VENATOR

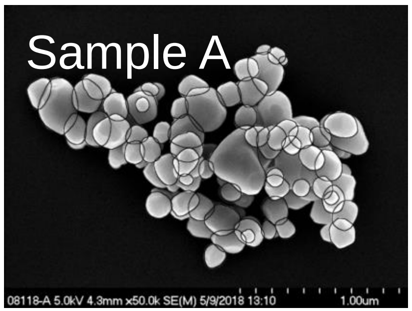
# Report on E171 (titanium dioxide) and E172 (iron oxide) - analytical perspectives from research

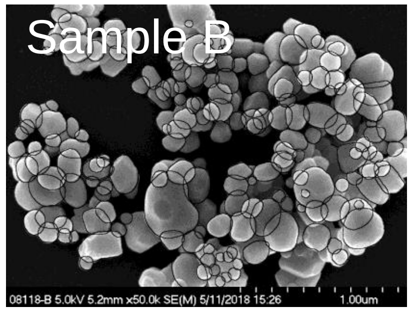
## Submitted on behalf of TDMA & TC E172

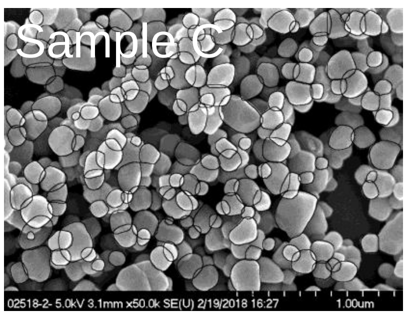
1./2. April 2019 Parma

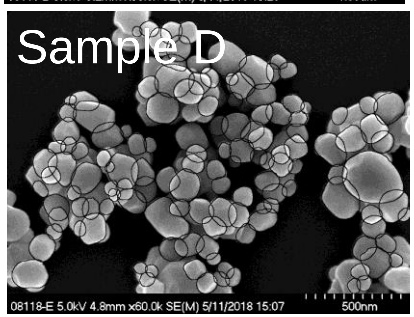
# Report on E171 (titanium dioxide) and E172 (iron oxide) - analytical perspectives from research

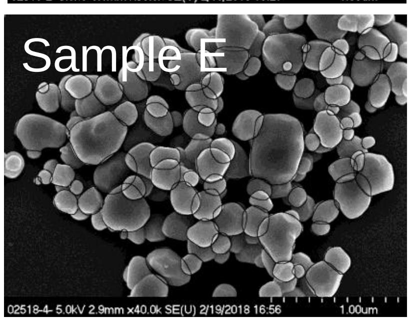
Five E171 grades were analysed by SEM, BET, Brookhaven XDC and CPS DC



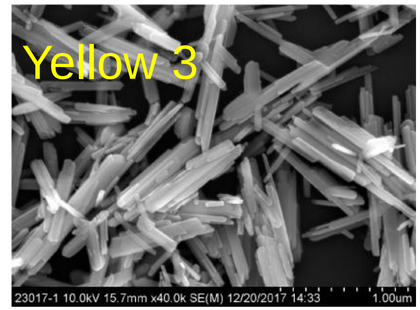



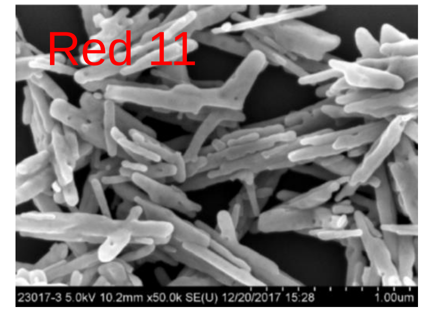



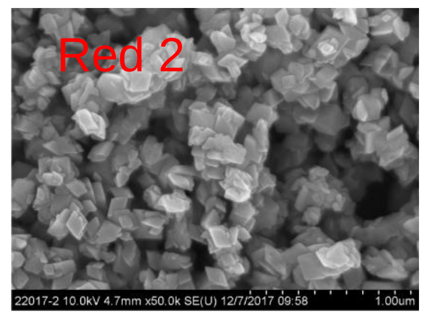



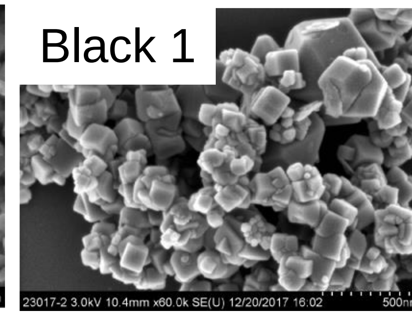

| Sample | Anatase (%) |
|---|---|
| A | 99,9 |
| B | 99,7 |
| C | 99,6 |
| D | 99,1 |
| E | 99,4 |

25 E172 grades were analysed by SEM, TEM, BET, Brookhaven XDC and LD



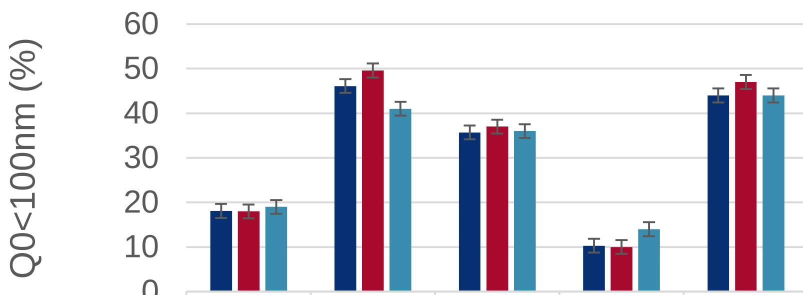




| Product Name | Colour | Crystal Phase |
|---|---|---|
| Yellow 3 | Yellow | Goethite FeO(OH) |
| Red 2 | Red | Hematite $Fe_2O_3$ |
| Red 11 | Red | Hematite $Fe_2O_3$ |
| Black 1 | Black | Magnetite $Fe_3O_4$ |

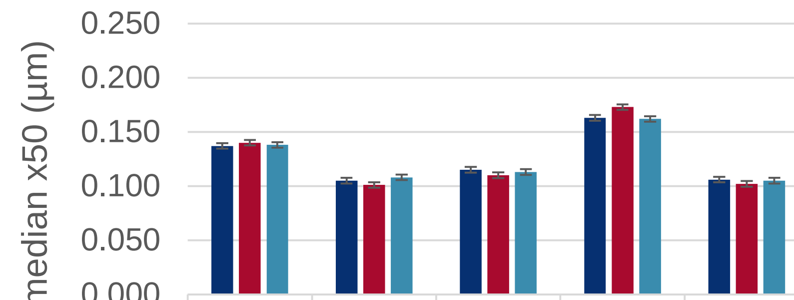
# SEM results E171

## E171 is **not** a nano product

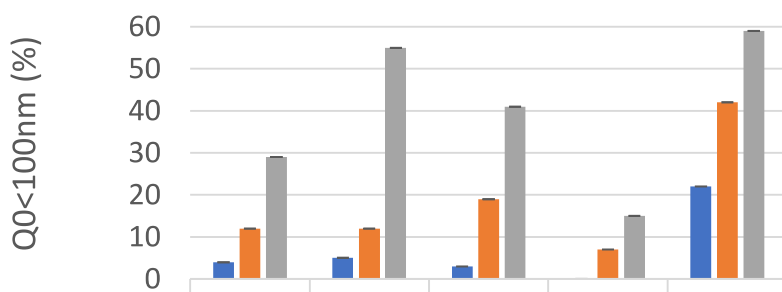
- SD low for E171 Manufacturer (M1, M2, M3)
- Inexperienced laboratories could find very different results



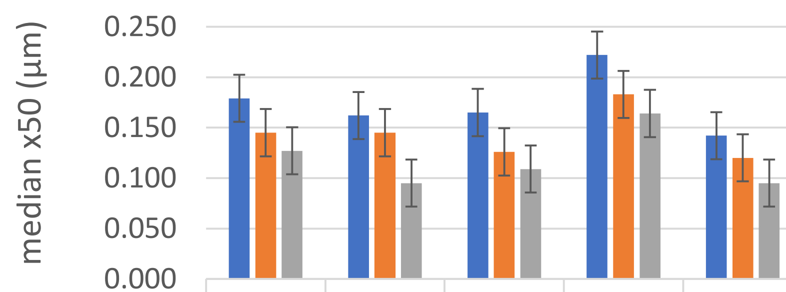

| | A | B | C | D | E |
|---|---|---|---|---|---|
| M-1 SEM | 18 | 46 | 36 | 10 | 44 |
| M-2 SEM | 18 | 50 | 37 | 10 | 47 |
| M-3 SEM | 19 | 41 | 36 | 14 | 44 |




| | A | B | C | D | E |
|---|---|---|---|---|---|
| M-1 SEM | 0.137 | 0.105 | 0.115 | 0.163 | 0.106 |
| M-2 SEM | 0.140 | 0.101 | 0.110 | 0.173 | 0.102 |
| M-3 SEM | 0.138 | 0.108 | 0.113 | 0.162 | 0.105 |



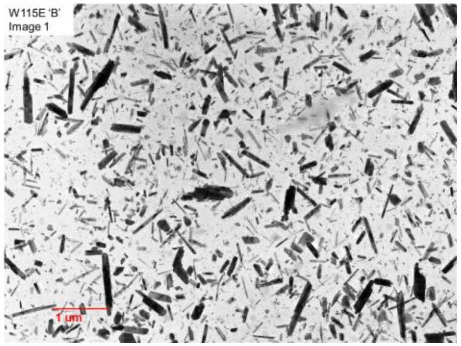

| | A | B | C | D | E |
|---|---|---|---|---|---|
| LAB A SEM | 4 | 5 | 3 | 0 | 22 |
| LAB A STEM | 12 | 12 | 19 | 7 | 42 |
| LAB B TEM | 29 | 55 | 41 | 15 | 59 |

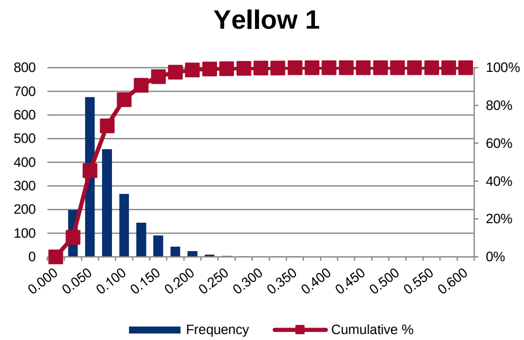


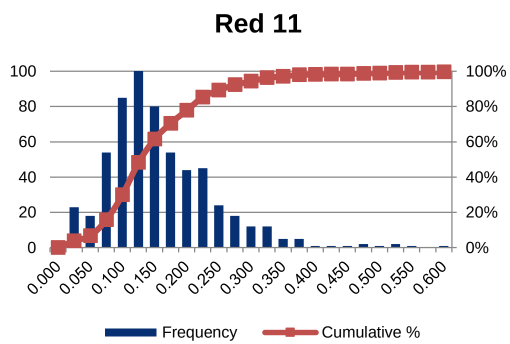

| | A | B | C | D | E |
|---|---|---|---|---|---|
| LAB A SEM | 0.179 | 0.162 | 0.165 | 0.222 | 0.142 |
| LAB A STEM | 0.145 | 0.145 | 0.126 | 0.183 | 0.12 |
| LAB B TEM | 0.127 | 0.095 | 0.109 | 0.164 | 0.095 |

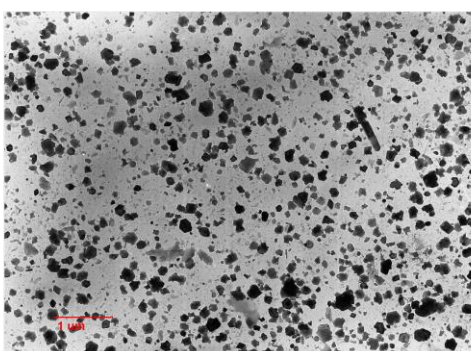
# TEM vs BET

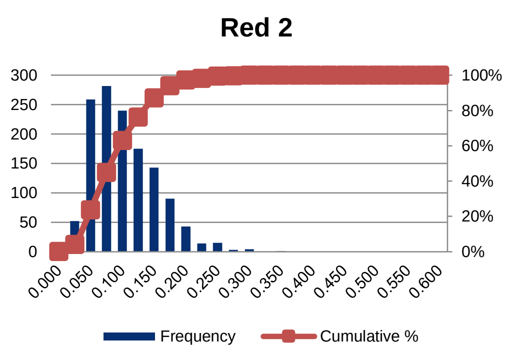
## Correlation $x_{50}$ with $d_{minVSSA}$ high



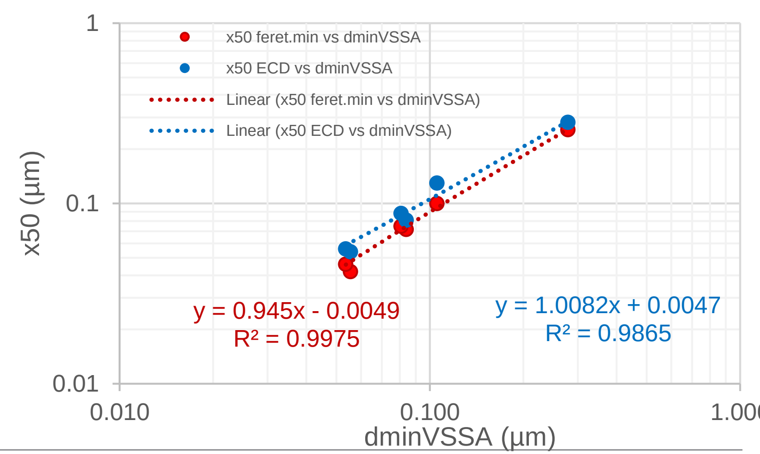






- VENATOR is the sole manufacturer of E172
- Primary particle size analysis possible for red and yellow but not for black Iron Oxides
- Rubout of crystals in a monolayer on the surface is important for accurate results
- Will be difficult to find an external lab which is able to measure Iron Oxides
- High correlation with dminVSSA



## Particle Size for Risk Assessment?

Constituent Particles

- We support the EFSA approach to analyse the particle size of food additives as **pristine** material, in the **food matrix** and in **biological** media
- However, the guidance document is **not consistent on page 21** in the evaluation of **agglomeration or aggregation** state by two independent methods
- **Standard** EM can only measure the **constituent** particles size and not the **agglomeration or aggregation** state
- The second method must corelate with EM  to be a **suitable screening** method and the sample **must** be dispersed to a **plateau**
- Nevertheless, for many products (Black Iron Oxides) EM **doesn't** work and **alternatives** must be possible
- The **Nano Define decision-flow scheme** for dispersion criteria on page 79 should be adjusted by the **dispersion technique** and mandatory **correlation with EM**

# Mobile Particle Size for Risk Assessment

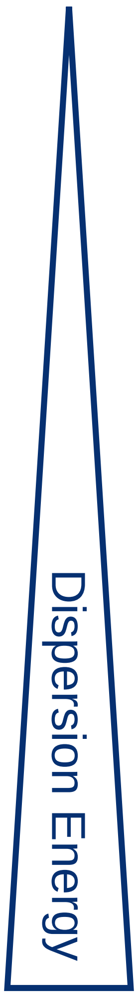
## Defined Dispersion Energy

VENATOR

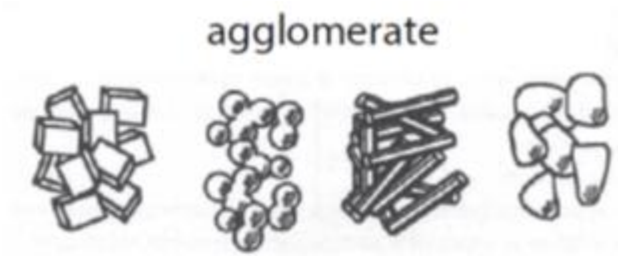
- "Once a material is **classified as nano** according the constituent particle size of the EU definition, the information on the **mobile** particle size under **realistic conditions** (food matrix, biological media, etc.) is needed.
- Dispersability has been reported as a **founding base for the grouping of the nano materials**" *(EChA, "Appendix R.6-1 for nano materials applicable to the Guidance on QSARs and Grouping)*
- The OECD TG318 for aqua toxicity could be a good base for food application, a **defined dispersion energy** according to **NIST 1200** is recommended and indicates the particle size in aqueous media
- The same issues apply for food, what is the **right dispersion energy**, what is the **dispersion medium, degradation, dissolution**…….
- An **initial** approach for the determination of the E171 and E172 **smallest mobile particle size** of the pristine material or in the food matrix **is presented on the next slides**

# Volume weighted Particle Size

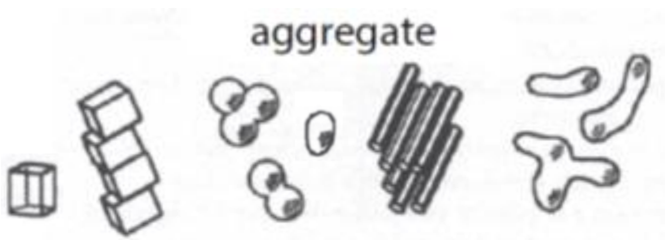
## Standardised dispersion energy



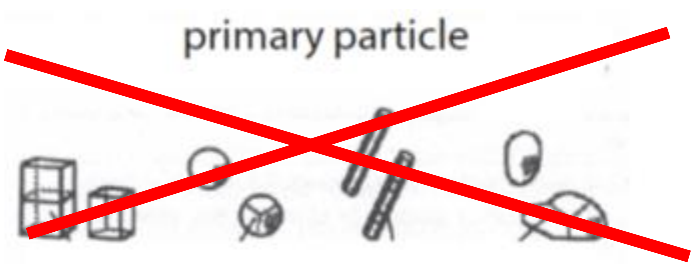

Dispersion with low energy




Aggregate size is determined by the production process (**page 17 line 14**)




Not possible to disperse **completely** to unbounded constituent particles




Particle size control of E171 and E172 by a standardised dispersion procedure:

- Comparing production dispersion energy density with laboratory scale using NIST 1200 TG
- The energy density **of 240 J/ml** is **three times** higher than normally applied in production wet milling of $TiO_2$
- Full **redispersion** of agglomerates **without breaking** up aggregates or constituent particles
- M. Stintz propose **270 J/ml** for synthetic amorphous silica (**SAS**), *Powder Technology* **318** (2017) 451-458 and *Nanomaterials* 8 (2018) 454

# Comparison E171/ E172

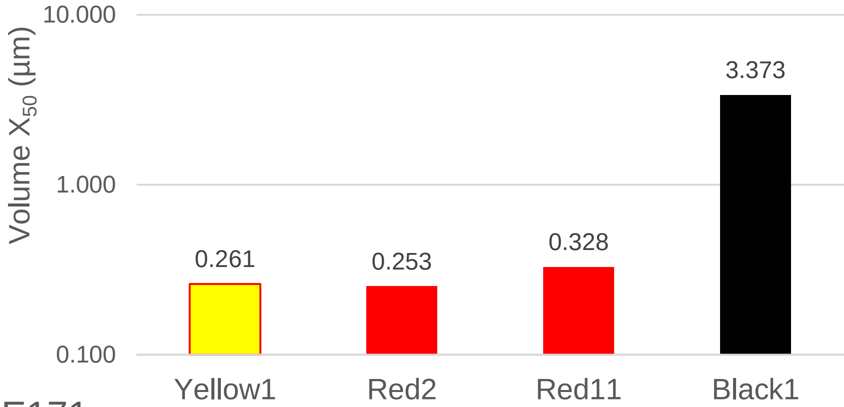
VENATOR

## Volume based particle sizes for risk assessment

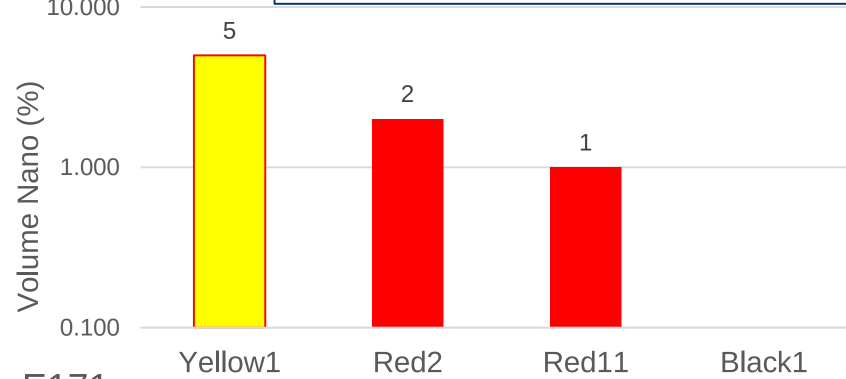
- “Dispersibility has been reported as a founding base for the grouping of the nano materials” *(EChA, “Appendix R.6-1 for nano materials applicable to the Guidance on QSARs and Grouping)*

Brookhaven XDC
Dispersion Energy 240 J/ml

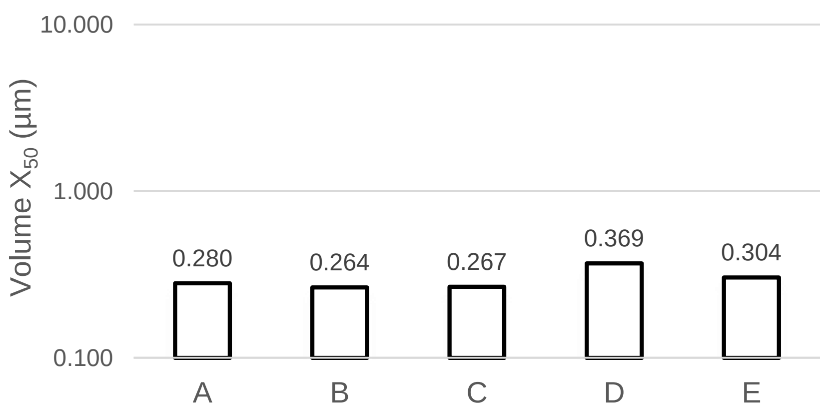
E172



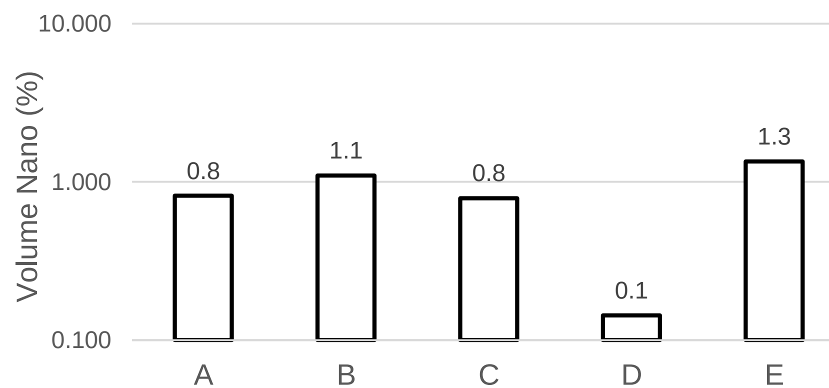

E172




E171




E171



# E171/ E172
## Conclusion on Particle Size Analysis

VENATOR

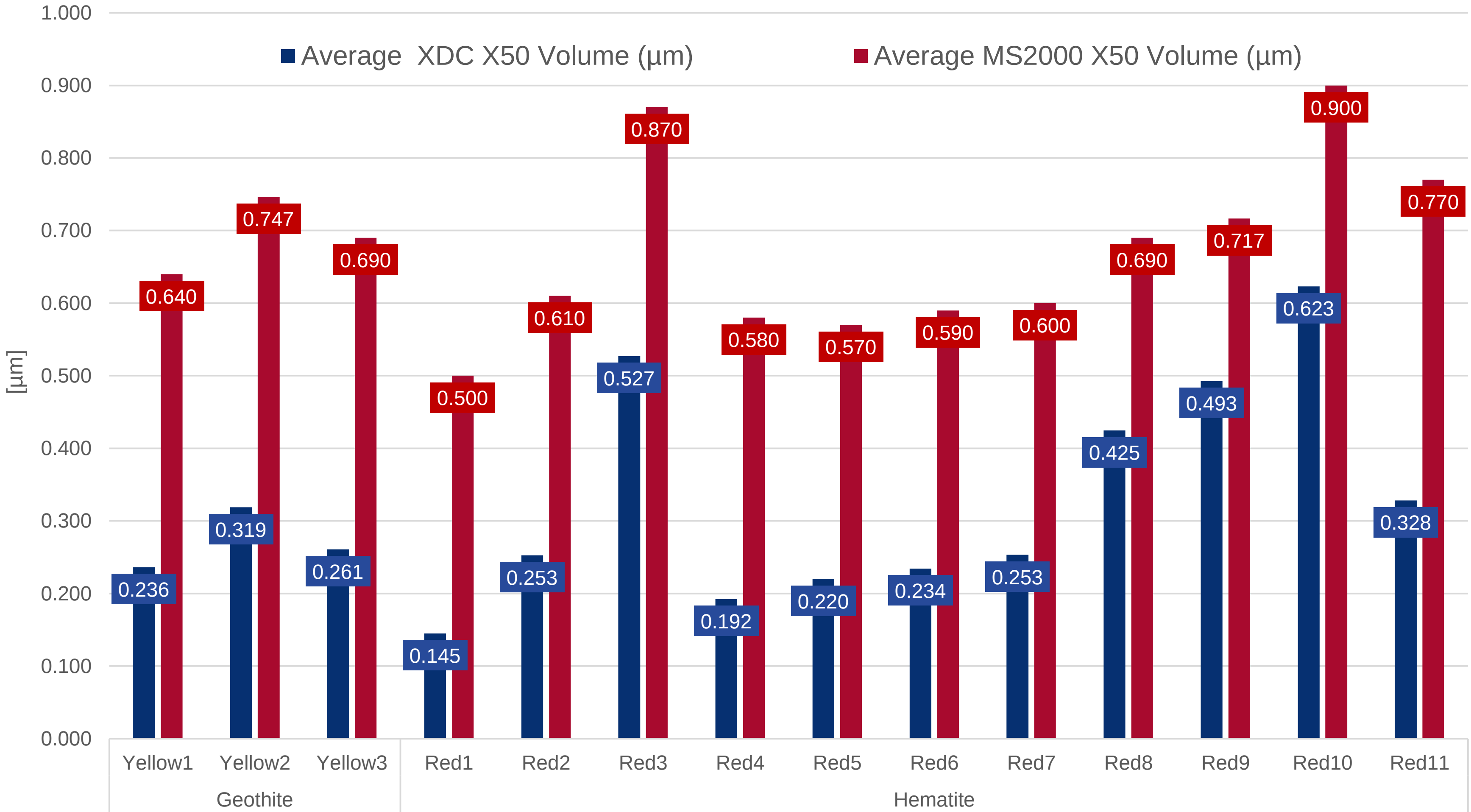
- E171 is **not a nano material** according the EU definition
- E172-Black Iron Oxides are **not nano** products
- The **dispersion criteria** of the Nano-Define decision-flow scheme shall be corrected for **“constituent particles”**
- **Realistic** volume based particle sizes for toxicological testing can be achieved by dispersion energies **<300 J/ml**
- Using the **NIST 1200 TG** volume based particle sizes of different products can be easily **compared** by **different laboratories**
- Implementation of a **dispersibility criterium** in the risk assessment
- CPS DC and Brookhaven XDC are **suitable instruments** to measure mobile nano particles

# Back Up

# E172 Particle Size by Brookhaven XDC & LD

Absolute particle size depends on the method

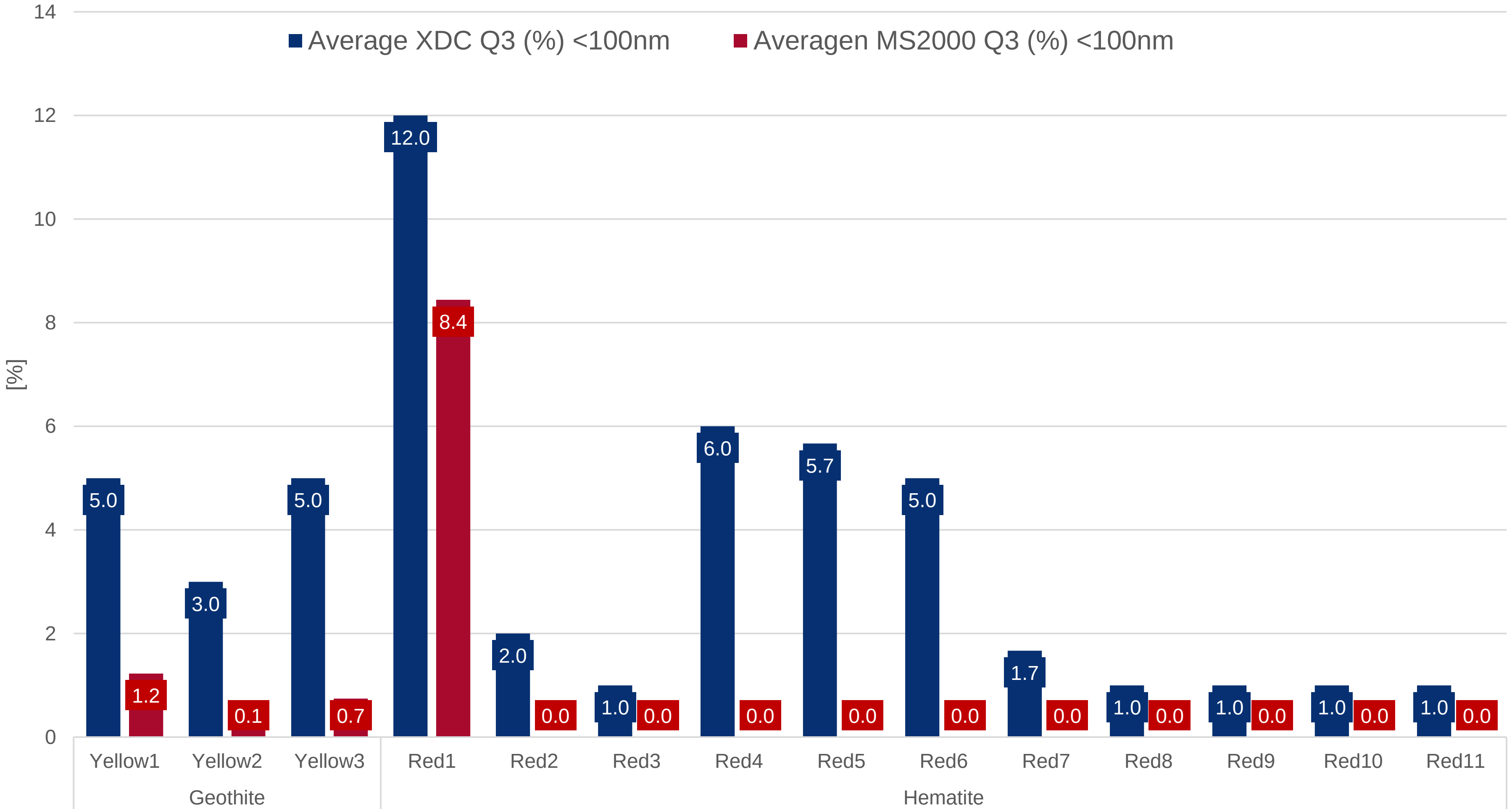
- Dispersion Energy 240 J/ml
- Same trend for both methods



# E172 Nano Content by XDC & LD

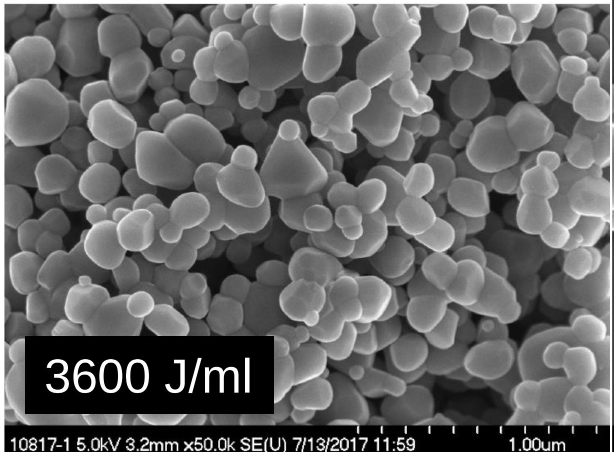
Good sensitivity for high nano contents

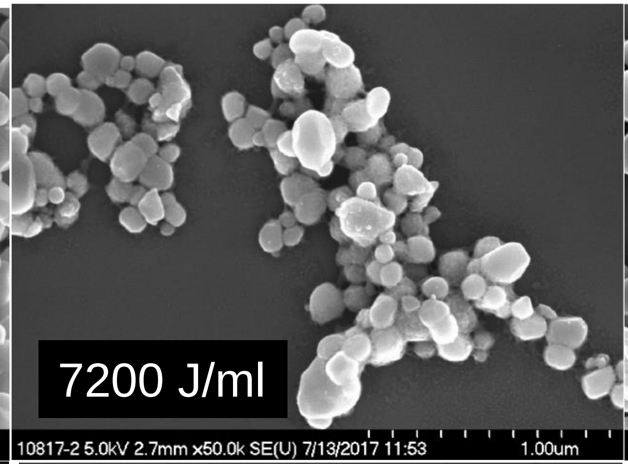
- Brookhaven XDC is more sensitive to fine particles than LD

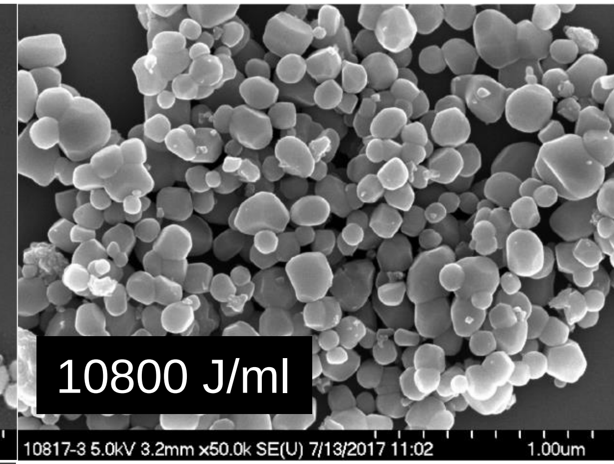


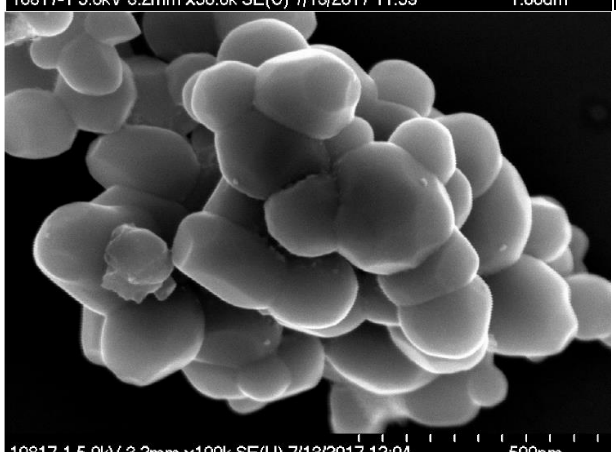
# Long Dispersion experiment

## No complete dispersion of aggregates after 3h

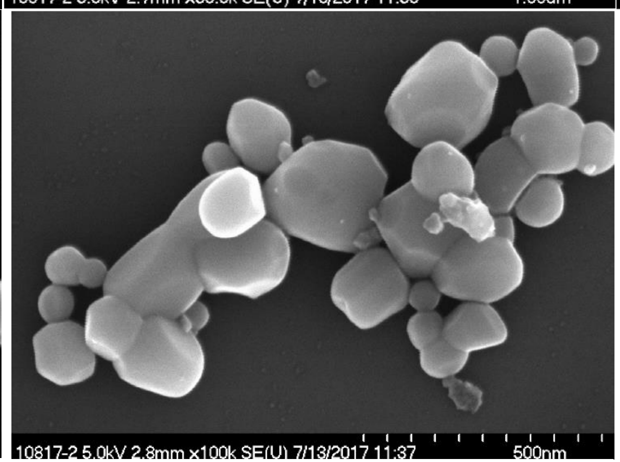


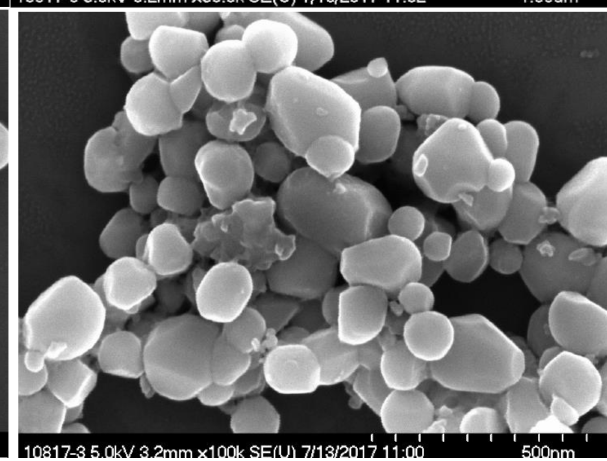




Anatase 1h probe sonication
some tip debris



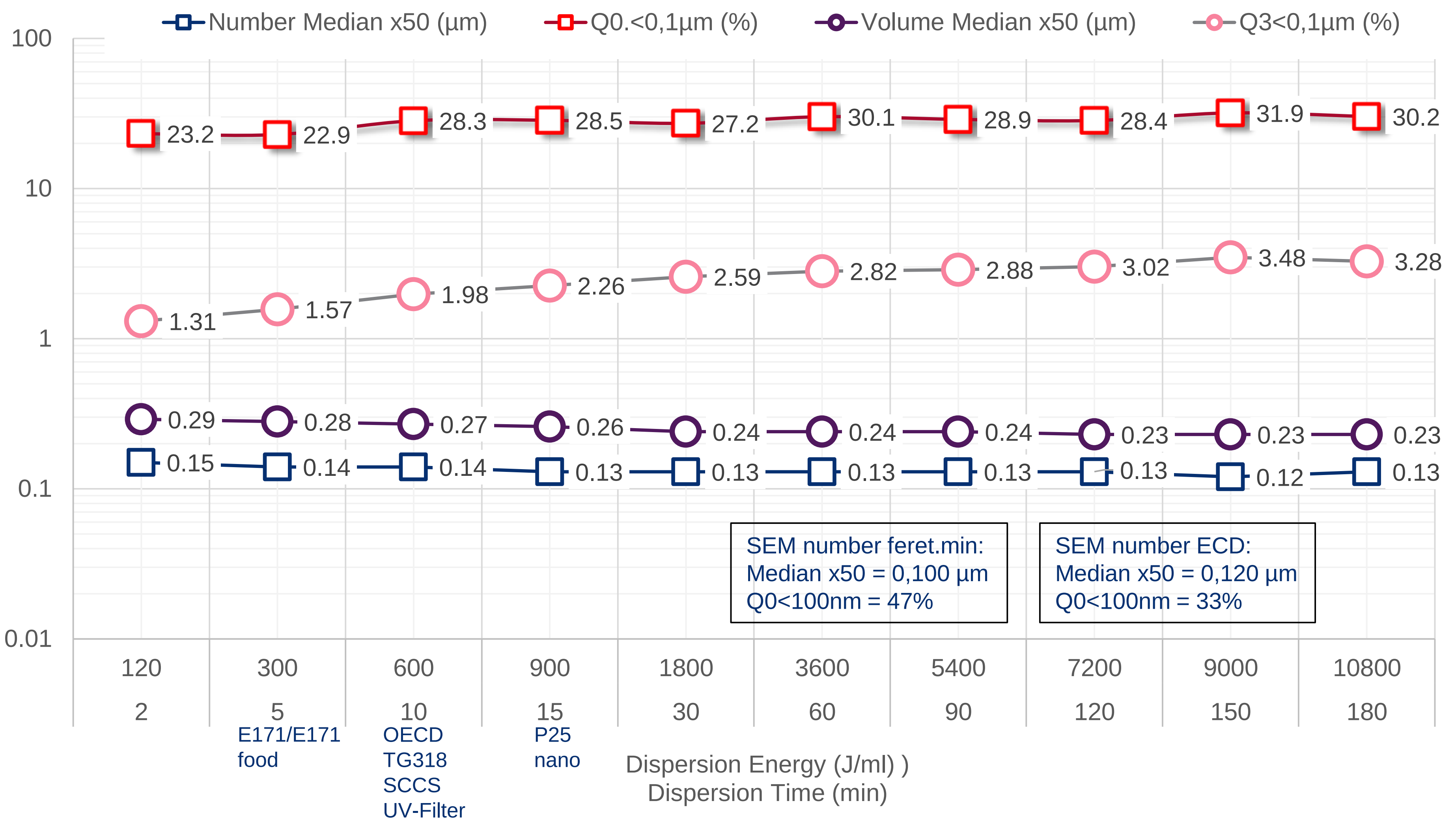

Anatase 2h probe sonication
more tip debris




Anatase 3h probe sonication
increased tip debris
aggregates still survived

# E171 Long Dispersion experiment

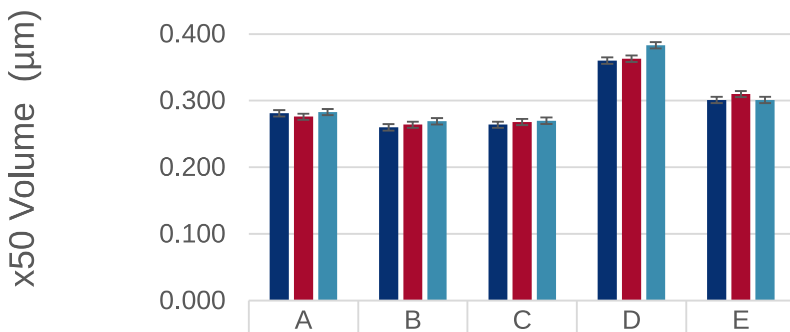
## Particle size analysed by CPS DC



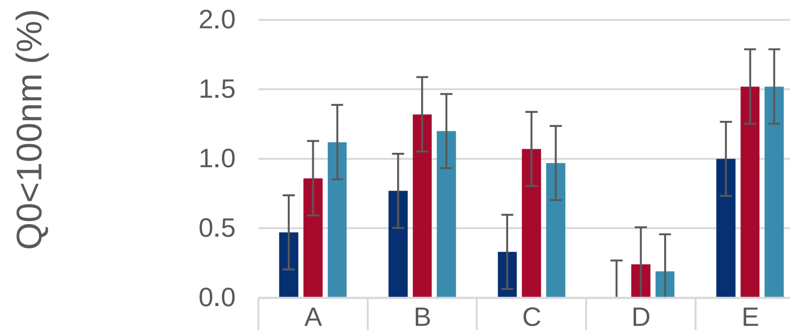
# E171 Brookhaven XDC & CPS DC results

## High agreement between different manufacturer

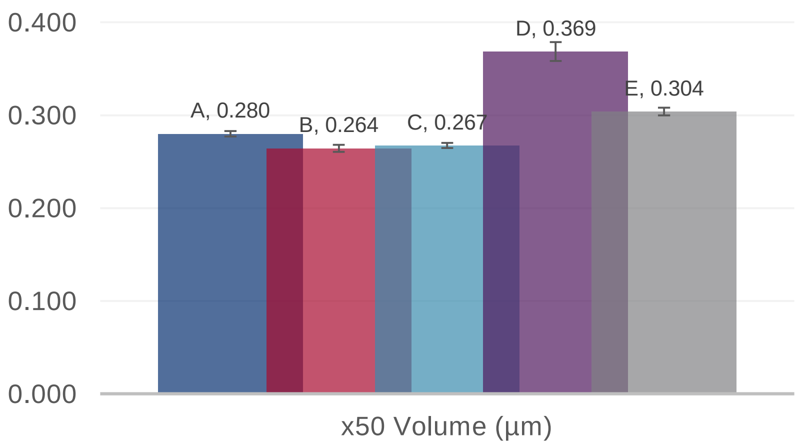
- Small interlaboratory SD on volume particle sizes and nano contents
- High reproducibility of results

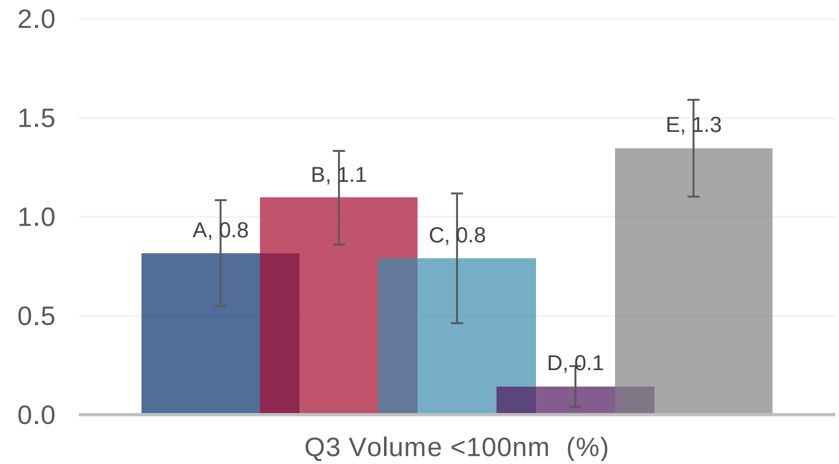



| | A | B | C | D | E |
|---|---|---|---|---|---|
| M 1 XDC | 0.281 | 0.260 | 0.264 | 0.360 | 0.301 |
| M 2 CPS DC | 0.276 | 0.264 | 0.268 | 0.363 | 0.310 |
| M 1 CPS DC | 0.283 | 0.269 | 0.270 | 0.383 | 0.301 |



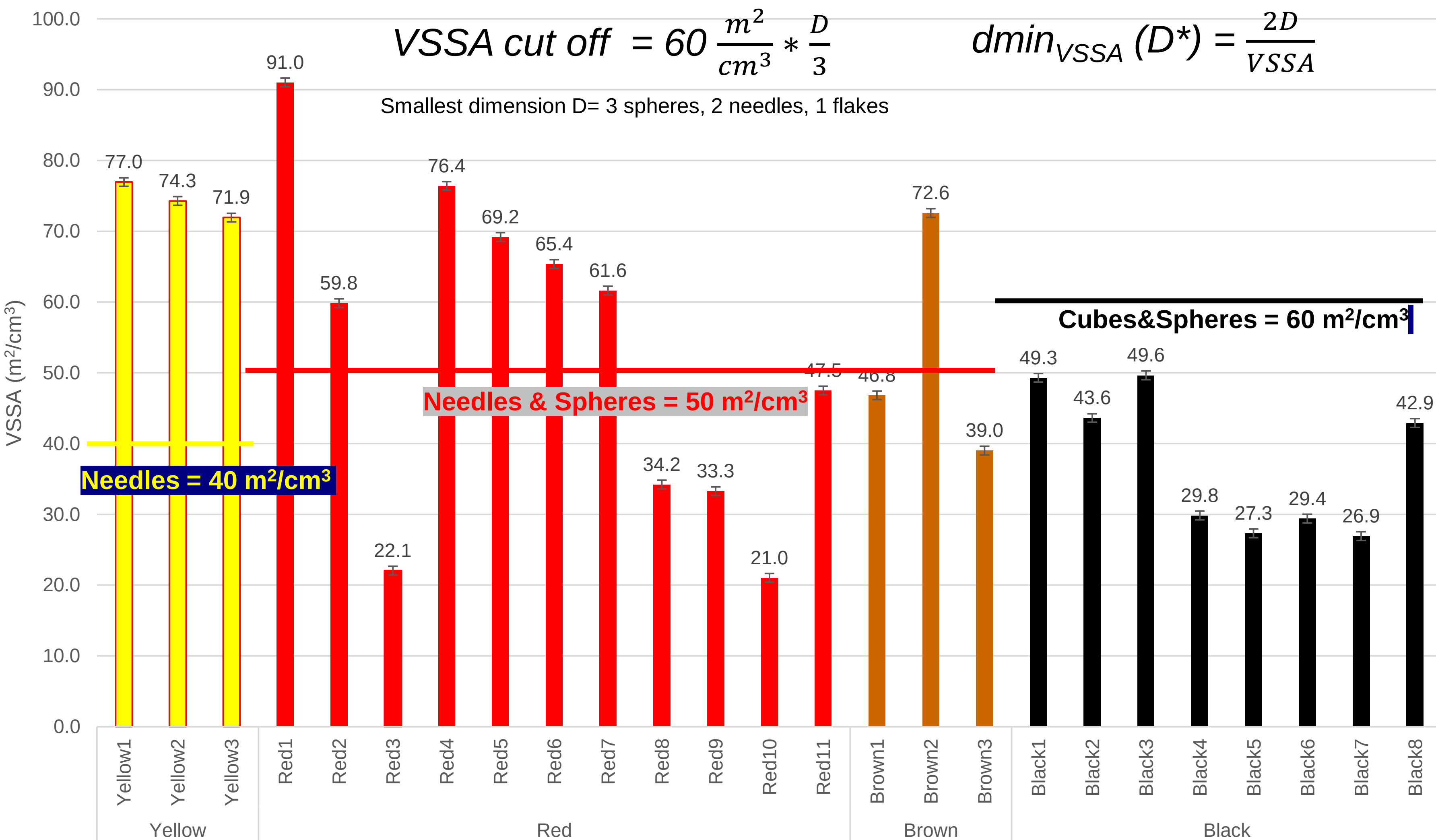

| | A | B | C | D | E |
|---|---|---|---|---|---|
| M 1 XDC | 0.5 | 0.8 | 0.3 | 0.0 | 1.0 |
| M 2 CPS DC | 0.9 | 1.3 | 1.1 | 0.2 | 1.5 |
| M 1 CPS DC | 1.1 | 1.2 | 1.0 | 0.2 | 1.5 |



# VSSA E172

## Screening of particle sizes and nano contents



# BET

VENATOR

**According to DIN ISO 9277, samples are heated up to 180˚C in 30 min and left at this temperature for one hour before determination of the SSA under Nitrogen at 5 different pressure ratios: 0,1 – 0,15 – 0,2 – 0,25 – 0,3.**

**The Volume Specific Surface Area (VSSA) is calculated by multiplication of the SSA with the gravity (ρ)**

$$VSSA = SSA \times \rho \qquad \text{Equation 1}$$

**The Monodisperse Diameter of the Volume Specific Surface Area ($dmin_{VSSA}$) is calculated for different particle shapes by the following equation**

$$dminVSSA\ (D^*) = \frac{2D}{VSSA} \qquad \text{Equation 2}$$

**The VSSA cut off is calculated by the equation below.**

$$VSSA\ cut\ off = 60\ \frac{m^2}{cm^3} * \frac{D}{3} \qquad \text{Equation 3}$$

***Smallest dimension D= 3 spheres, 2 needles, 1 flakes**

# Disc Centrifuge and Dispersion

VENATOR

## *Instrumentation, parameters and formulation*

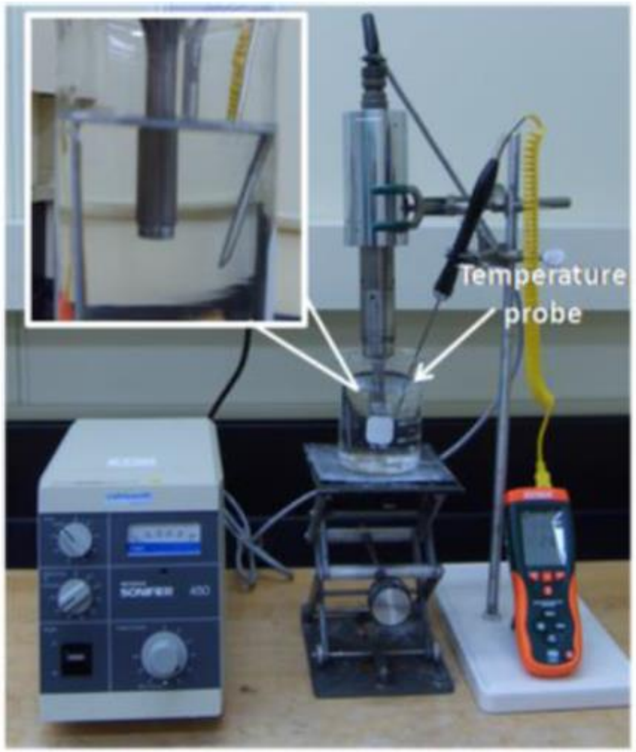
| Company | Instrument | Detector | Disc Speed | Formulation |
|---|---|---|---|---|
| **M-2** | CPS DC | UV-Light 405nm | 18000 rpm | 0,1g E171, 100 ml water, 0,06 g Calgon N |
| **M-1** | Brookhaven XDC | X-Ray | 3000 rpm | 2g E171 in 50 ml water, 0,02 g calgon N |
| **M-1** | CPS DC | UV-Light 470nm | 18000 rpm | 0,1g E171, 38 ml water, 12g PDO*, 0,05 g Calgon N |

## *Dispersion Equipment*

| Company | Sonic Probe | Tip Diameter | Tip Length | Eglible volume | Nominal Power |
|---|---|---|---|---|---|
| **M-2** | Sonoplus 2200 | 13 mm | 250 mm | 25-500 ml | 750 W |
| **M-1** | Sonics VCX750 | 13 mm | 136 mm | 25-500 ml | 750 W |

# NIST 1200 Technichal Guideline

## Power Calibration




*Experimental set up for the power calibration of the sonic probe*

The delivered power is calculated from the equation below :

$$P=dT/dt*M*cp$$

The applied energy density is specified by setting the sample size to 50 ml, dispersion time to 5 min and dispersion power to 40 W. The energy density can be calculated using the following equation.

$$ED = Power * time / volume$$

For the defined parameters the applied energy is 240 J/ml or 67 KWh/$m^3$.