COMSOL CONFERENCE 2019 BOSTON

A Multiphysics Model for Microparticle Transport through Hypodermic Needles

M. Sarmadi, A. Behrens, R. Langer, A. Jaklenec

Massachusetts Institute of Technology, Cambridge, MA, United States

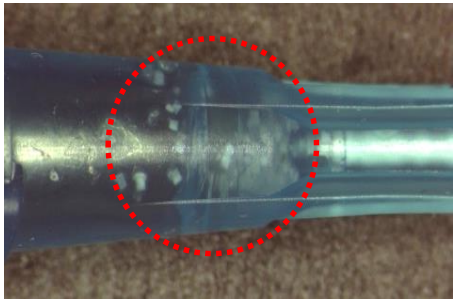
Outline

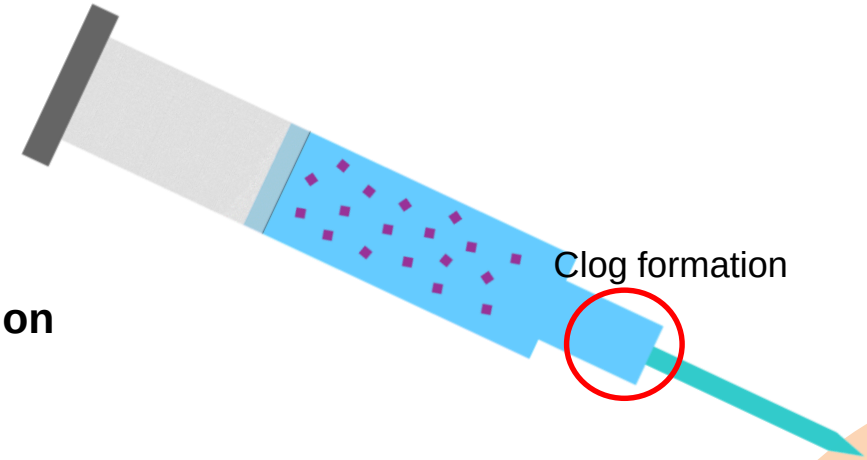
- Introduction
- Modeling approach
- Results
- Conclusions

Inefficient microparticle delivery imposes significant challenge on administration of biopharmaceutical products

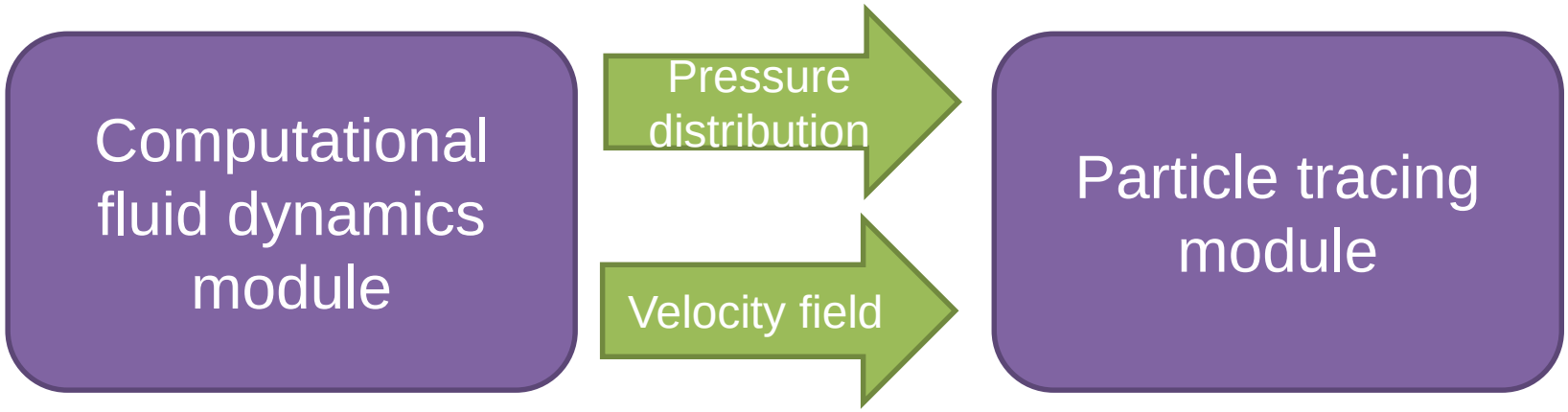
Inefficient drug delivery

Unsuccessful drug administration

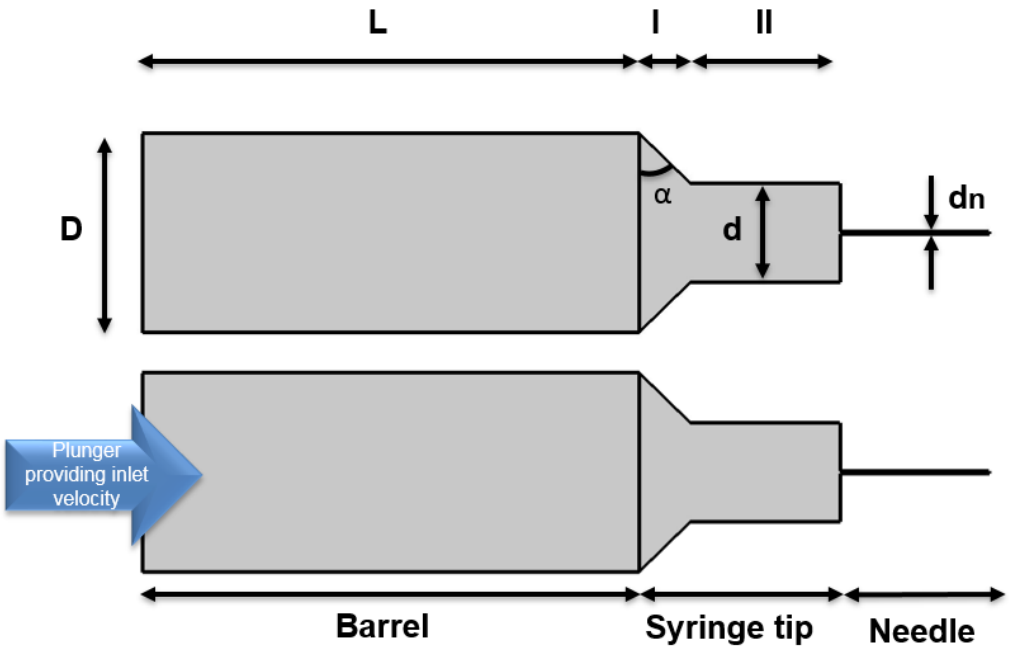


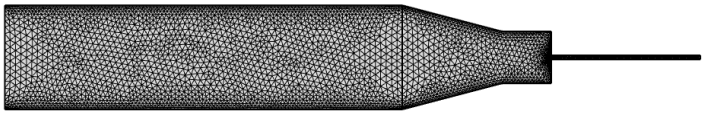


Model definition in COMSOL Multiphysics V5.3 ®



A parametric model was defined in COMSOL Multiphysics V5.3® to study the effect of different geometrical parameters





Governing Equations

CFD module

$$\rho \frac{\partial \bar{u}}{\partial t} = -\bar{\nabla} p + \mu \bar{\nabla}^2 u + \rho \bar{g} \quad (1)$$

$$\rho \cdot \nabla \bar{u} = 0 \; (2)$$

Particle tracing module

$$\frac{d(m_p \bar{v})}{dt} = \bar{F}_D + \bar{F}_G + \bar{F}_{Ext} \quad (3)$$

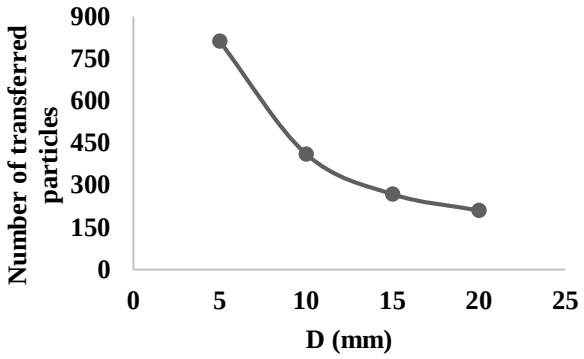
Assumptions and boundary conditions

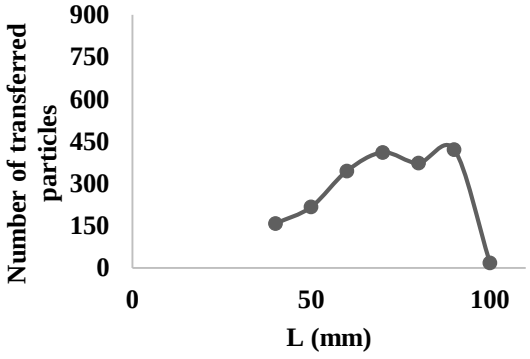
- Laminar steady state flow
- Poiseuille (pressure-driven) flow
- Newtonian fluid (μ=0.01 Pa.s, ρ=1000 kg/m^3)
- Sticky walls
- Inlet velocity of 10 mm/s
- Needle outlet open to atmospheric pressure
- Output: the number of particles in the needle outlet

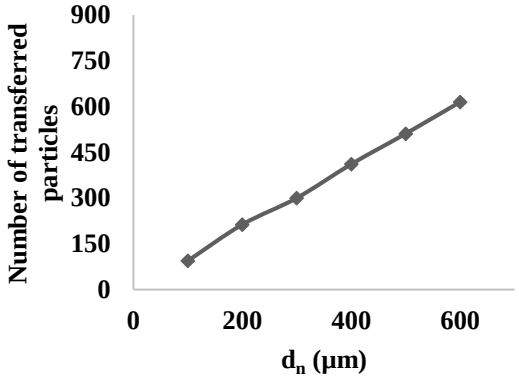
Values used as the default:

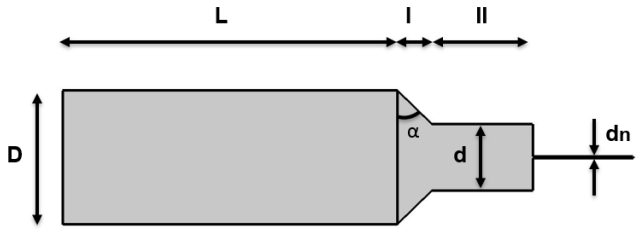
Parameter	Value
D	10 mm
d	5 mm
d_n	0.4 mm
L	70 mm
l	5 mm
ll	5 mm
α	30°
Initial number of particles in the syringe	5000
Particle density	2200 kg/m^3
Particle diameter	10 μm

Effect of different parameters on the microparticle injection was investigated



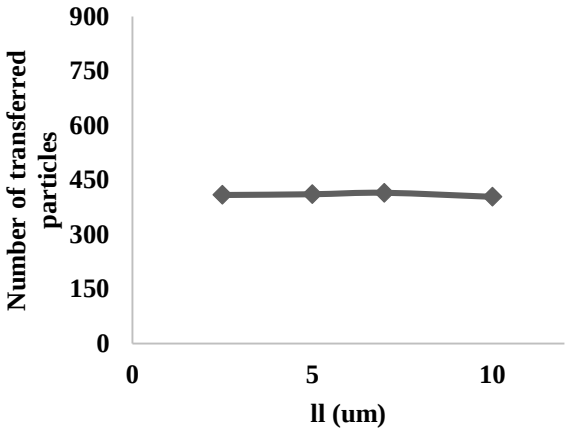


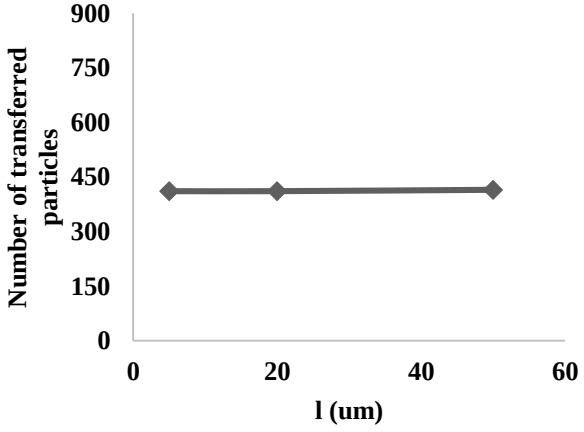


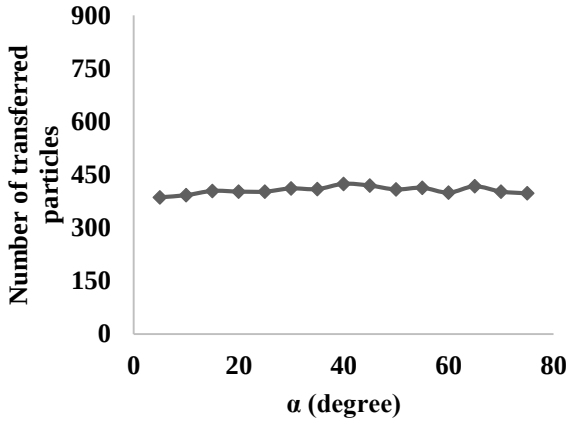


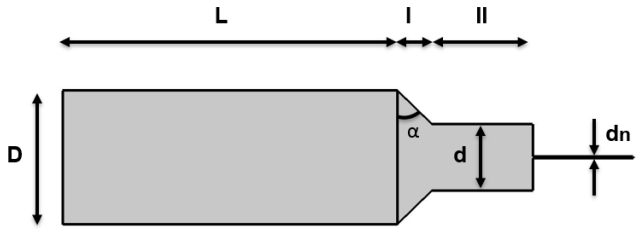
Introduction | Modeling approach | Results | Conclusions

Not all the design parameters were found equally important

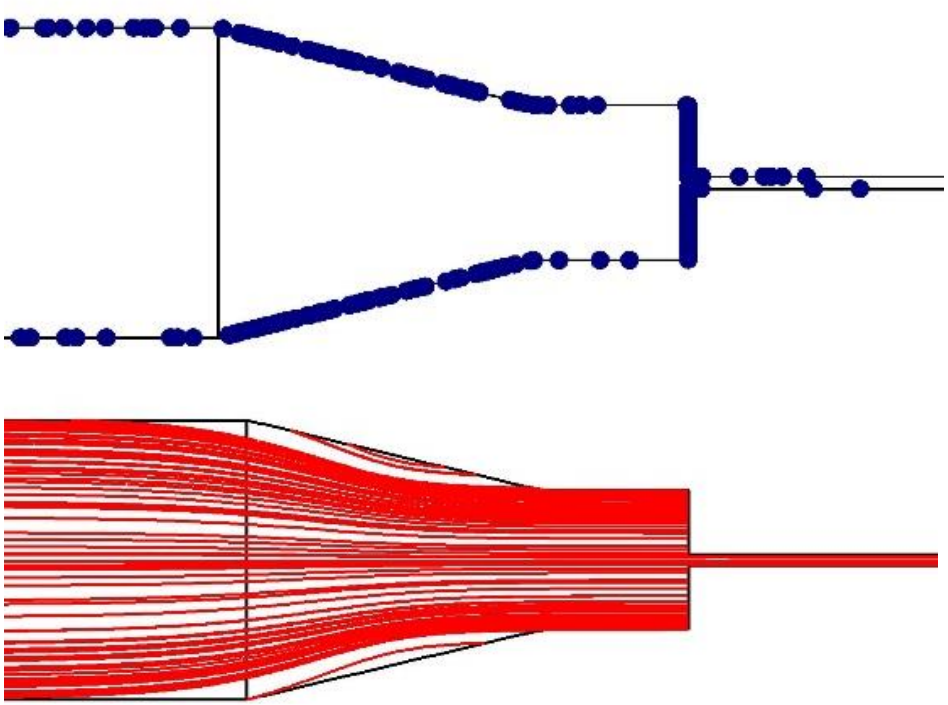








Particles tend to accumulate in areas with less condense streamlines (stagnation area)



Conclusions

- Geometry of commercial syringes is not optimized for microparticle delivery
- Some geometrical parameters in syringe design are more important
- Increased stagnation area increases risk of particle loss

Thank you for your attention

Questions?