7th Slovenian-Serbian-Croatian Symposium on Zeolites

ENVIRONMENTAL IMPACT OF FOAMED GLASS PREPARED FROM SEWAGE SLUDGE ASH

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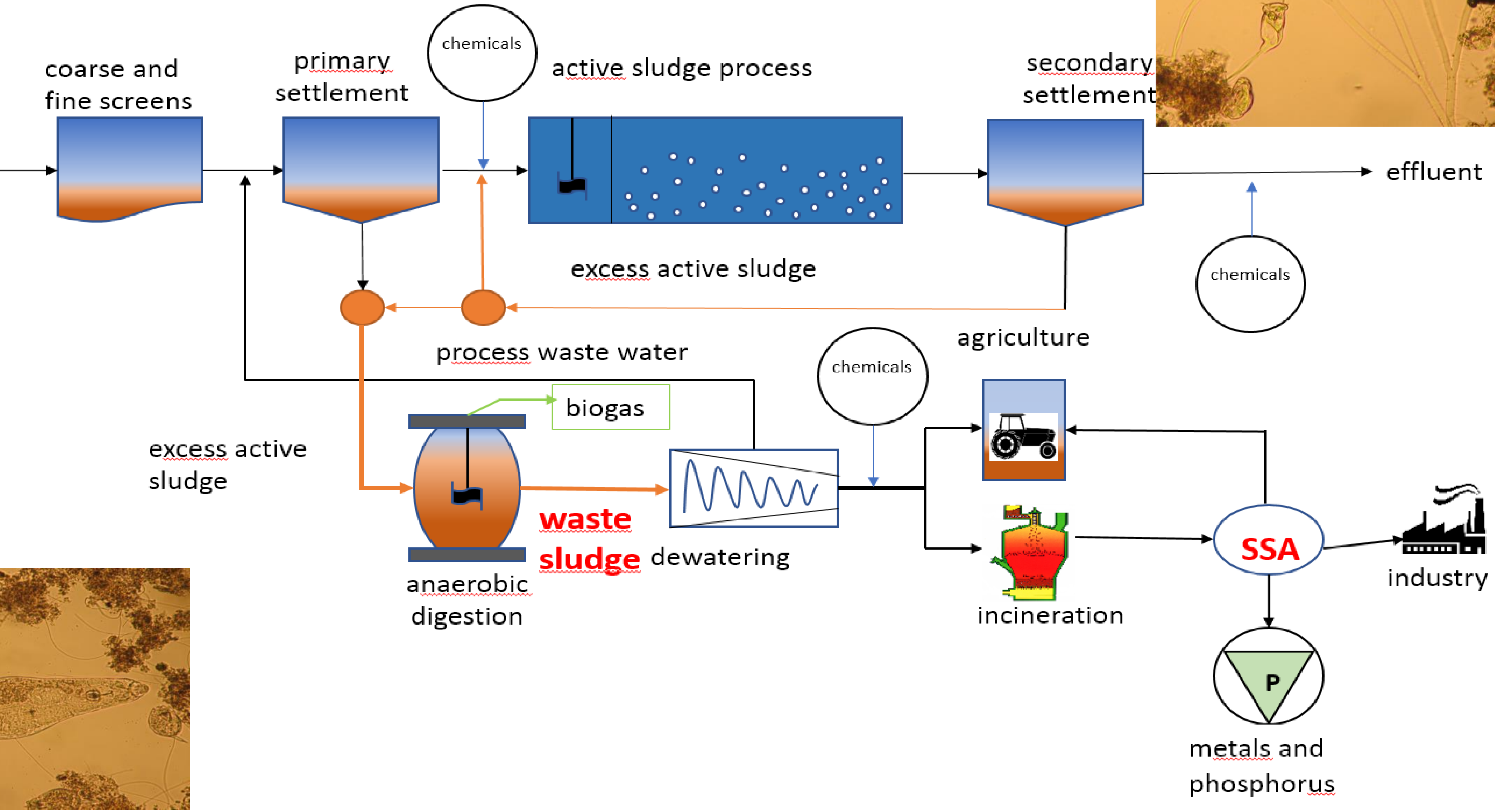
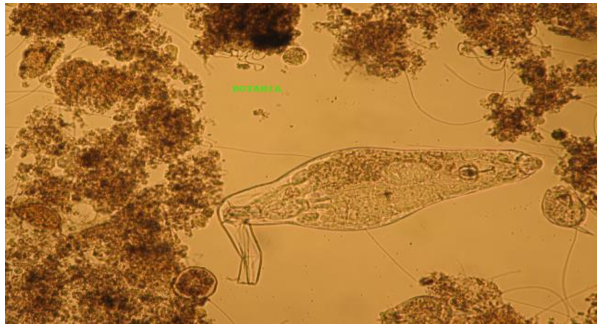
Future significant waste material

WASTE (SEWAGE) SLUDGE – *from Waste water treatment plants – encourage by directive 91/271/EEC for* urban waste water treatment





↑ *Waste Water Treatment Plant -> ↑ waste sludge – everyday waste material*

EU stat. data: cca. 9 million ton of DS for 2010.

- > 13 million ton of DS for 2013.

Waste sludge menagement / EU stat. 2013.:

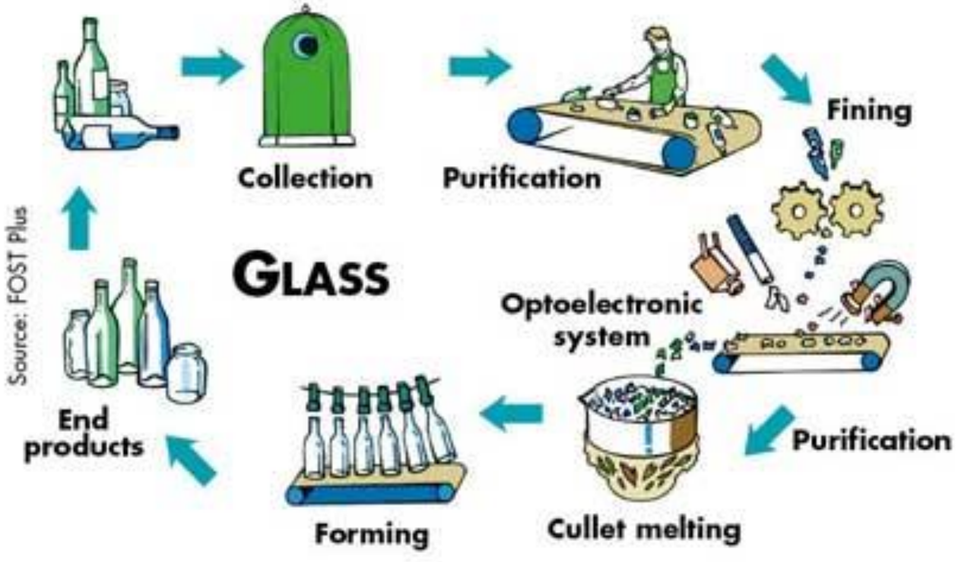
35% agriculture

20% incineration

10% landfill + rest for composting and other applications

Incineration -> Sewage sludge ash (***SSA)***

- quantity reducing (organic content loss)
- hygienization



Reuse of Sewage sludge ash (***SSA) depends of*** !

quantities and composition !

≈ 70% SSA reused in construction and building industry

Everyday packaging glass –> waste glass

- waste glass recycling for EU 2014. ≈ 50%
- ! No culet recycling !

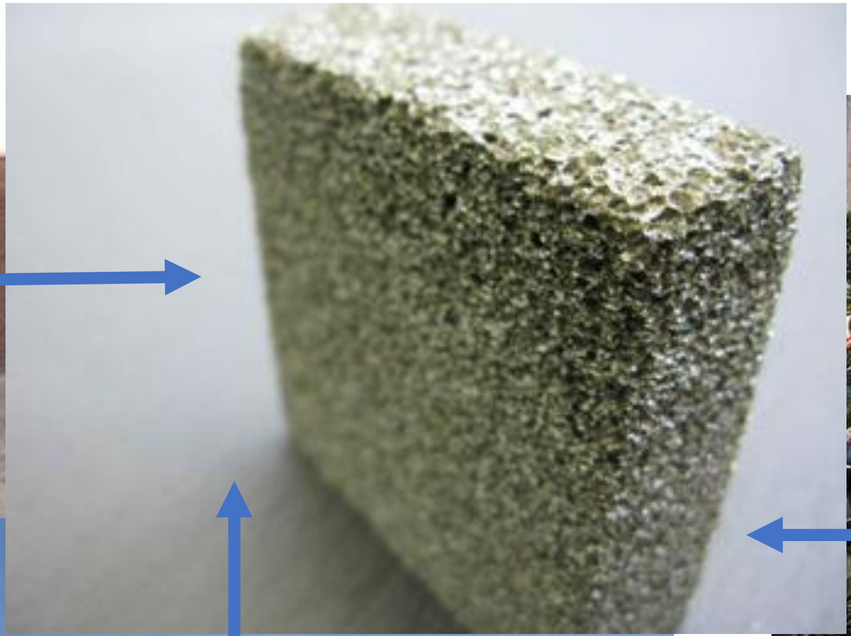
Aim: synthesis of commercially comparable Foam glass (***FG***) material from powder mixture of SSA, recycled bottle glass culet, and carbonate foaming agent

FG - heterogeneous system consisted of solid (glass cell walls) and gaseous phase (trapped inside cells)

- high porosity up to 90%,
- made from pristine glass with addition of foaming agent (SiC or TiN) that produce uniform cells inside controlled thermal treatment and atmosphere.

FG application in building industry for isolation (sound, heat, water) and in chemical industry (reactors, separators, filters).

Aim: synthesis of commercially comparable Foam glass (***FG***) material from powder mixture of sewage sludge ash (**SSA)**, recycled bottle glass culet (**G)**, and carbonate foaming agent (**F)**, determination of ***FG*** environmental impact



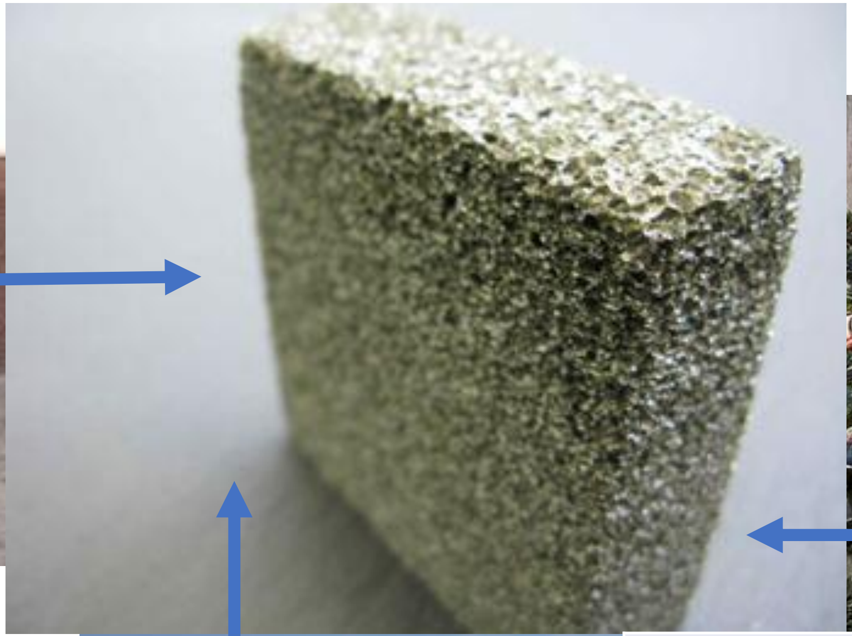
SSA - ignition of waste sludge at 550°C for 2h

$CaCO_3$ (F) - by-product originating from dedusting limestone mills.

Waste glass (G) - recycled bottle glass, prewashed, dried, and crashed to form cullet.

Aim: synthesis of commercially comparable Foam glass (***FG***) material from powder mixture of sewage sludge ash (**SSA)**, recycled bottle glass culet (**G)**, and carbonate foaming agent (**F)**, determination of ***FG*** environmental impact

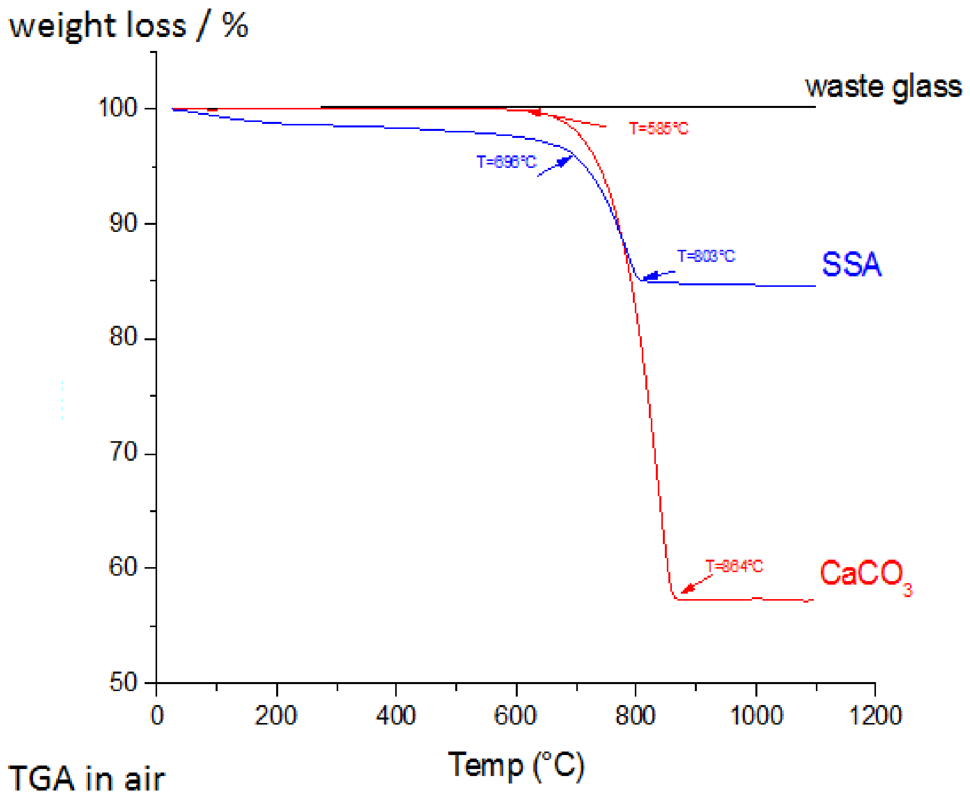
SSA oxide	wt%
SiO_2	40.79
CaO	17.63
Al_2O_3	11.0
Fe_2O_3	5.35
MgO	3.43
Na_2O	0.42
other	21.38



G. oxide	wt%
SiO_2	84.3
CaO	5.92
Al_2O_3	2.1
Fe_2O_3	0.2
MgO	1.97
Na_2O	3.57
other	1.94

F. oxide	wt%
SiO_2	0.15
CaO	54.83
Al_2O_3	0
Fe_2O_3	0.13
MgO	0.29

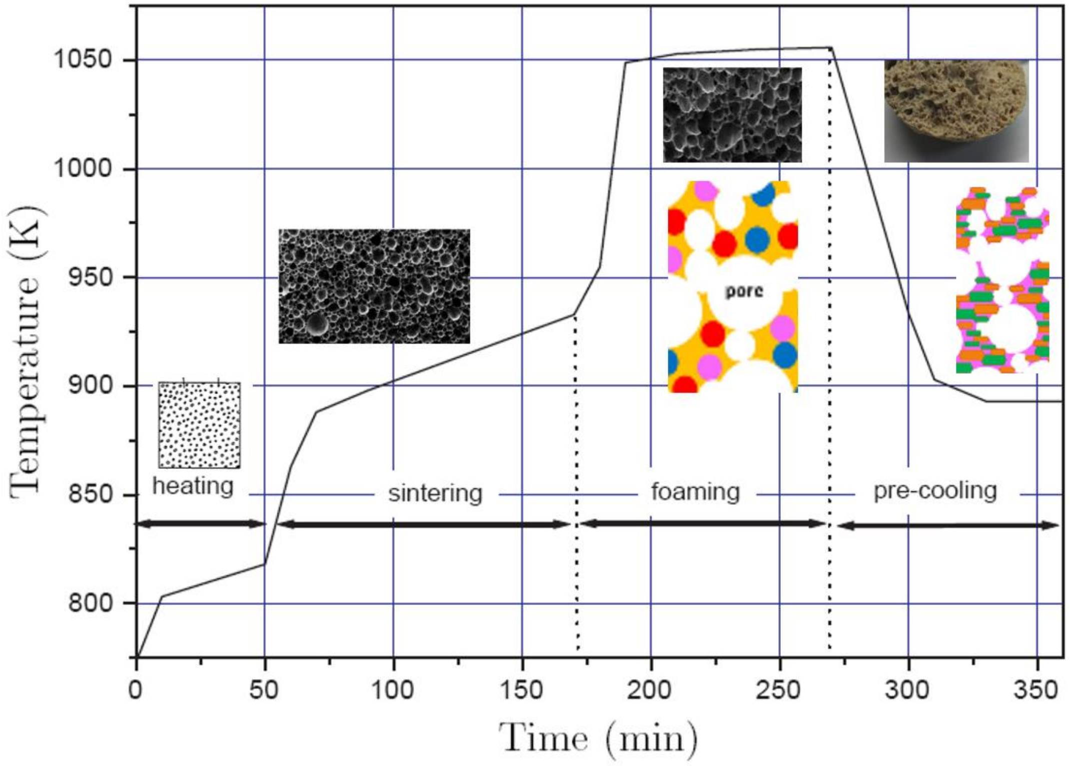
FG synthesis – thermal treatment



Sample wt%	FG1	FG2	FG3
Waste glass	85	82	75
CaCO3	2	2	2
SSA	13	17	23

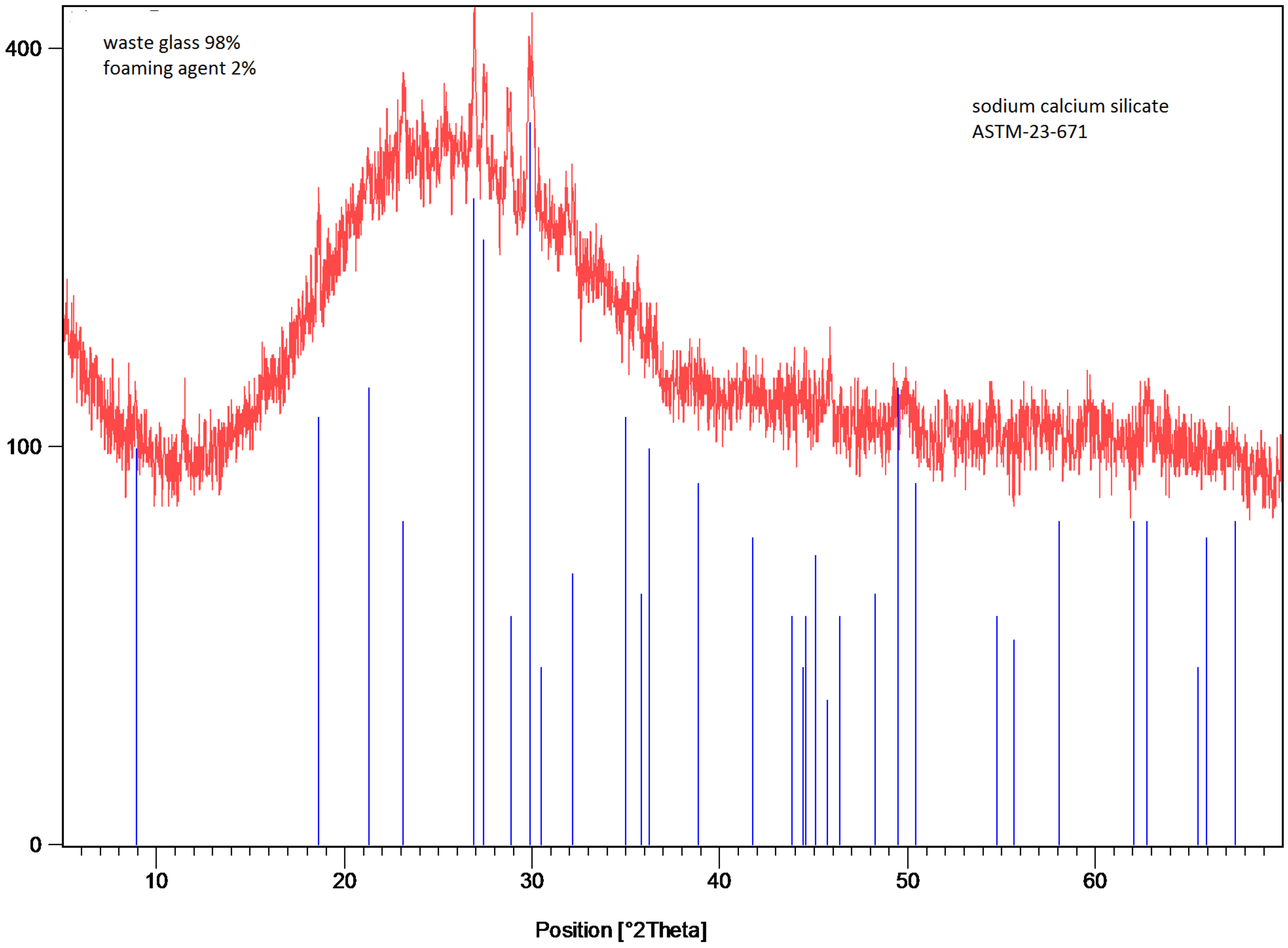
Raw materials - milling – powder particle size ≤ 0.71mm

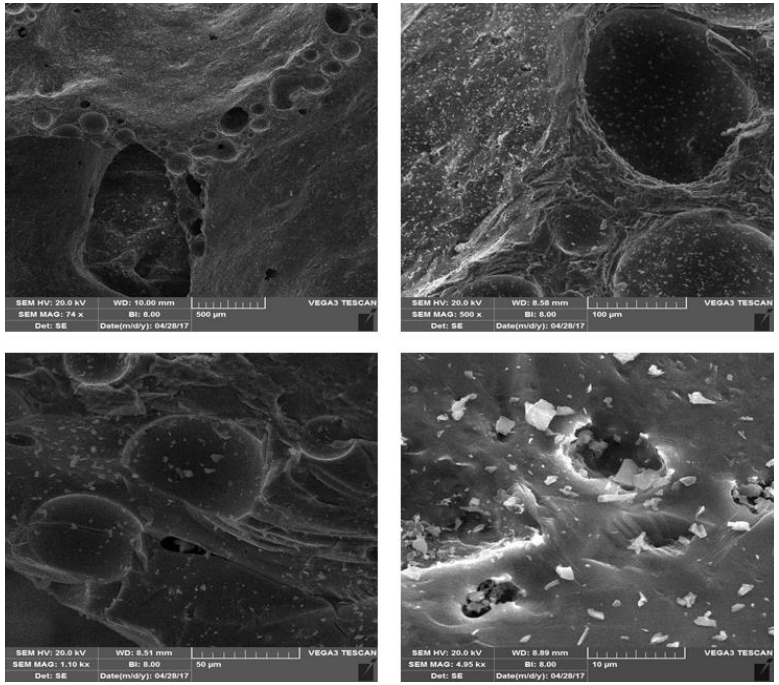
Wet homogenization of powder raw materials with 96% ethanol - drying for 6h/80°C - dry molded uniaxial pressure of 12t - kiln at ambient air pressure through one-step thermal treatment of 5°C/min/850°C – isothermic 15min/850°C



The morphology of FG

X-ray diffraction (XRD) / scanning electron microscopy (SEM) analysis





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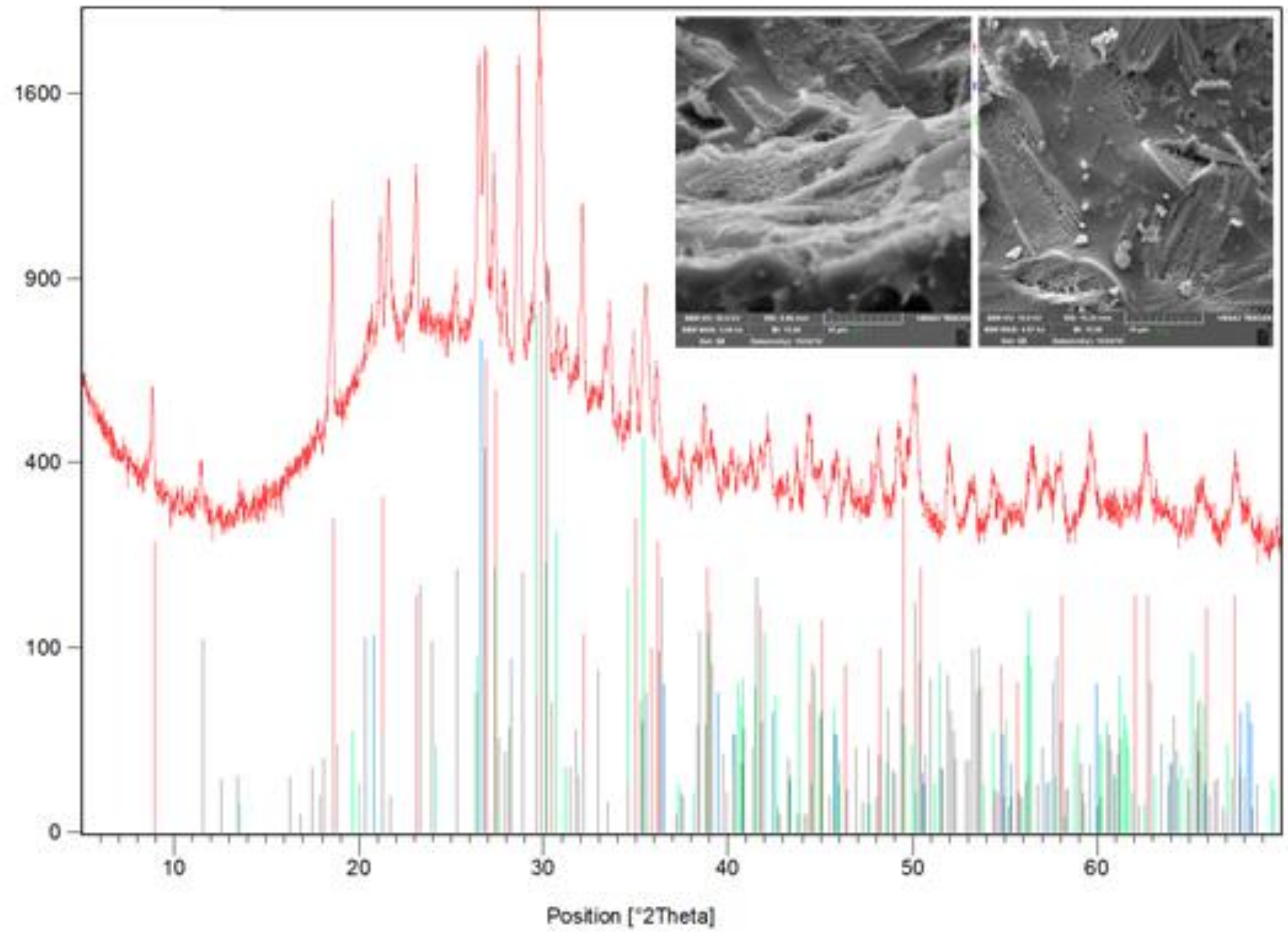
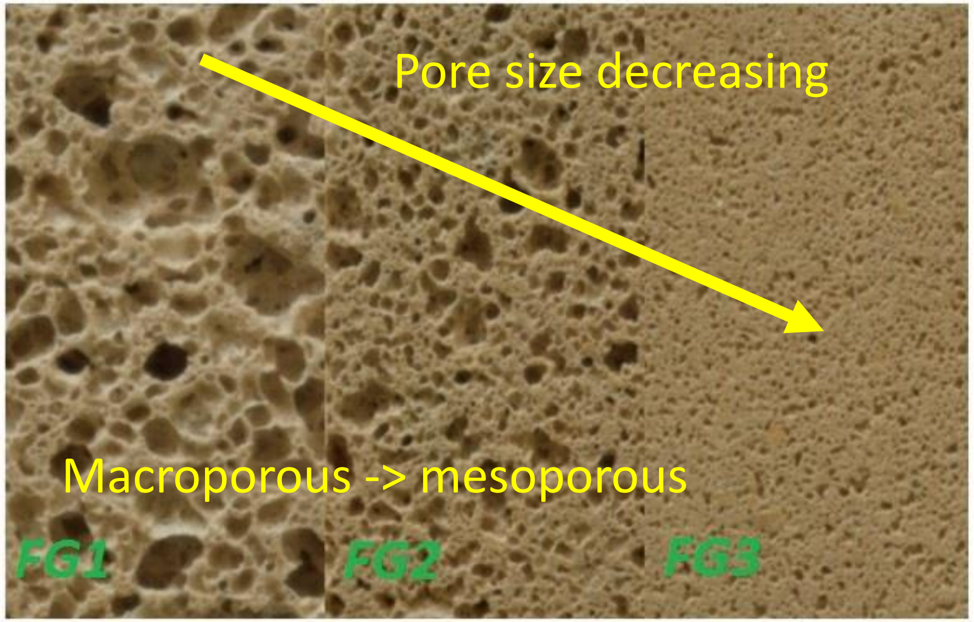
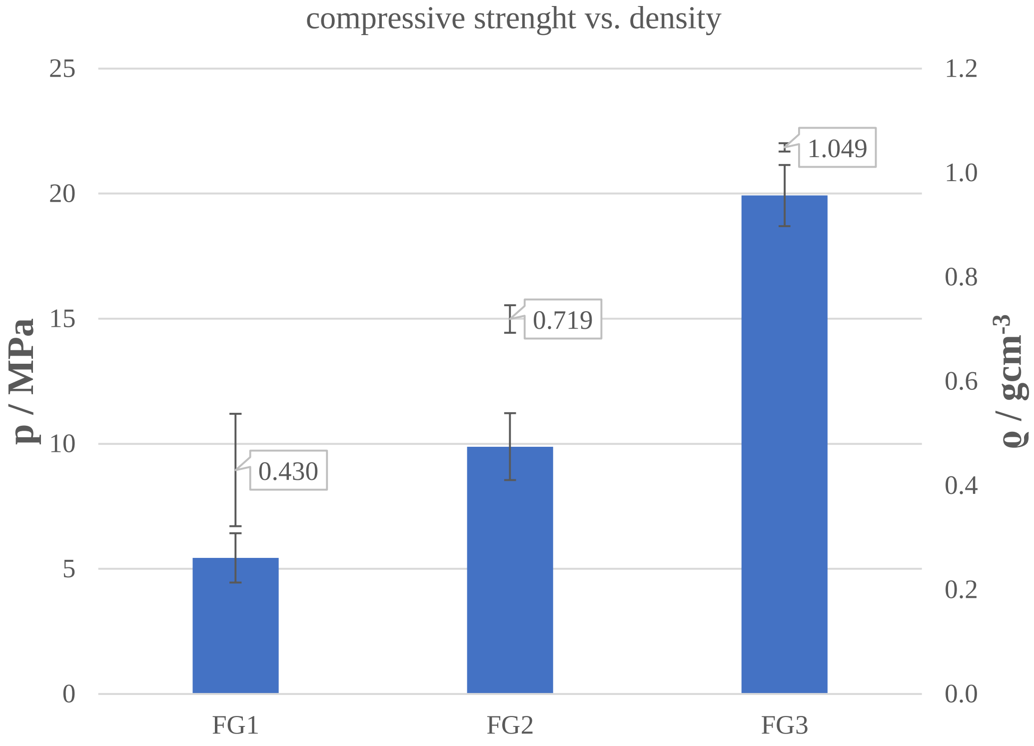
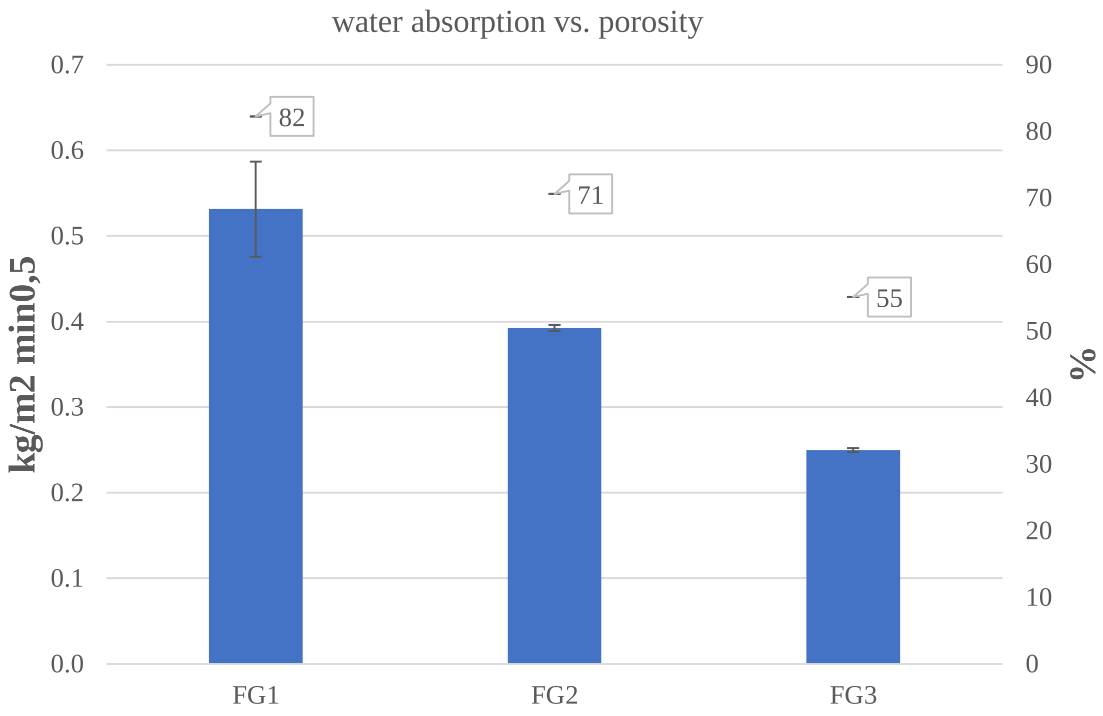


Amorphous phase mixed with wollastonite $CaSiO_3$, and quartz / HT quartz SiO_2



Physical mechanical properties





Waste glass 98% + foaming agent 2%: ρ=0.330g/cm^3 ; σ=0.28MPa; P=86.42%

Commercial ***FG***: density < 0.5 g/cm^3; σ ≈ 0.6MPa, P ≈ 85-95%

ENVIRONMENTAL IMPACT OF FG

The antibacterial activity of FG and SSA was tested on the multidrug-resistant environmental isolate of *Acinetobacter baumannii* from wastewater of city Zagreb[*Hrenović et al.*, EuroSurveill. 21, (2016) 21].

- information about possible control of pathogenic multidrug-resistant bacteria in water environment by contact with FG,
- eluate treatment from waste material landfill.

The leaching of major heavy metals from SSA and FG were determined in deionized water [EN 12457-4] and leachates were analyzed by inductively coupled plasma optical emission spectrometry.

The ability of the waste glass as a binder of heavy metals was evaluated through leaching in aqua regia [EN 13657].

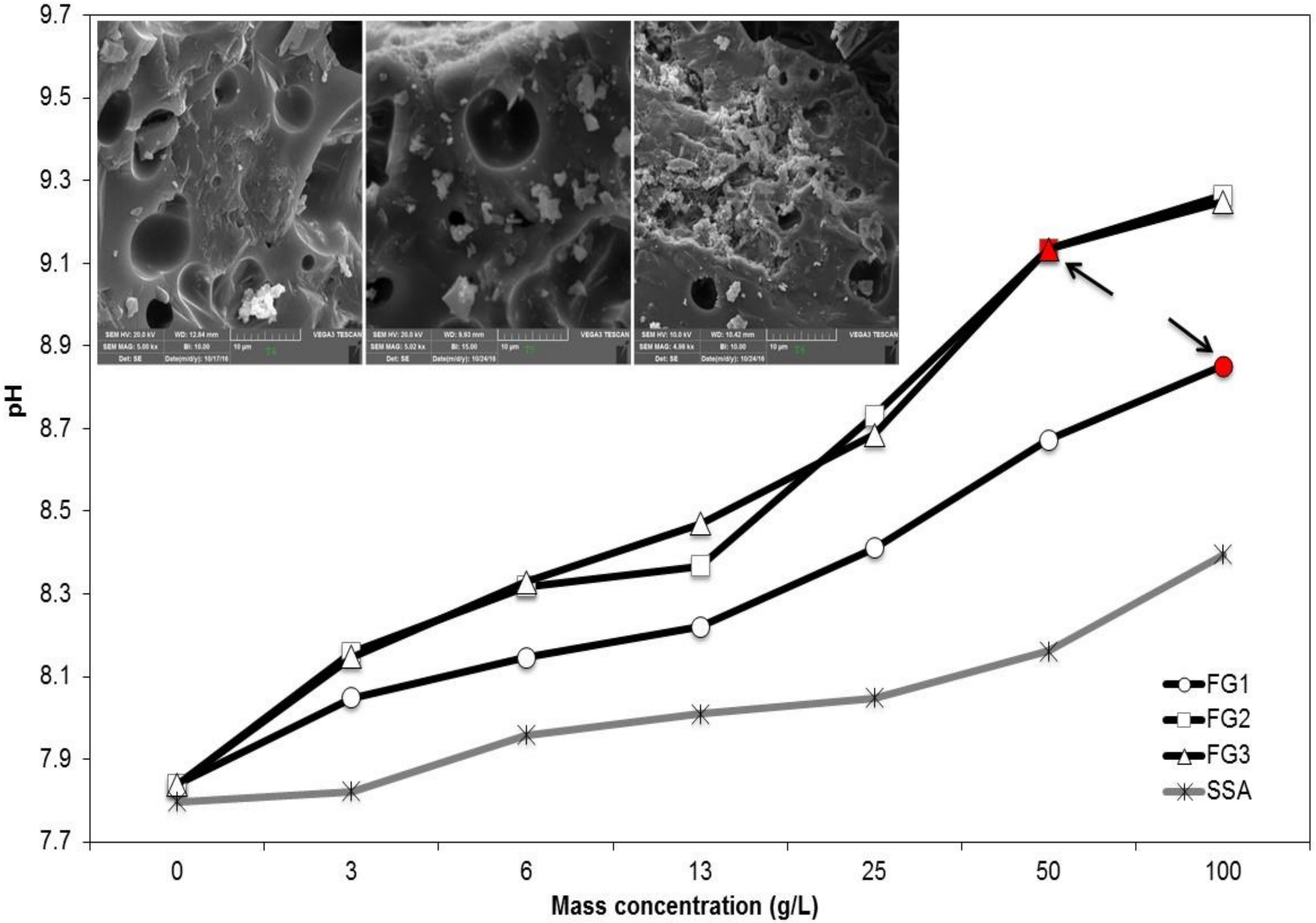
- safe incorporation of heavy metals inside FG,
- safe landfill after life cycle of FG.

ENVIRONMENTAL IMPACT OF FG

The antibacterial activity of FG and SSA was tested on the multidrug-resistant environmental isolate of *Acinetobacter baumannii* [*Hrenović et al.*, EuroSurveill. 21, (2016) 21].

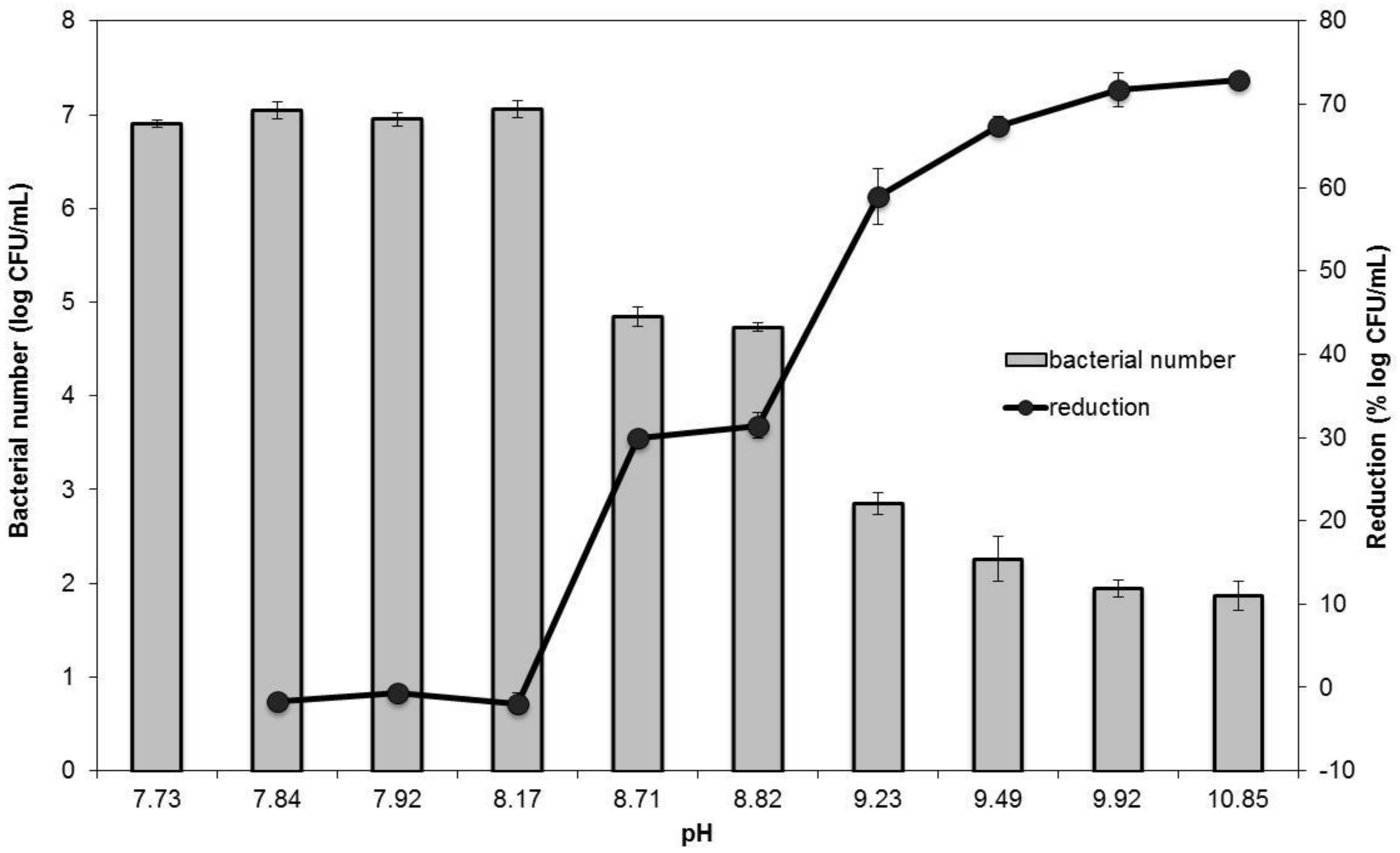
Bacterial biomass -> suspended in autoclaved
natural spring water **<- 3-100 g/L dry-sterilized FG/SSA** (p. size 0.125-0.250mm)

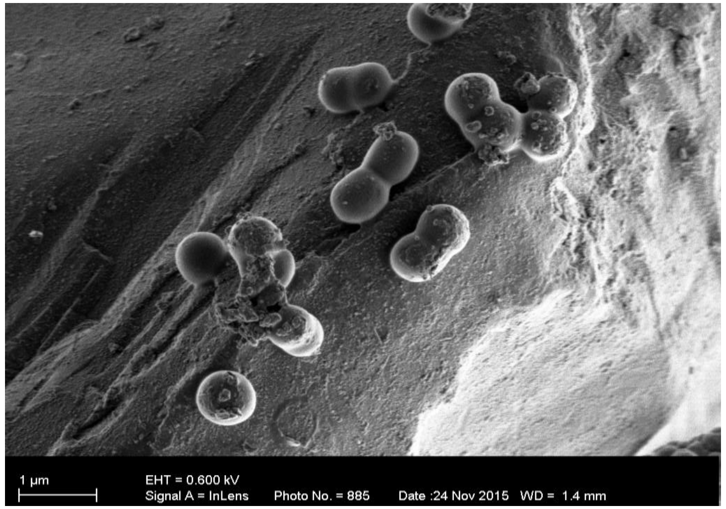
Experiments: at 37°C/24h (shaking at 170rpm.); decimal dilution of sample in sterile physiological solution; inoculation of dilutions on nutrient agar; incubation at 42°C for 24h.
Number of *A. baumannii* determination (colony forming units (CFU) per 1mL of slurry) at 0 and 24h of incubation.
Minimum inhibitory concentration (MIC) of FG = lowest concentration of FG which caused the visible inhibition of bacterial growth as compared to positive control (without FG addition).
MIC confirmed by CFU counting and SEM analysis.



SEM micrographs of samples FG1 (left), FG2 (middle) and FG3 (right).

Increase of the pH value of spring water by addition of different amounts of FG samples, and the MIC values of FG against *A. baumannii*. MIC values are marked in arrows; MIC were observed above pH 8.85; c_0 (log CFU/mL) = 7.05±0.01.





The influence of elevated pH on the numbers of viable *A. baumannii* was confirmed in artificially adjusted pH of the natural spring water after 24h of contact at 37°C. Native pH of spring water (7.73) was used as positive control; reduction of bacterial numbers was calculated as ((log CFUcontrol – log CFUpH)/log CFUcontrol)*100; reduction higher than 31% was observed above pH 8.82; c0 (log CFU/mL) = 6.90±0.04.

ENVIRONMENTAL IMPACT OF FG

The leaching of major heavy metals from SSA and FG

parameter concentration in eluate (mg/kg)	EN 12457-4:2002				EN 13657			
	SSA	*FG1*	*FG2*	*FG3*	*SSA*	*FG1*	*FG2*	*FG3*
pH		12,13	11,75	11,43				
Cr	24,9	4,81	4,42	7,69	84,3	13,9	16,3	19,2
Cd	<0,3	<0,01	<0,01	<0,01	<0,1	<0,1	<0,1	<0,1
Pb	<2	<0,01	<0,01	<0,01	408	9,63	12,5	8,6
Hg	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Mo	5,23	1,04	1,08	1,24	8,71	5,3	3,7	14,7
As	<0,05	0,0391	0,008	<0,01	5,88	<0,1	<0,1	<0,1
Cu	<1	<0,01	<0,01	<0,01	736	44	50,8	70,3
Ni	<2	<0,01	<0,01	<0,01	29,6	7,04	10,2	7,93
Zn	1,77	<0,01	<0,01	<0,01	1460	52	71	108

EN 12457-4:2002 - characterisation of waste - Leaching - Compliance test for leaching of granular waste materials and sludges.

EN 13657 - characterization of waste - Digestion for subsequent determination of aqua regia soluble portion of elements.

Conclusion:

- *FG obtained by simple production method from waste materials without additives showed comparable characteristics to commercial FG material and fulfil requirements for masonry mortars.*

- *Low leaching of heavy metals and antibacterial activity classify prepared FG as environmental friendly material.*

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Hrvatska zaklada za znanost

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