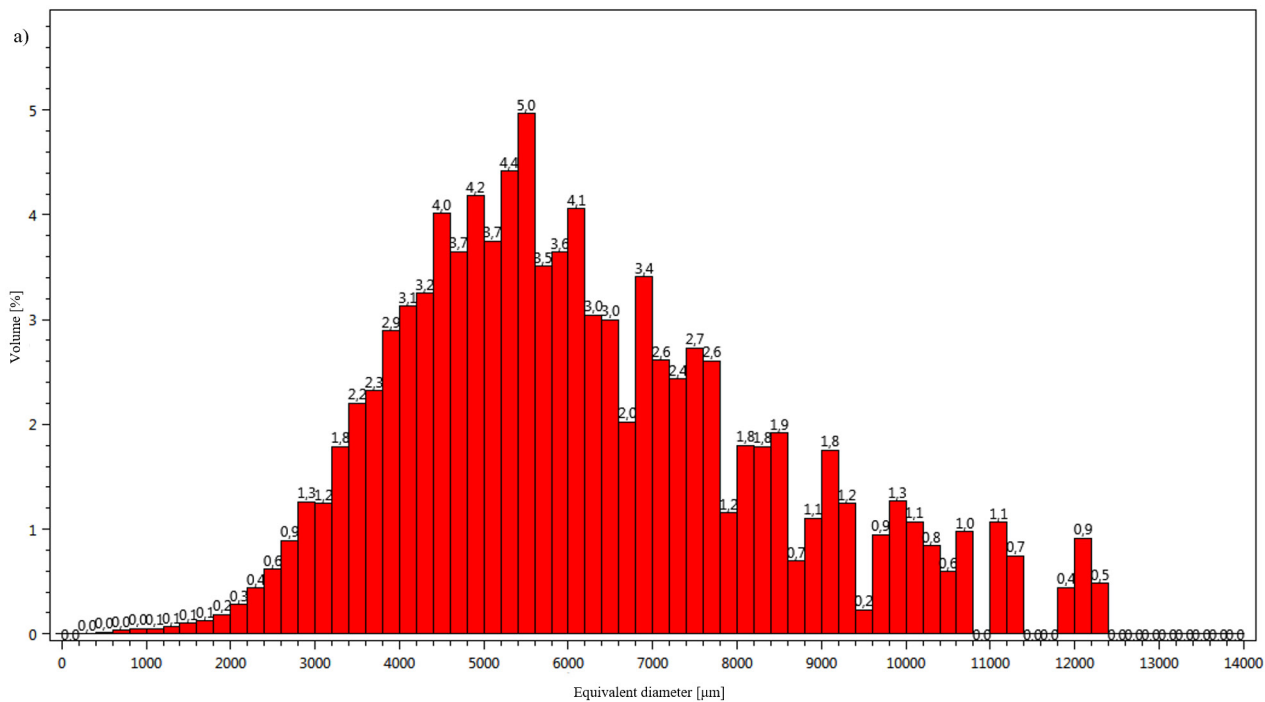
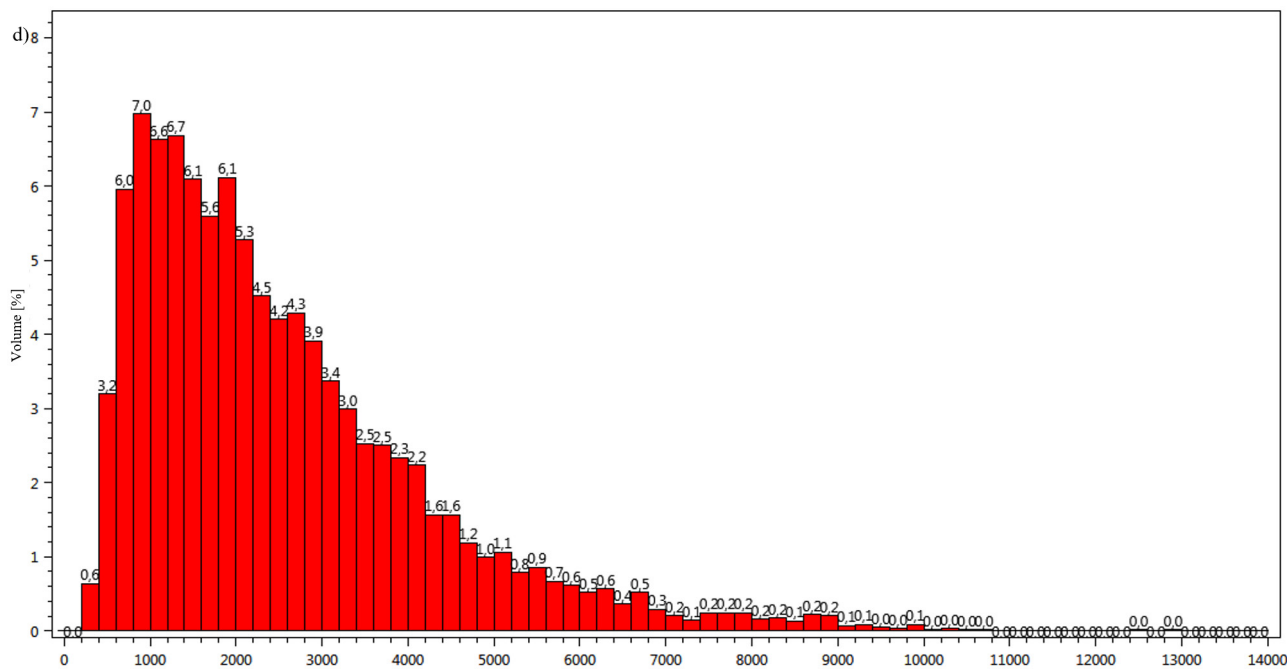
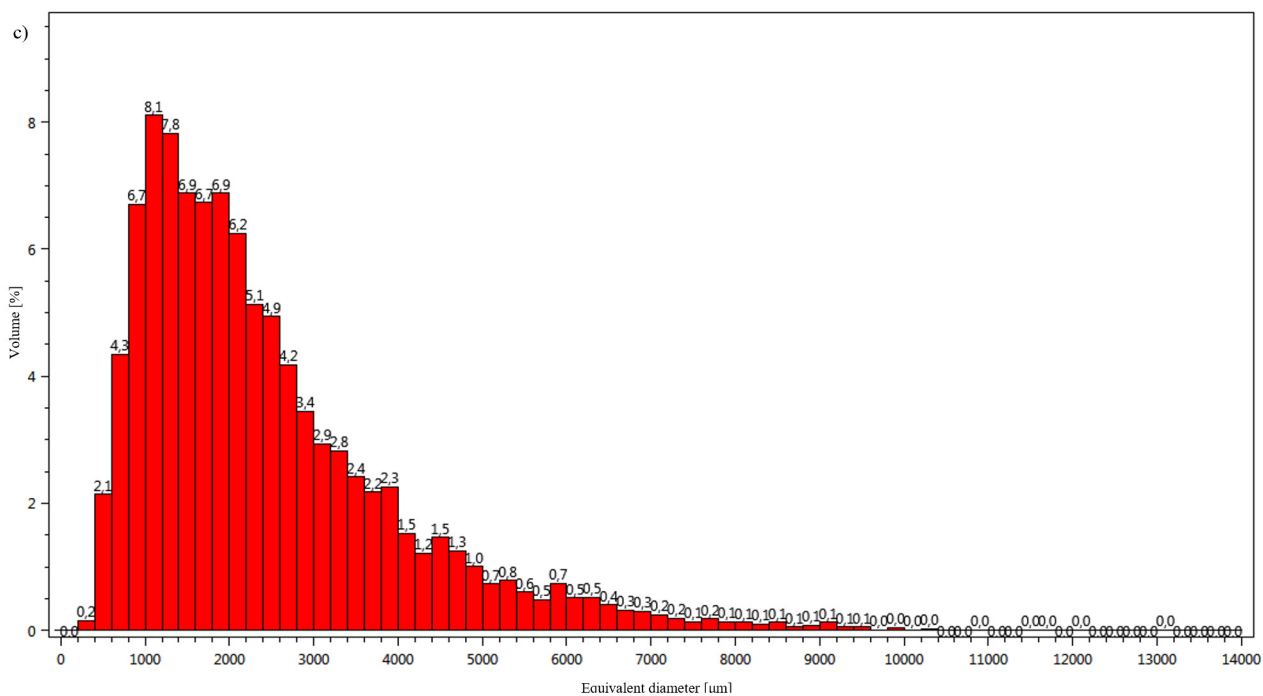
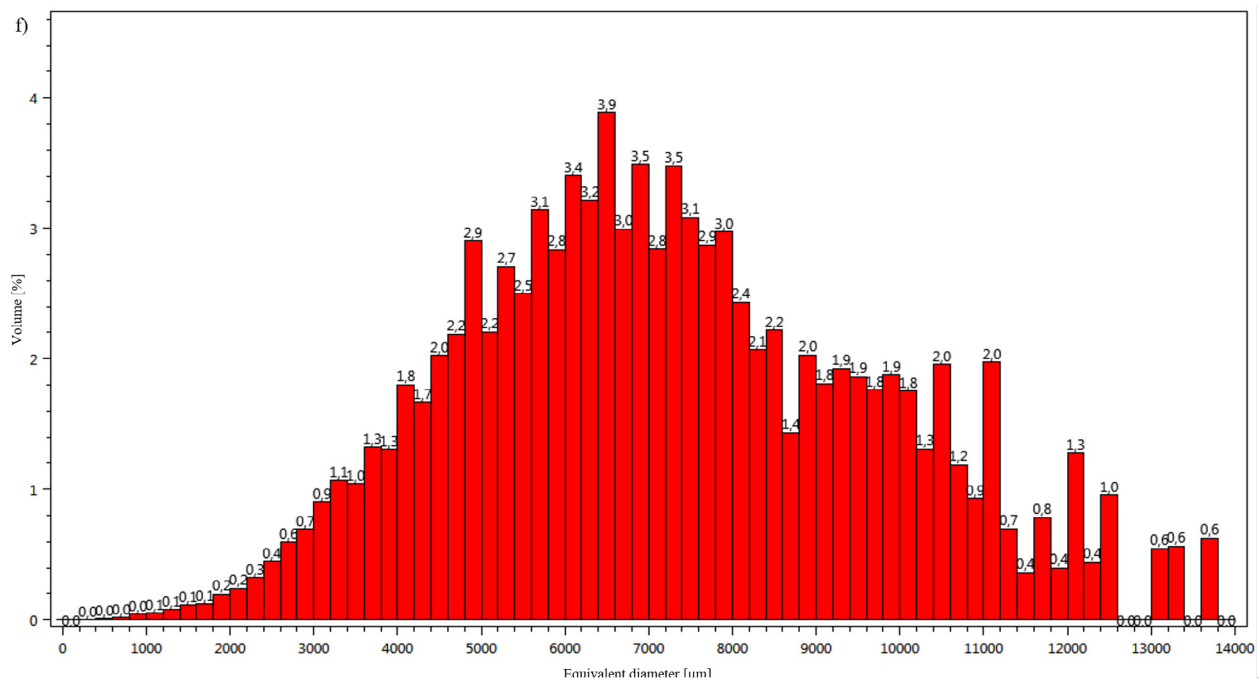
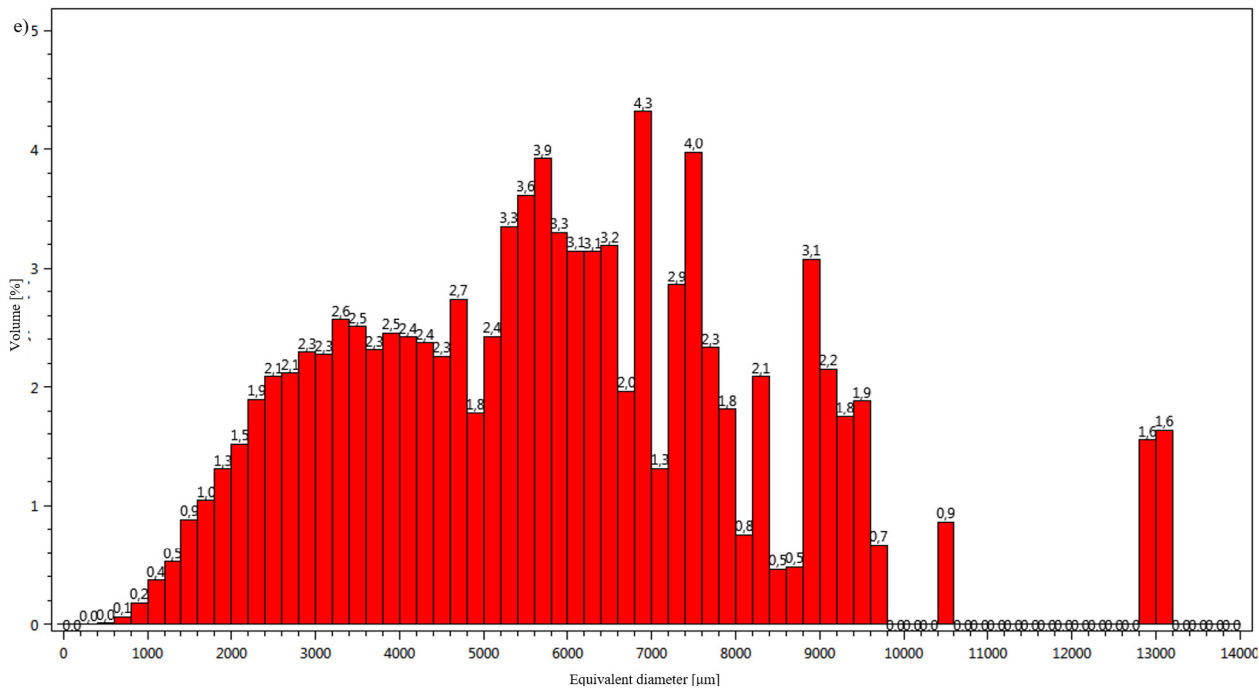
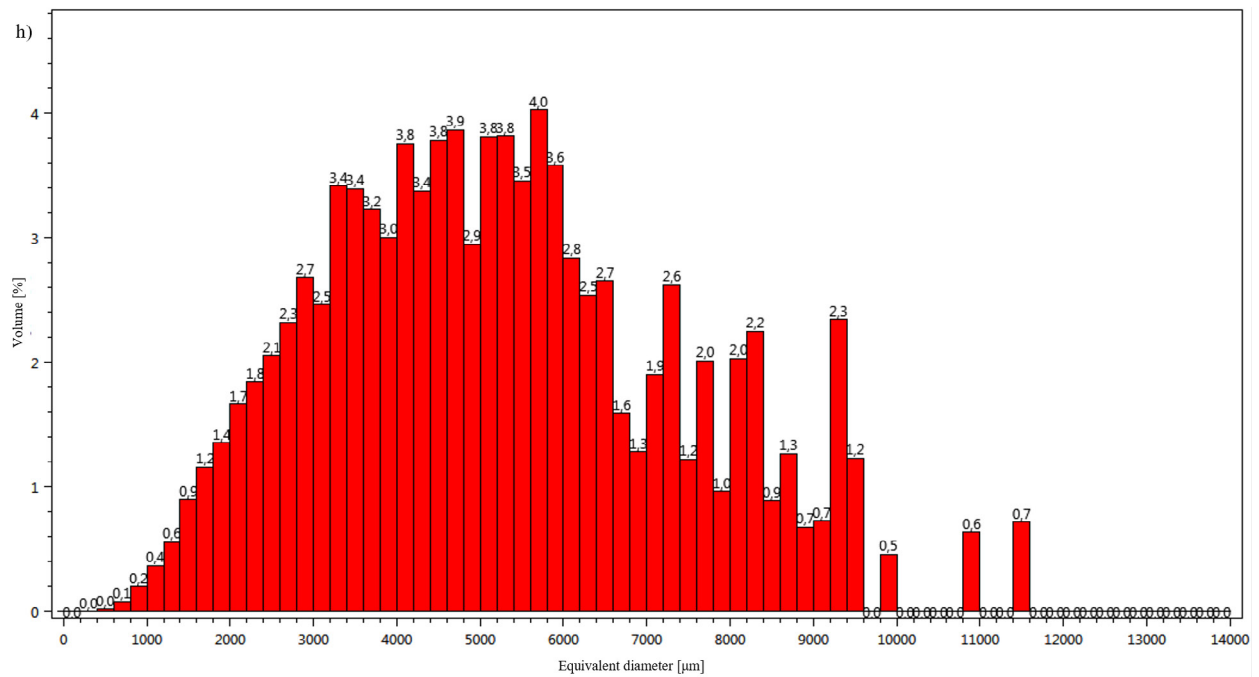
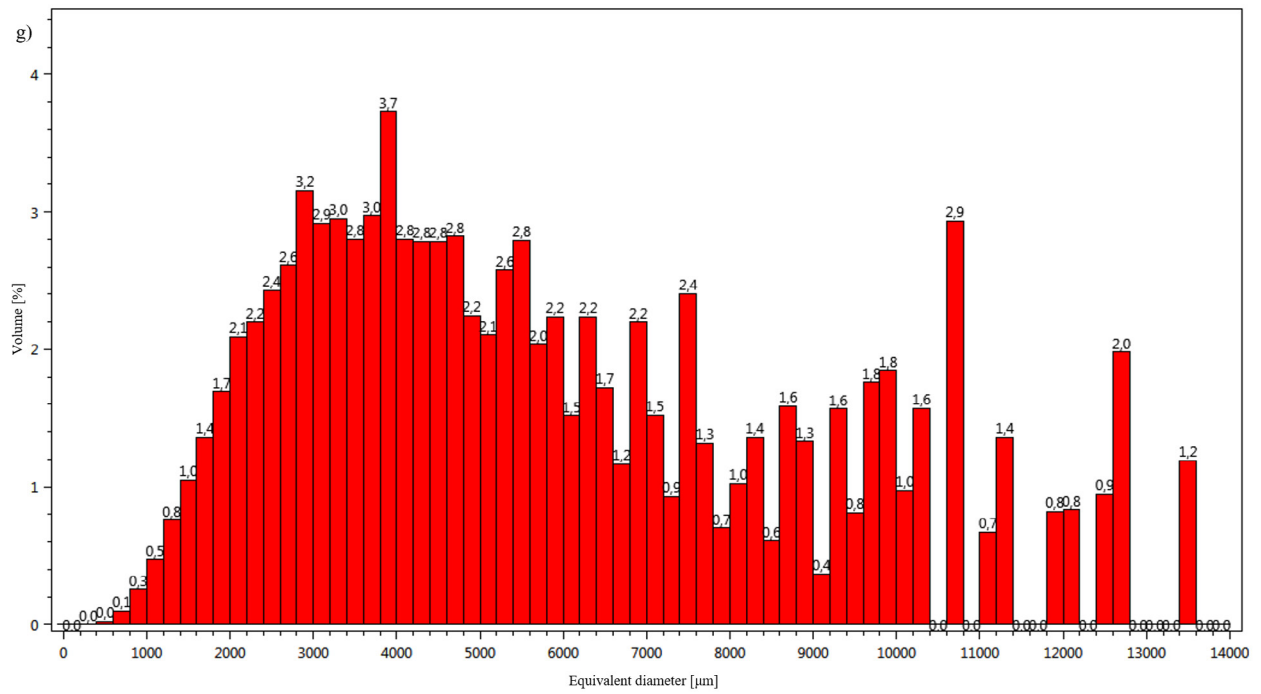


Fig. S1. Temperature and humidity during field trial.









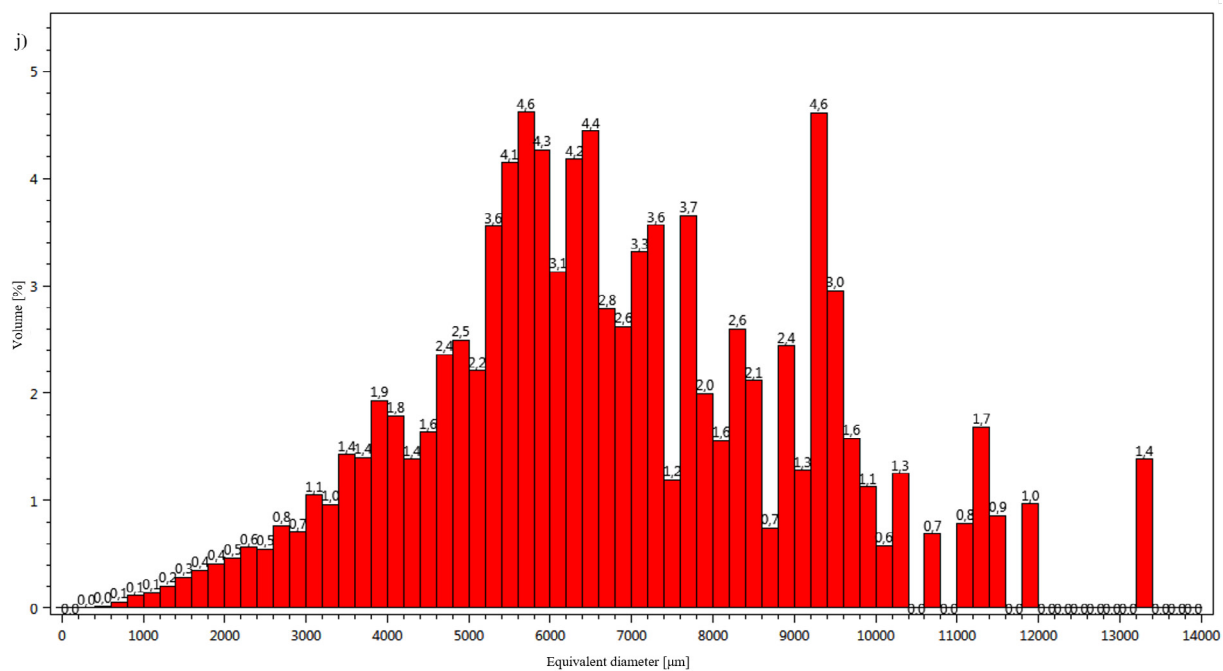
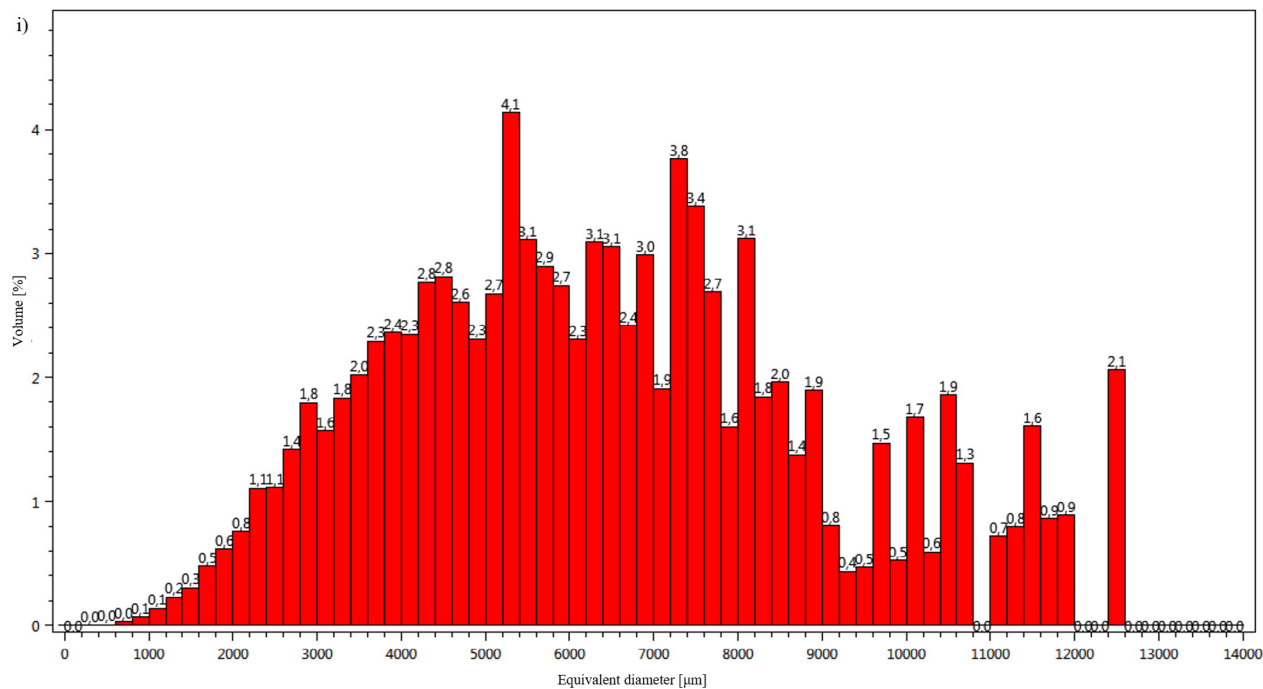
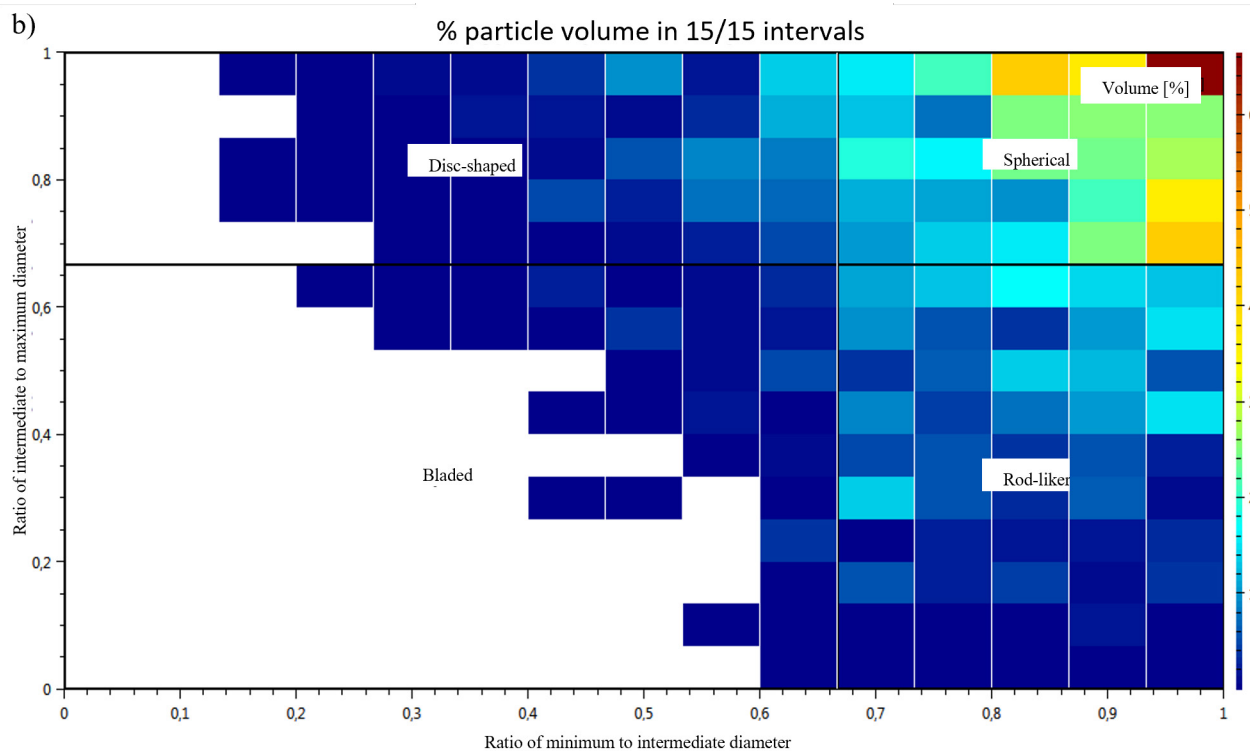
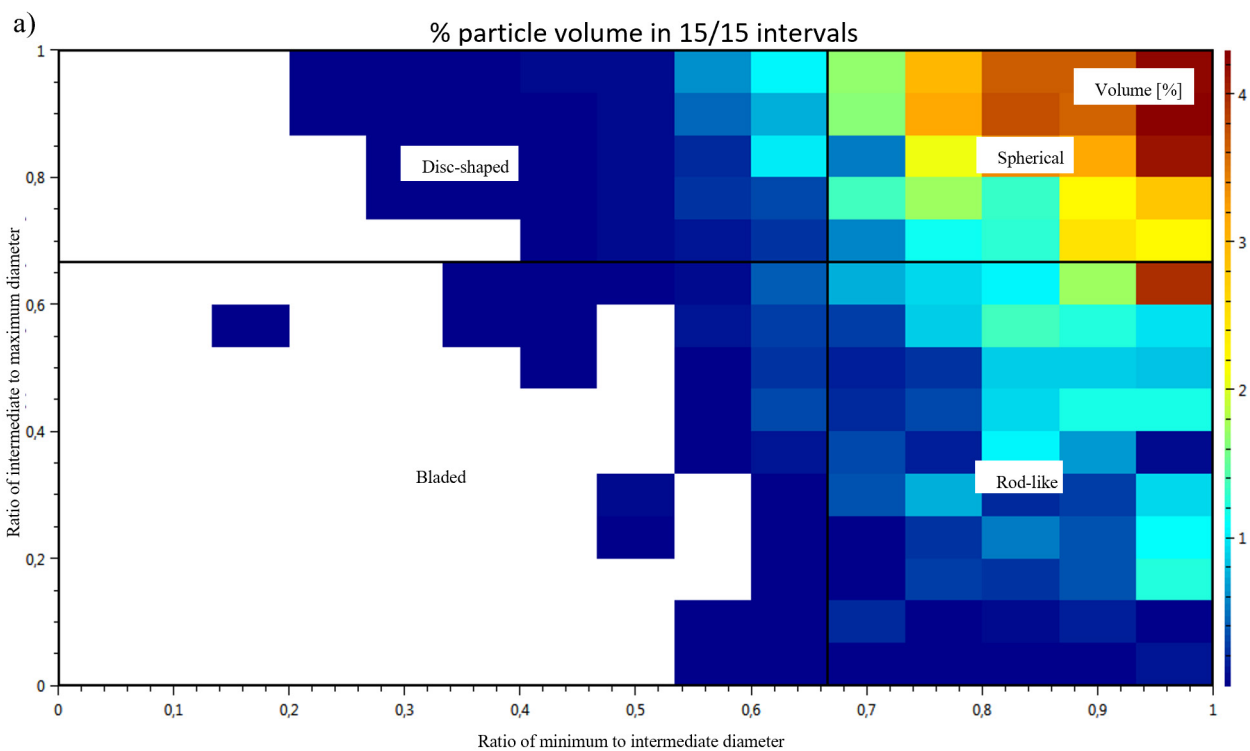
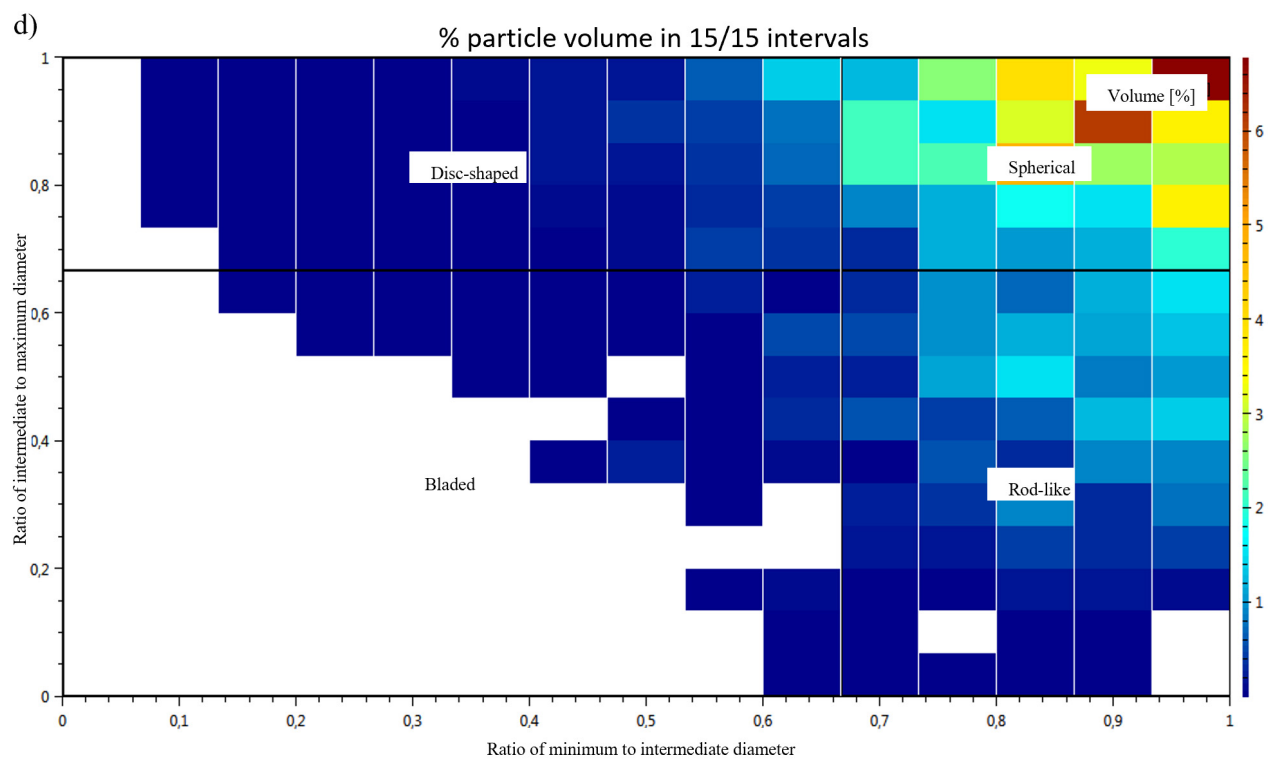
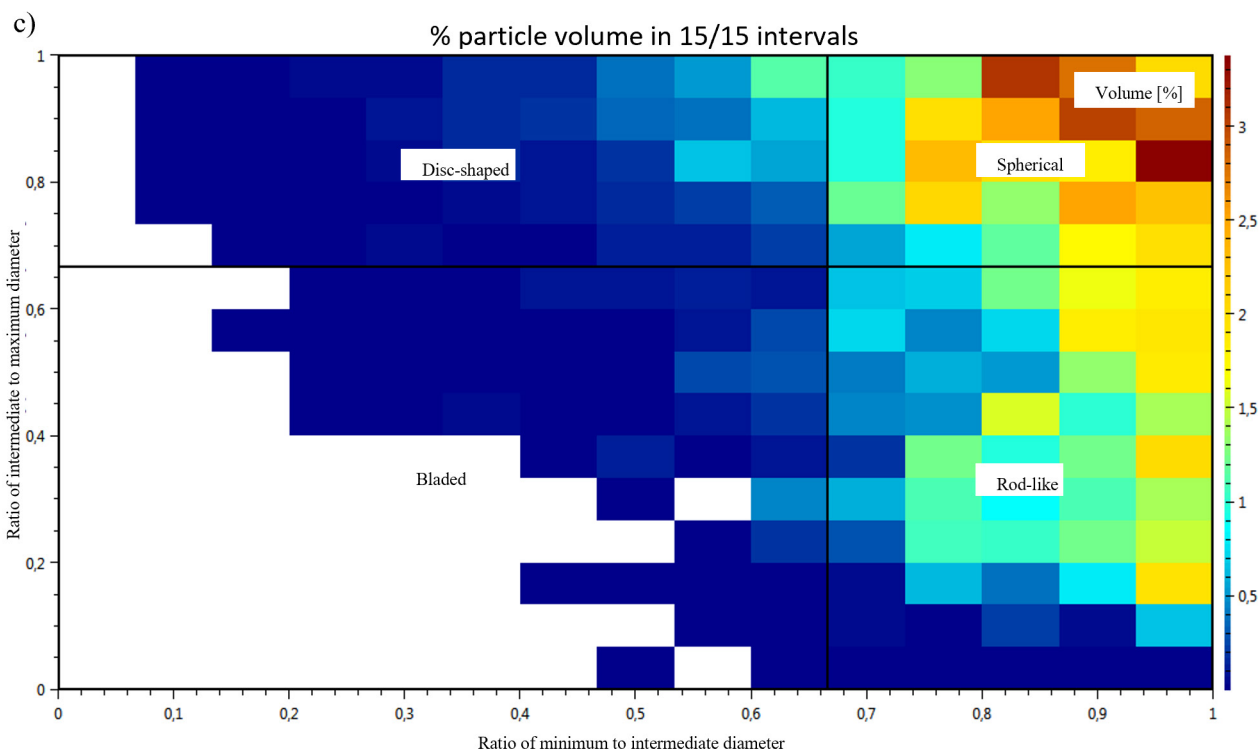
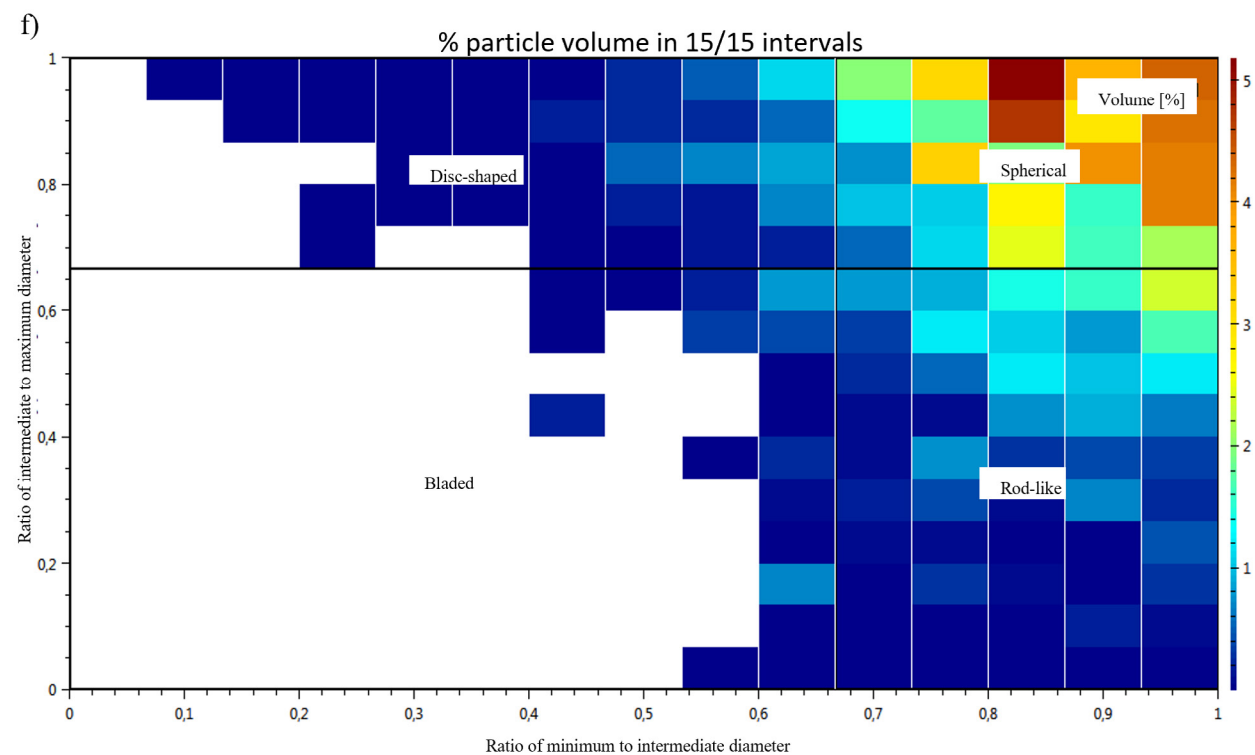
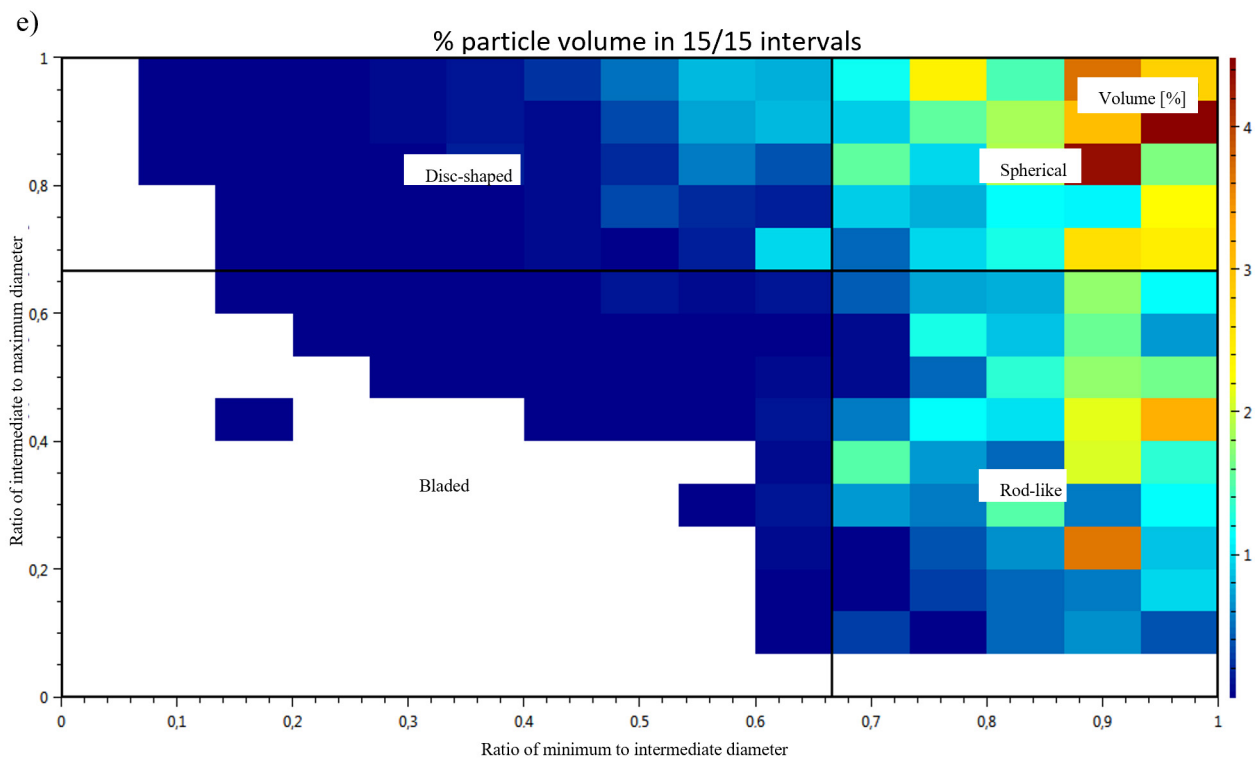
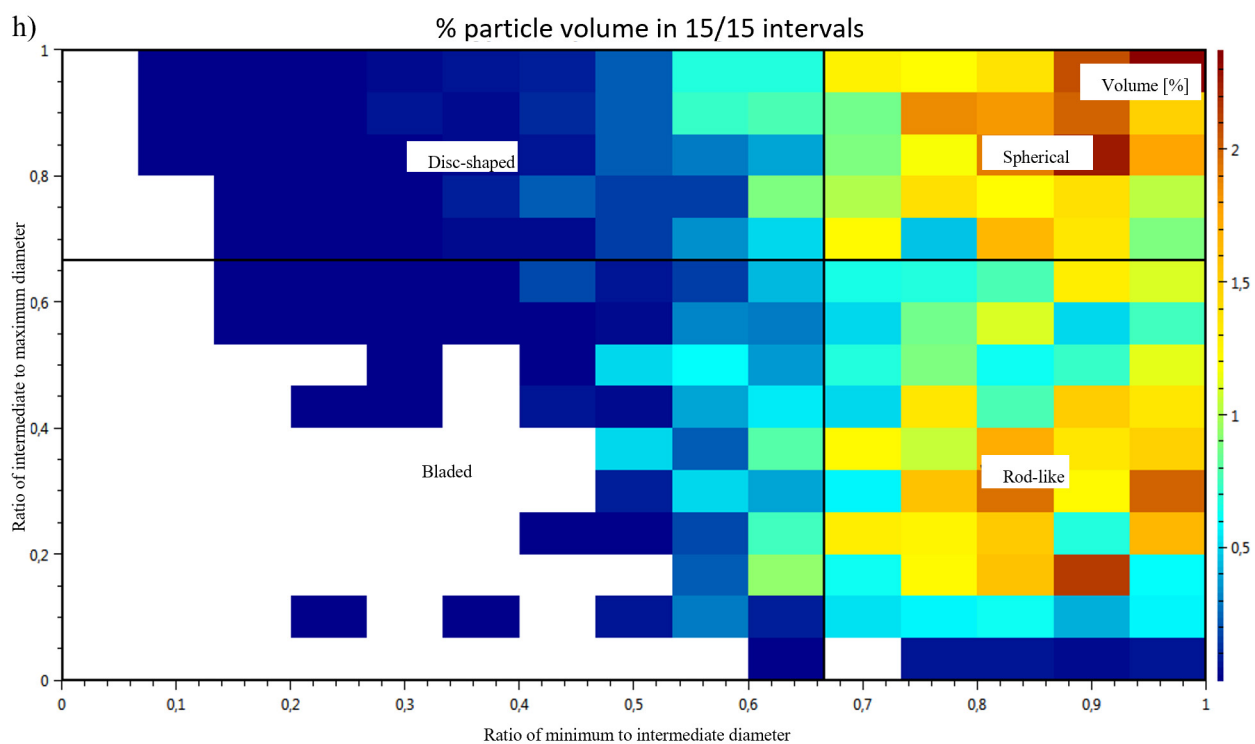
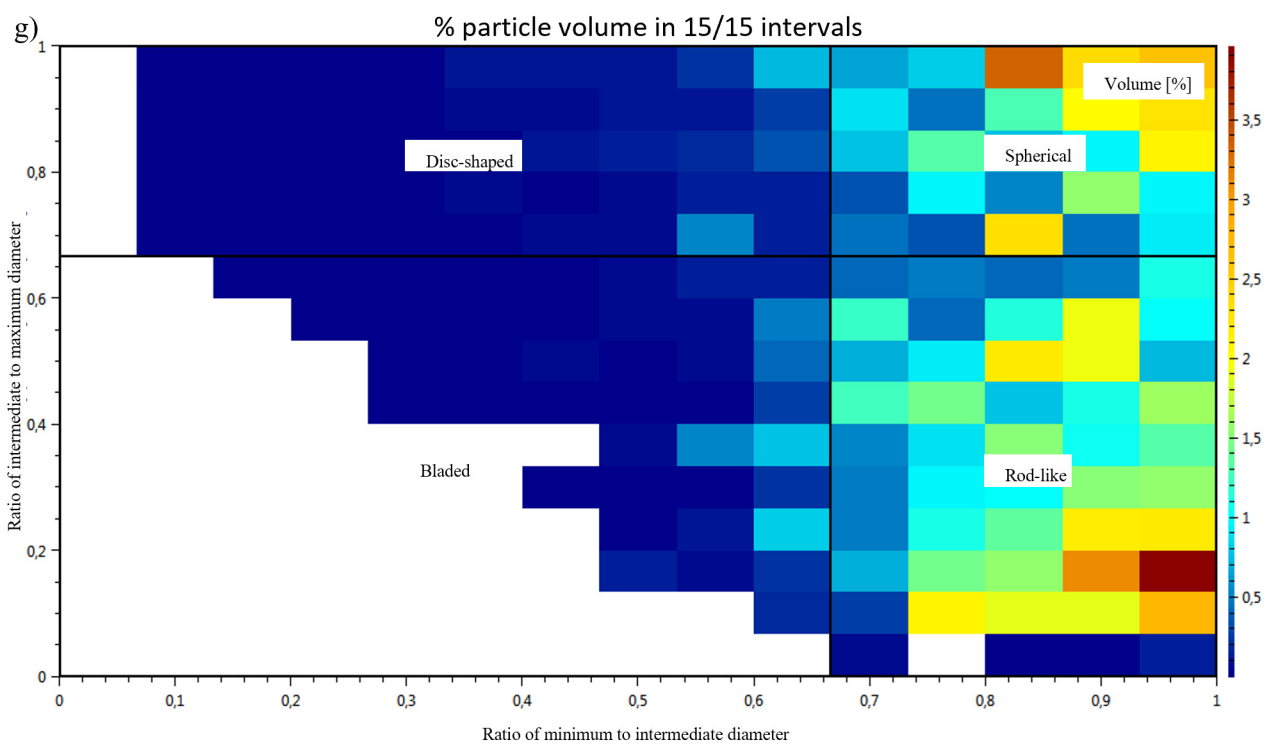


Fig. S2. Volumetric share a) BBM, b) BBW, c) CBM, d) CBW, e) CP, f) BP, g) CW, h) CM, i) BW, j) BM.









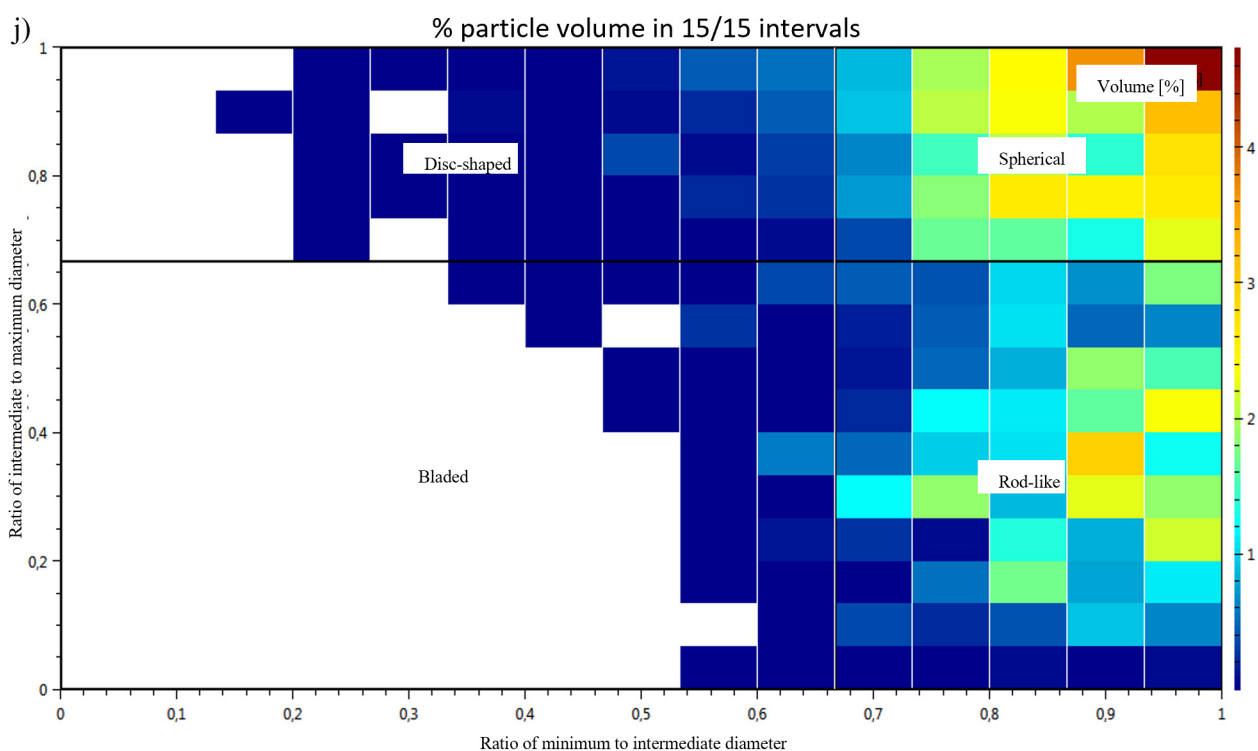
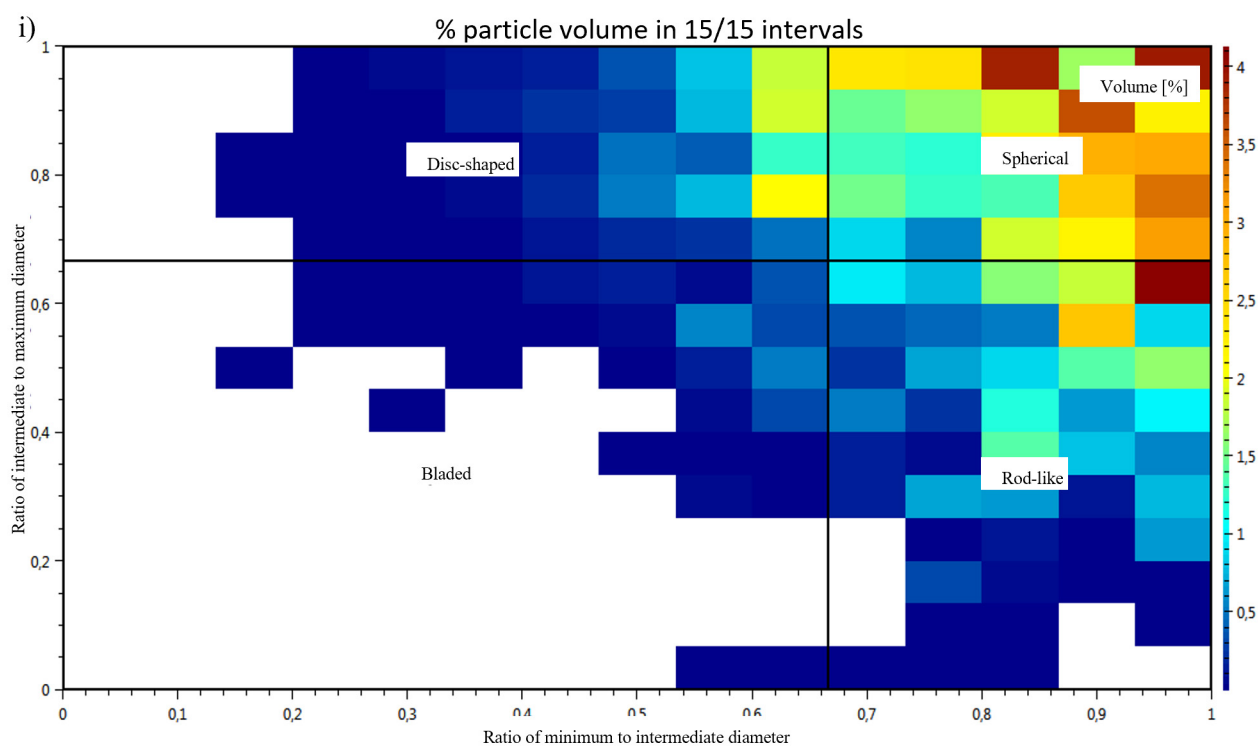


Fig. S3. Grain shape a) BBM, b) BBW, c) CBM, d) CBW, e) CP, f) BP, g) CW, h) CM, i) BW, j) BM.

Table S1. Survivability bacteria during storage

Granulate	0 month	2 month	4 month	6 month	12 month
	(LOG CFU g ⁻¹)				
Vegetative cells					
BBM	7.87 ± 0.01 ^{def}	7.77 ± 0.06 ^{fg}	7.44 ± 0.10 ^h	7.23 ± 0.03 ^{jk}	7.26 ± 0.04 ^{jk}
BBW	7.91 ± 0.02 ^{cde}	7.40 ± 0.02 ^{hi}	7.22 ± 0.01 ^{jk}	7.40 ± 0.05 ^{hi}	7.23 ± 0.04 ^{jk}
CBM	8.04 ± 0.01 ^{ab}	7.99 ± 0.02 ^{bcd}	8.12 ± 0.06 ^a	7.79 ± 0.02 ^{efg}	7.71 ± 0.01 ^g
CBW	7.95 ± 0.01 ^{bcd}	7.80 ± 0.02 ^{efg}	8.04 ± 0.03 ^{abc}	7.99 ± 0.05 ^{bcd}	7.91 ± 0.02 ^{cde}
CP	7.33 ± 0.01 ^{hij}	6.93 ± 0.05 ^l	6.87 ± 0.08 ^l	6.68 ± 0.06 ^m	6.66 ± 0.02 ^m
BP	7.30 ± 0.02 ^{ij}	7.28 ± 0.01 ^{ijk}	7.32 ± 0.06 ^{hij}	7.32 ± 0.03 ^{hij}	7.16 ± 0.05 ^k
Spores					
BBM	7.85 ± 0.01 ^{ef}	7.99 ± 0.02 ^{cd}	8.32 ± 0.02 ^a	8.06 ± 0.05 ^{bc}	7.74 ± 0.05 ^g
BBW	7.75 ± 0.02 ^{fg}	7.31 ± 0.03 ^{jk}	7.31 ± 0.02 ^{jk}	7.41 ± 0.05 ^{hij}	7.35 ± 0.03 ^{ij}
CBM	7.99 ± 0.01 ^{cd}	8.40 ± 0.01 ^a	8.39 ± 0.06 ^a	8.10 ± 0.07 ^b	8.00 ± 0.02 ^{bcd}
CBW	7.97 ± 0.01 ^{cd}	7.83 ± 0.01 ^{efg}	7.48 ± 0.01 ^h	7.86 ± 0.04 ^e	7.93 ± 0.01 ^{de}
CP	7.33 ± 0.02 ^{ijk}	7.01 ± 0.03 ⁿ	7.14 ± 0.05 ^{lm}	7.21 ± 0.05 ^{lm}	7.11 ± 0.02 ^{mn}
BP	7.36 ± 0.02 ^{ij}	7.11 ± 0.04 ^{mn}	7.43 ± 0.02 ^{hi}	7.24 ± 0.04 ^{kl}	7.17 ± 0.03 ^{lm}

Different letters indicate statistically different groups (Tukey's test (p<0.05)).

Table S2. Disintegration of granules assessment in distilled water

Time	Granulate			
	Granule status	Medium coloration	Turbidity	Morphology
BBM				
0 min	Intact – gray granules	Colorless	Crystal clear	Hard granules, undamaged surface
1 min	Intact – gray granules	Colorless	Crystal clear	Hard granules, undamaged surface
15 min	Softened	Colorless	Crystal clear	Extended diameter, bulking
30 min	Softened	Pale gray	Nearly clear	No changes
60 min	No changes	No changes	No changes	No changes
2 h	No changes	No changes	No changes	No changes
3 h	Partially dissolved	Light gray at the bottom	Slightly cloudy at the bottom	Soft granule, extended diameter, mushy
4 h	Partially dissolved	Light gray	Slightly cloudy at the bottom	Soft granule, extended diameter, mushy, granules breaking
8 h	No changes	No changes	No changes	No changes
20 h	No changes	No changes	No changes	Soft granule, extended diameter, mushy, sediment at the bottom
28 h	Dissolved	No changes	No changes	No visible intact granules, sediment present
32 h	No changes	No changes	No changes	No changes
CBM				
0 min	Intact – light brown granules	Colorless	Crystal clear	Hard granules, undamaged surface
1 min	Intact – light brown granules	Colorless	Crystal clear	Hard granules, undamaged surface
15 min	disintegrated	Colorless	Crystal clear	Fragmentation
30 min	disintegrated	Pale brown	Slightly cloudy	disintegrated
60 min	Dissolved	Light brown	Moderately cloudy	Fine particles visible, slight sediment
2 h	Complete dissolution	Light brown	Moderately cloudy	No visible intact granules, sediment present
3 h	No changes	No changes	No changes	No changes
4 h	No changes	No changes	No changes	No changes
8 h	No changes	No changes	No changes	No changes
20 h	No changes	No changes	No changes	No changes
28 h	No changes	No changes	No changes	No changes
32 h	No changes	No changes	No changes	No changes
CBW				
0 min	Intact – light brown granules	Colorless	Crystal clear	Hard granules, undamaged surface
1 min	Intact – light brown granules	Colorless	Crystal clear	Hard granules, undamaged surface
15 min	disintegrated	Colorless	Crystal clear	Fragmentation
30 min	Fragmentation	Pale brown	Slightly cloudy	Fragmentation
60 min	Dissolved	Light brown	Moderately cloudy	Fine particles visible, slight sediment
2 h	Complete dissolution	Light brown	Moderately cloudy	No visible intact granules, sediment present
3 h	No changes	No changes	No changes	No changes
4 h	No changes	No changes	No changes	No changes
8 h	No changes	No changes	No changes	No changes
20 h	No changes	No changes	No changes	No changes
28 h	No changes	No changes	No changes	No changes
32 h	No changes	No changes	No changes	No changes

Table S2. Continuation

Time	Granulate			
	Granule status	Medium coloration	Turbidity	Morphology
			BP	
0 min	Intact – gray granules	Colorless	Crystal clear	Hard granules, undamaged surface
1 min	Intact – gray granules	Colorless	Crystal clear	Hard granules, undamaged surface
15 min	Softened	Colorless	Crystal clear	Extended diameter, bulking
30 min	Softened	Pale gray	Nearly clear	No changes
60 min	No changes	No changes	No changes	No changes
2 h	Partially dissolved	Light gray at the bottom	Slightly cloudy at the bottom	Soft granule, extended diameter, mushy
3 h	Partially dissolved	Light gray at the bottom	Moderately cloudy at the bottom	Soft granule, extended diameter, mushy
4 h	Partially dissolved	Light gray	Moderately cloudy at the bottom	Soft granule, extended diameter, mushy, sediment at the bottom
8 h	No changes	No changes	No changes	No changes
20 h	Dissolved	No changes	No changes	No visible intact granules, sediment present
28 h	No changes	No changes	No changes	No changes
32 h	No changes	No changes	No changes	No changes

Table S3. Total number of bacteria in the soil

Granulate	Sampling date					
	11.03.2025	13.03.2025	16.03.2025	24.03.2025	01.04.2025	08.04.2025
	(LOG CFU g ⁻¹)					
	Vegetative cells					
BBM	6.31 ± 0.04 ^{efg}	6.79 ± 0.03 ^a	6.76 ± 0.04 ^{ab}	5.44 ± 0.19 ^k	6.49 ± 0.03 ^{cdc}	6.09 ± 0.05 ^{hi}
CBM	6.33 ± 0.04 ^{ef}	6.69 ± 0.07 ^{abc}	6.26 ± 0.03 ^{fgh}	5.41 ± 0.10 ^k	6.19 ± 0.03 ^{fghi}	6.13 ± 0.04 ^{ghi}
CBW	6.21 ± 0.01 ^{fghi}	6.58 ± 0.02 ^{bcd}	6.19 ± 0.02 ^{fghi}	5.16 ± 0.02 ^l	6.23 ± 0.06 ^{fgh}	6.01 ± 0.06 ^{ij}
BP	6.34 ± 0.01 ^{ef}	6.47 ± 0.02 ^{dc}	6.21 ± 0.03 ^{fghi}	5.11 ± 0.14 ^l	6.08 ± 0.06 ^{hi}	5.88 ± 0.04 ^j
	Spores					
BBM	6.33 ± 0.07 ^{bc}	6.59 ± 0.02 ^a	6.38 ± 0.04 ^b	5.13 ± 0.07 ⁱ	6.15 ± 0.02 ^{defg}	6.13 ± 0.03 ^{efg}
CBM	6.16 ± 0.07 ^{defg}	6.36 ± 0.02 ^b	6.20 ± 0.02 ^{cdefg}	5.01 ± 0.07 ⁱ	6.30 ± 0.06 ^{bcd}	6.10 ± 0.02 ^{fg}
CBW	6.05 ± 0.04 ^g	6.33 ± 0.03 ^{bc}	6.19 ± 0.09 ^{cdefg}	5.09 ± 0.06 ⁱ	6.22 ± 0.03 ^{bcdef}	6.10 ± 0.03 ^{fg}
BP	6.12 ± 0.06 ^{efg}	6.27 ± 0.02 ^{bcdc}	6.18 ± 0.02 ^{cdefg}	5.15 ± 0.10 ⁱ	6.04 ± 0.07 ^g	5.84 ± 0.03 ^h

Different letters indicate statistically different groups (Tukey's test (p<0.05)).