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Continuous reaction crystallization of struvite from diluted aqueous solutions of phosphate(V) ions in DT MSMPR crystallizer

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Abstract

Experimental work concerning continuous reaction crystallization of struvite $MgNH_4PO_4 \cdot 6H_2O$ from diluted aqueous solutions of phosphates(V) (1.0 mass % of PO_4^{3-}) is presented. Laboratory tests were carried out in a DT MSMPR type crystallizer in 298 K assuming stoichiometric ratio of the reagents. Influence of pH (8.5 – 10) and mean residence time of suspension in a crystallizer (900 – 3600 s) on product crystal size distribution, their size-homogeneity and process kinetics was identified. Struvite crystals of mean size from ca. 23 to ca. 86 μm, of diverse homogeneity (CV 62 – 90%) were produced. The largest crystal sizes of acceptable homogeneity corresponded to pH 8.5 and mean residence time elongated up to 3600 s. Under these conditions struvite nucleation rate did not exceed $2.9 \cdot 10^7$ 1/(s m^3) according to SIG MSMPR kinetic model. Linear growth rate of struvite crystals within the parameter ranges tested varied from $4.33 \cdot 10^{-9}$ to $1.75 \cdot 10^{-8}$ m/s.

Keywords: Struvite; reaction crystallization; continuous DT MSMPR crystallizer; crystal size distribution; SIG MSMPR kinetic model

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Nomenclature

B	– nucleation rate, $1/(m^3 s)$;
CV	– coefficient of (crystal size) variation, defined as $100(L_{84} - L_{16})/(2L_{50})$, %;
G	– linear growth rate of crystals, m/s;
k_v	– volumetric shape factor of crystals;
K_{sp}	– solubility product;
L	– characteristic linear size of crystal, m;
L_a	– crystal length, m;
L_b	– crystal width, m;
L_d	– dominant crystal size, m;
L_i	– mean size of i–th crystal fraction, m;
L_m	– mean size of crystal population, defined as $\Sigma x_i L_i$, m;
L_{50}	– median crystal size for 50 mass % undersize fraction, m;
$[Mg^{2+}]_{RM}$	– concentration of magnesium ions in a feed, mass %;
M_T	– crystal concentration in suspension (suspension density), kg_{cryst}/m^3 susp.;
n_0	– nuclei (zero–size crystals) population density, $1/(m\,m^3)$;
$n(L)$	– population density (number of crystals within the specified size range in unit volume of the suspension per this size range width), $1/(m\,m^3)$;
$[NH_4^+]_{RM}$	– concentration of ammonium ions in a feed, mass %;
$[PO_4^{3-}]_{ML}$	– concentration of phosphate(V) ions in a mother solution, mass %;
$[PO_4^{3-}]_{RM}$	– concentration of phosphate(V) ions in a feed, mass %;
q_v	– volumetric (out)flow rate of crystal suspension from the crystallizer, m^3/s;
T	– process temperature, K;
V_w	– crystallizer working volume, m^3;
x_i	– mass fraction of crystals of mean fraction size L_i.

Greek letters

τ – mean residence time of suspension in a crystallizer working volume, defined as V_w/q_v, s;

Abbreviations

CSD – Crystal Size Distribution
DT – Draft Tube (crystallizer)
GRD – Growth Rate Dispersion (kinetic growth model)
MSMPR – Mixed Suspension Mixed Product Removal (crystallizer)
SDG – Size-Dependent Growth (kinetic growth model)