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Investigation of the Multiple Side Injections on Hydrodynamics of the Gas-Solids Fluidized Bed Using Radiotracer Based Techniques

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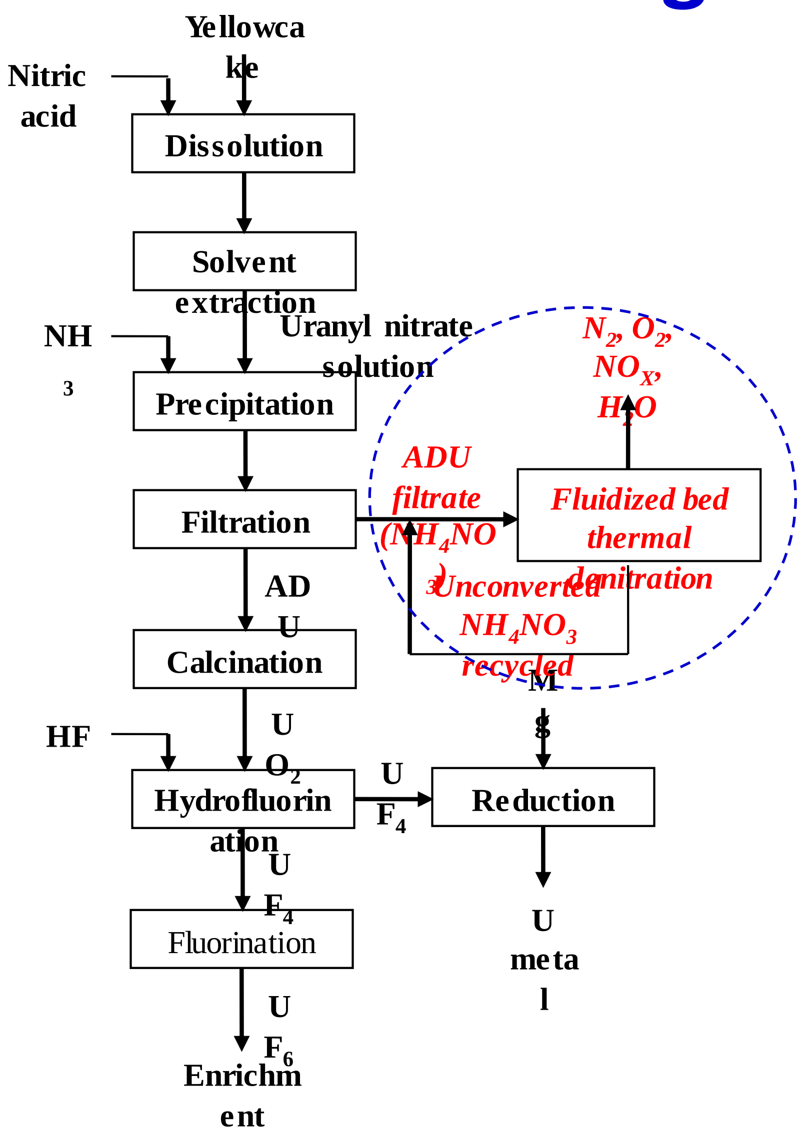
Background



Flow diagram of various conversion processes and fluidized bed thermal denitration scheme

- Nitrate bearing waste streams is produced during processing of various nuclear materials [like ammonium diuranate (ADU) filtrate produces in the processing of natural uranium]

- The ADU filtrate poses disposal problem mainly due to high nitrate content (80 g/l of NH_4NO_3).

- In thermal denitration process NH_4NO_3 decomposes in N_2, O_2 and H_2O.

$$NH_4NO_3 \xrightarrow{>250^0C} N_2 + \frac{1}{2}O_2 + 2H_2O$$

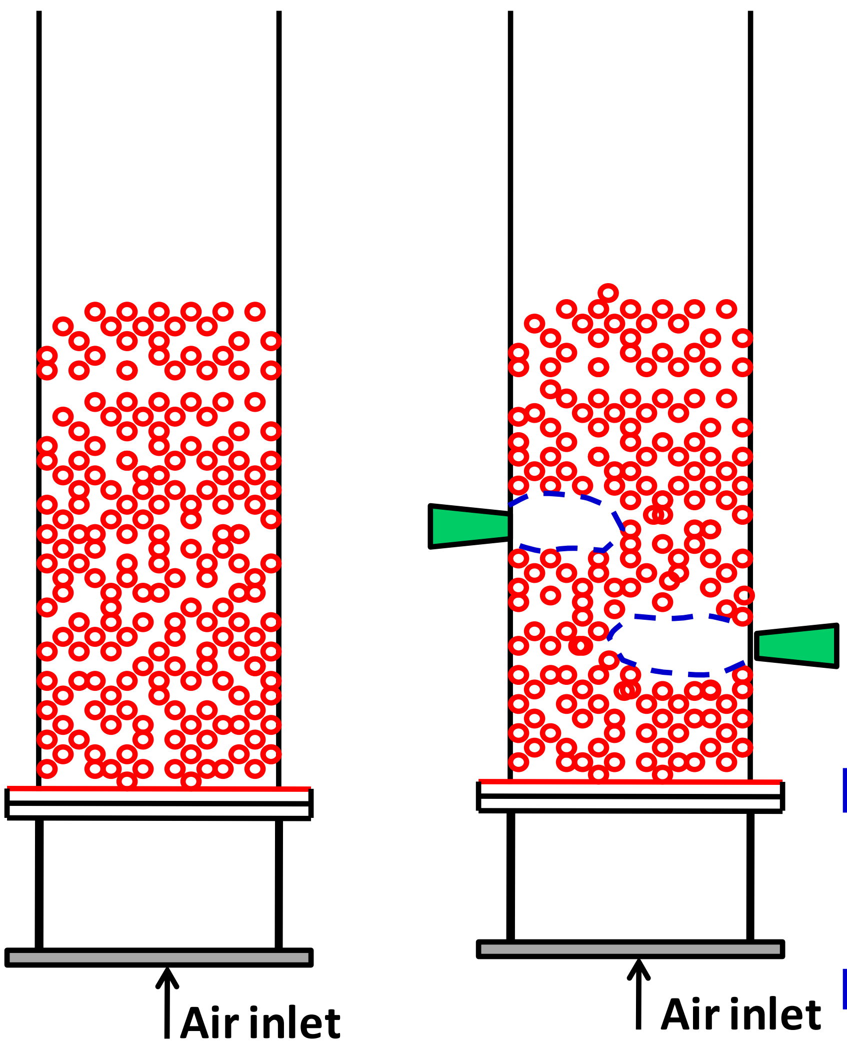
- Thermal denitration is an economical and environmental friendly process.z

Gas –Solid bubbling fluidized bed for Denitration

BARC News Letter, Issue No. 326, 22-29, 2012.

- Current denitration setup is a gas-solids bubbling fluidized bed setup.
- Air is used as a fluidizing medium and silica is used as a solid to maintain the constant temperature in the bed.
- Heat is supplied to the column through induction heater coils.
- Ammonium Nitrate is sprayed through the side nozzles placed at the side walls
- Sprayed NH_4NO_3 interacts with hot solids maintained at a temperature > 250 ^{0}C and decomposes.
- Gases are separated from the top of the column.

Scale-up Issues with Existing System



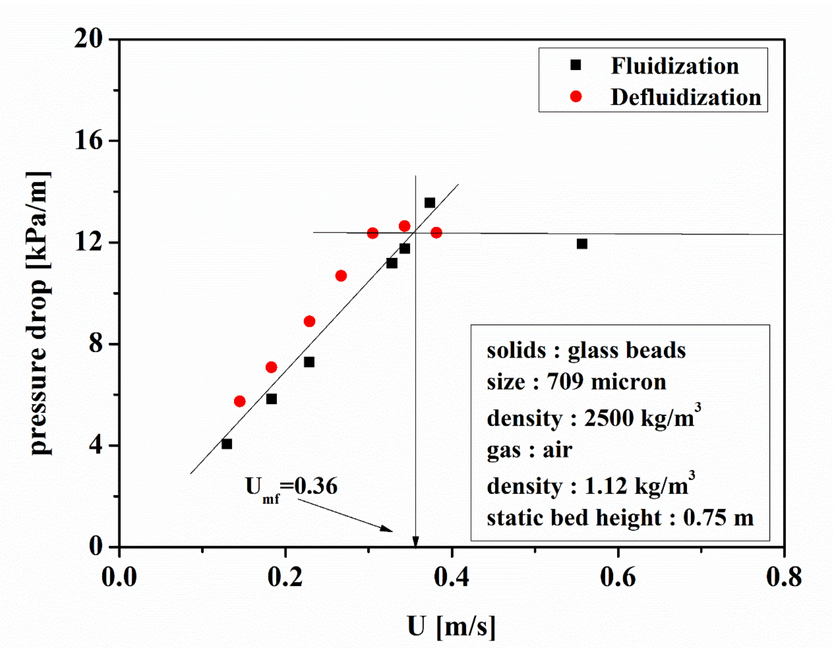
Conventional Bubbling Fluidized bed

Side nozzle sprayed Bubbling Fluidized bed

- NH_4NO_3 sprayed from side nozzles creates extra voids in vicinity of nozzles.
- These extra voids leads to insignificant contact between NH_4NO_3 vapour and heated solids.
- Even at laboratory scale significant amount of NH_4NO_3 escape from system untreated.
- This problem will be more significant at higher scale due to larger number of nozzles.
- For better design and scale-up interaction between sprays vapor and solids need to be understood.
- Effect of nozzles assembly (location and orientation) on performance of system needs to be quantified

Experimental Conditions:
Physical Properties & Parameters

Bed media	Glass beads (group B)
Particle density	2500 kg/m³
Mean particle diameter	709 micron
Volumetric flow	~3000 LPM (U=1.2 m/s)
Nozzle flow rates	80-120 LPM
Bed mass	37 kg
Column diameter	21 cm
Bed height (H)	75 cm
Nozzle operating planes	z = 0.20 m / 0.40 m

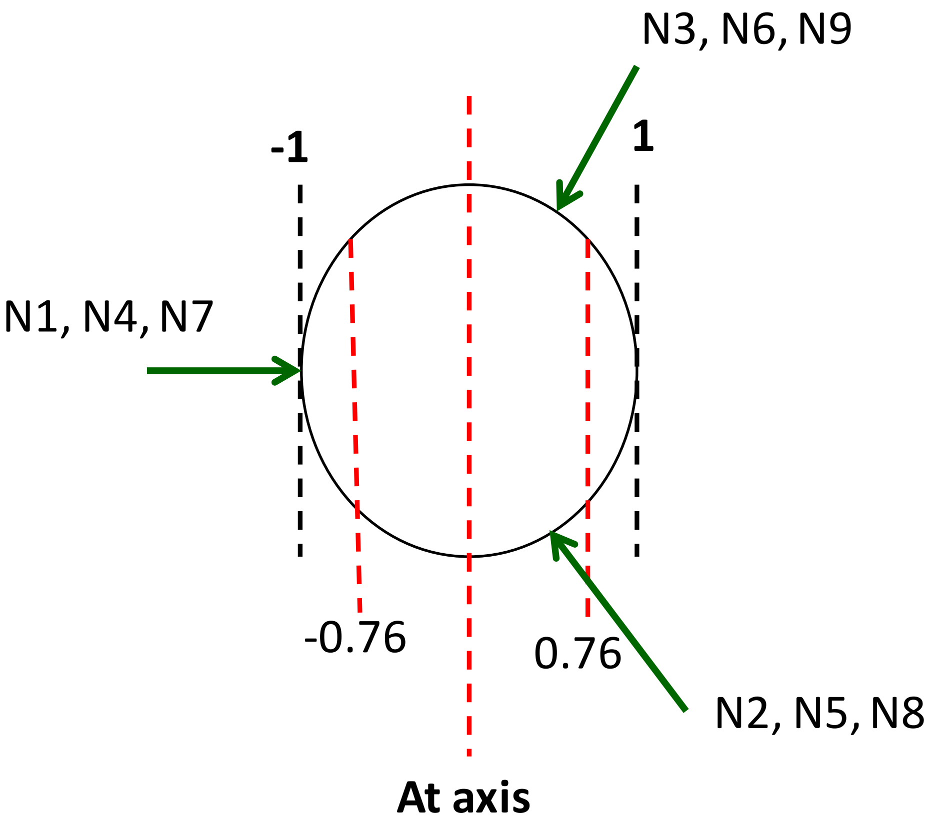


Experimental Conditions

Cases	Description (Operating nozzles)	Nozzle Height (s) (in m)
A	Without Nozzle	-
B	With N1	0.20
C	With N1, N2	0.20, 0.20
D	With N1, N2, N3	0.20, 0.20, 0.20
H	With N1, N2, N4	0.20, 0.20, 0.40
I	With N1, N2, N6	0.20, 0.20, 0.40

B80 mean : investigation is done for case B for nozzle injection flow rate of 80 LPM

Nozzle(s) Configuration and Alignment

Where:
N1---N9: Shows the nozzles locations

- Three nozzles are placed at one axis which are 120^0 apart.
- Distance between two nozzles planes is 20 cm
- Measurements are performed at three radial locations for all the heights to find axial solid distribution at specified locations
- Further, Measurements are performed at four different heights from the bottom of the column to get radial solid distribution with height

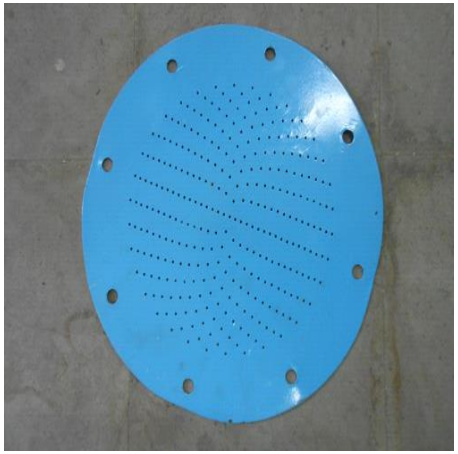
Experimental Set Up for Gamma Ray Densitometry

Column ID : 0.21 m

Column Height : 2.25 m

Nozzle Inlet ID : 12 mm

Nozzle Exit ID : 6 mm



Type : Perforated Plate

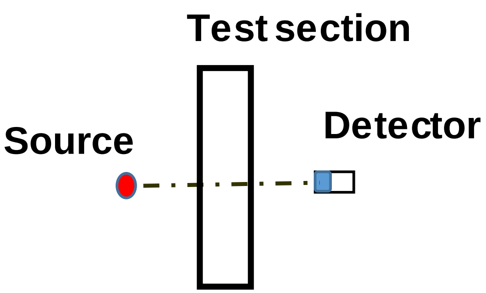
Hole Diameter : 2 mm

Number of Holes : 120

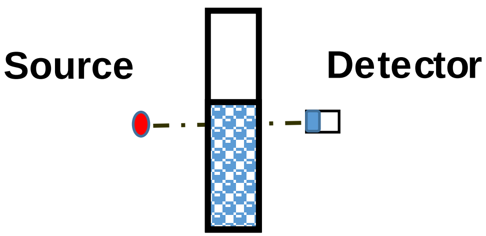
Pitch : 6 mm

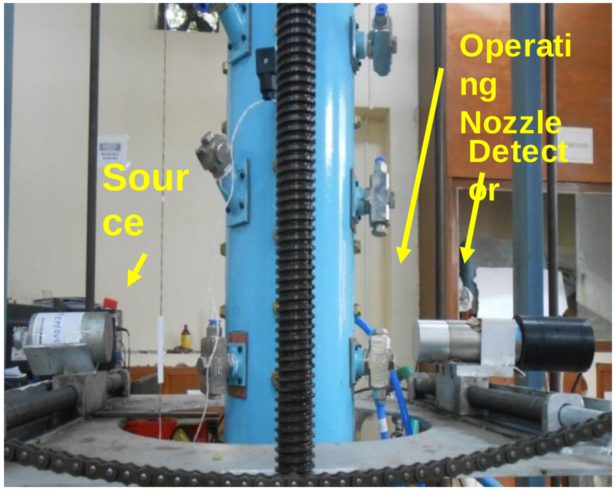
Gamma Ray Densitometry Techniques

to measure phase distribution



$$I = I_0 e^{-\mu_1 L}$$





Gamma Ray Densitometry technique is based on the ***Beer Lambert's Law***

$$I = I_0 \exp(-\mu L)$$

Where I & I_0 are radiation intensity without and with attenuation respectively. It is three steps scanning process

The volume fraction can be calculated using:

$$\boldsymbol{\mu_{eff} = \mu_a \varepsilon_a(x,y) + \mu_s \varepsilon_s(x,y)}$$

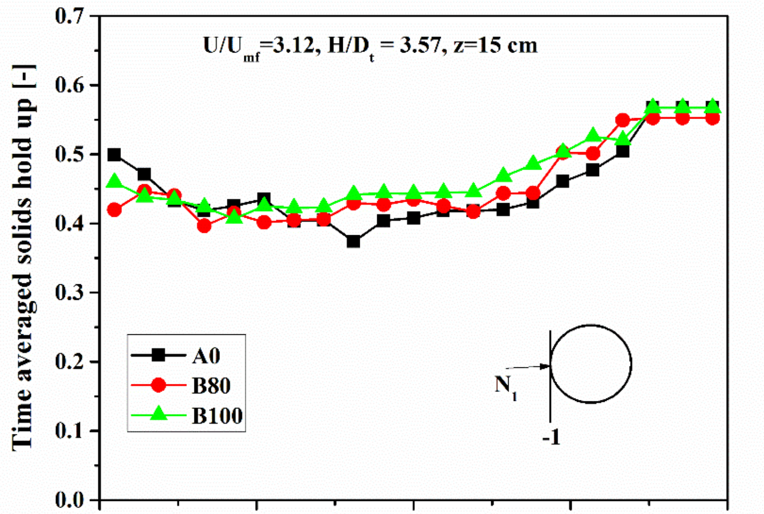
$$\boldsymbol{\varepsilon_a(x,y) + \varepsilon_s(x,y) = 1}$$

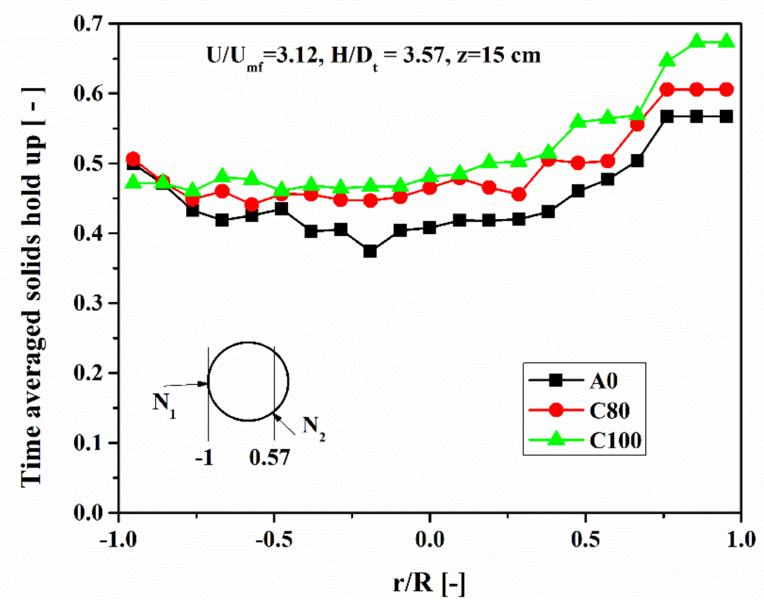
Hardware Used

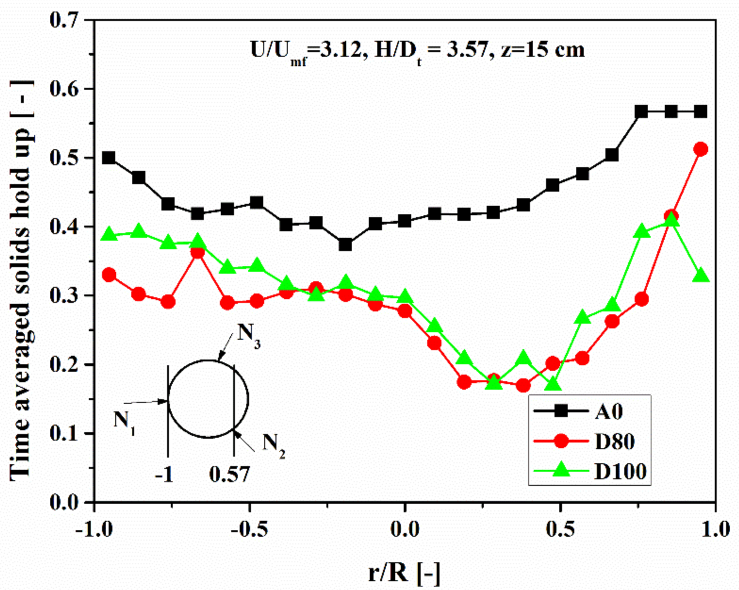
- **Cs – 137 (7 mCi)**
- **NaI (Tl) scintillator detectors with crystal size 2"**

Effect of Number of Nozzles Placed at the Same Plane on Solid Fraction below the Injection Plane (z=15 cm)

U=1.12 m/s



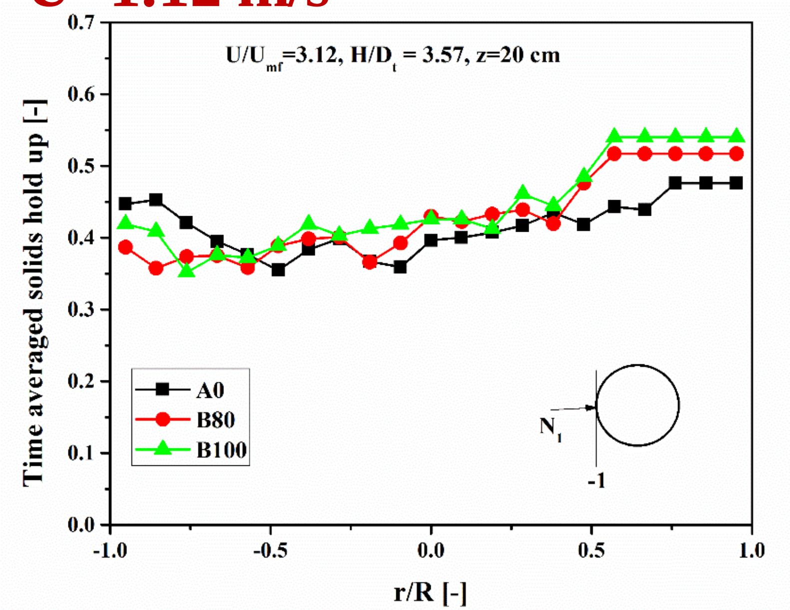


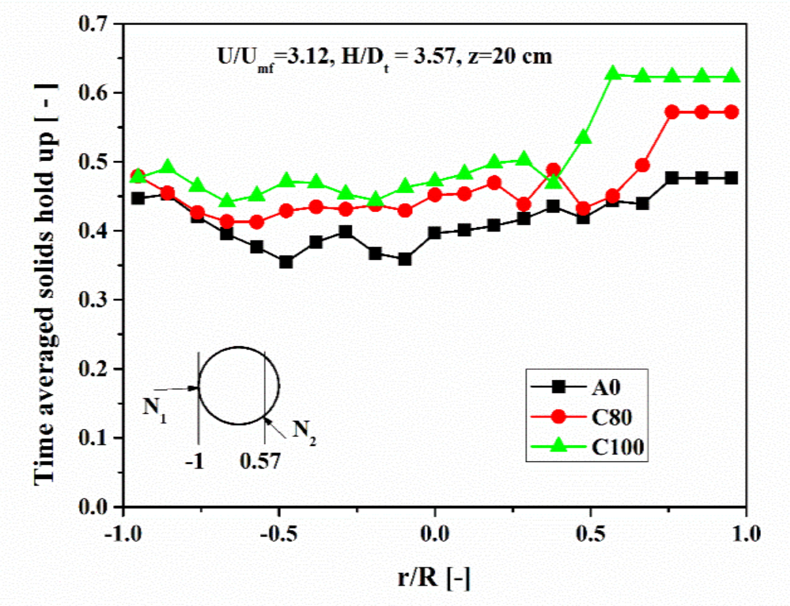


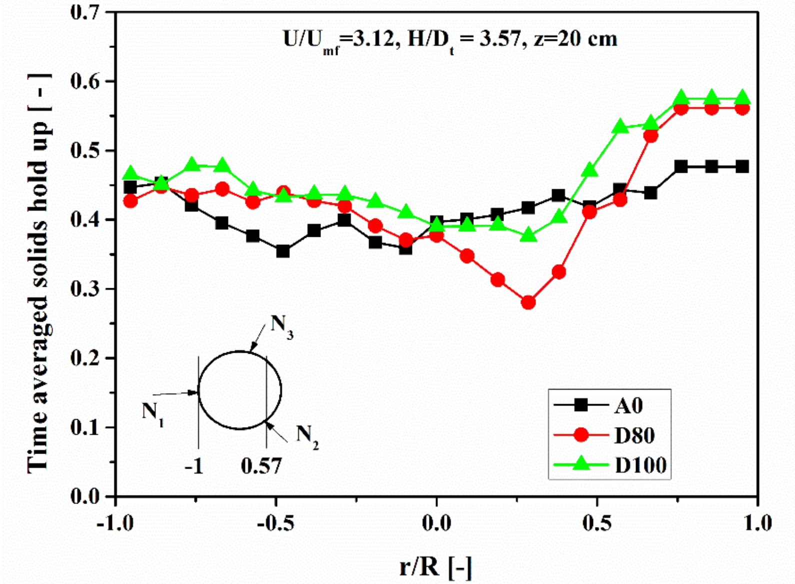
- At the lower injection flow-rate, the interaction between the jetting bubble(s) and fluidized bubble(s) starts below the injection plane
- Solid fraction marginally increase below the nozzle injection plane for two nozzle injection at the same plane
- Solid hold-up below the nozzle plane drastically reduce for three nozzle at the same plane.

Effect of Number of Nozzles Placed at the Same Plane on Solid Fraction at the Injection Plane (z=20 cm)

U=1.12 m/s



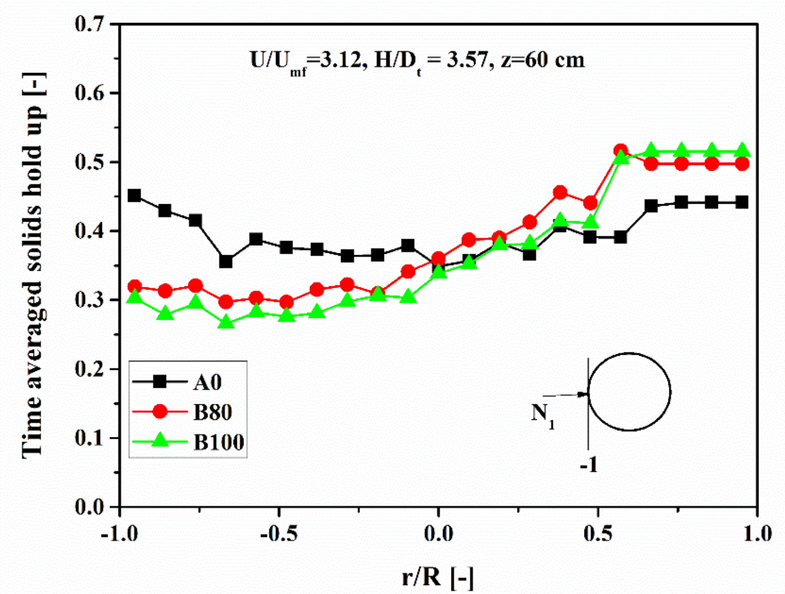


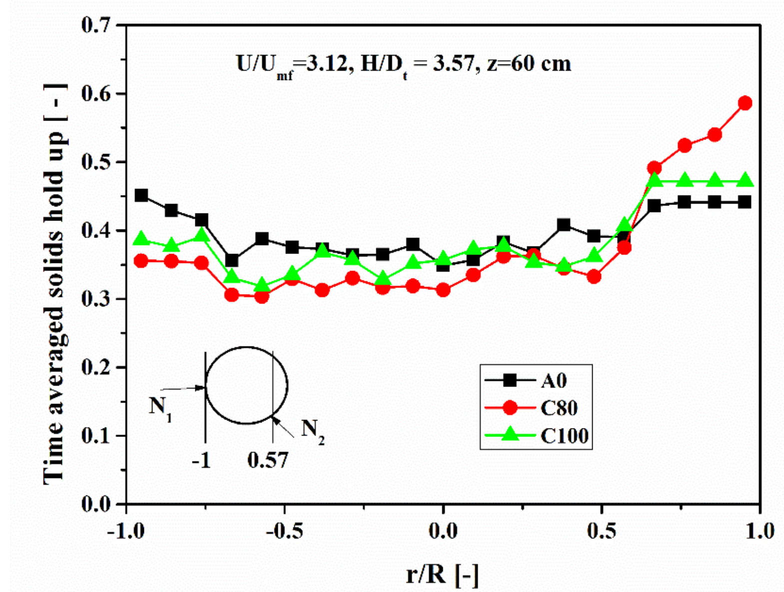


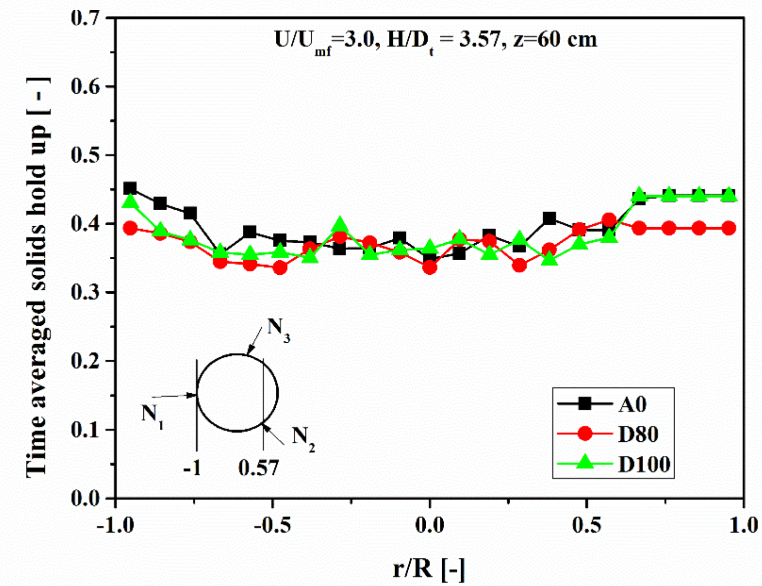
- In all the cases (case B/C/D), increasing the injection flow-rate increases the solids hold up at the injection plane.
- However, at the point of injection solid volume fraction is decreased for all the cases

Effect of Number of Nozzles Placed at the Same Plane on Solid Fraction above the Injection Plane (z=60 cm)

U=1.12 m/s



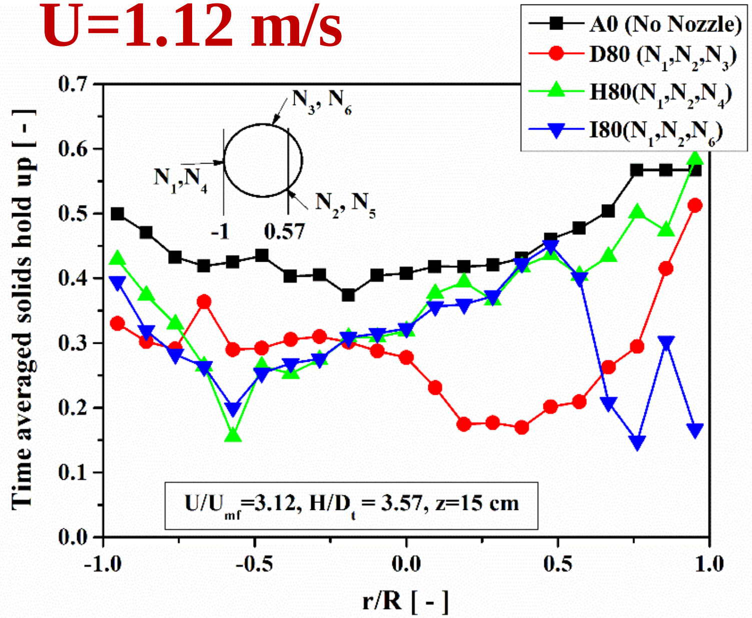


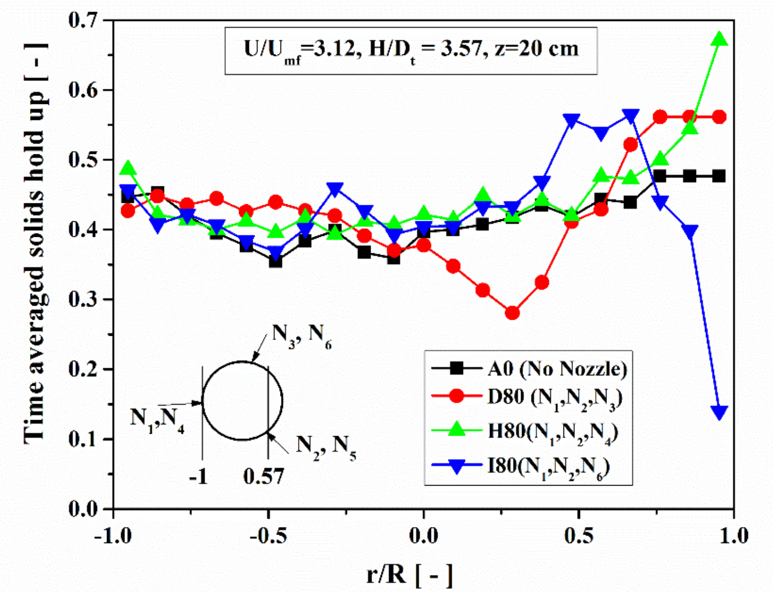


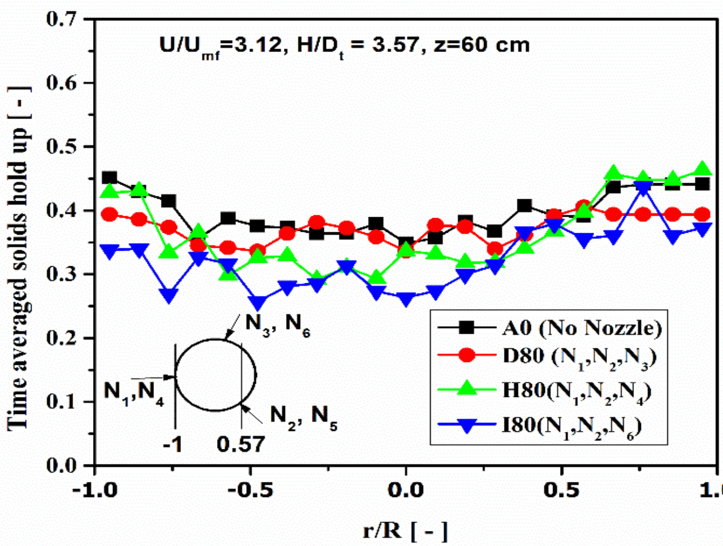
- For single nozzle injection nozzle gas interact with fluidizing bubble at the nozzle injection point and moves upward near the nozzle injection wall .
- For two nozzle injection the interaction occurs near the center of the column
- While for three nozzle the effect of nozzle injection get diminish above the injection plane

Effect of Number of Nozzles Placed at Different Planes on Solid Fraction for Low Nozzle Injection Flowrate

U=1.12 m/s



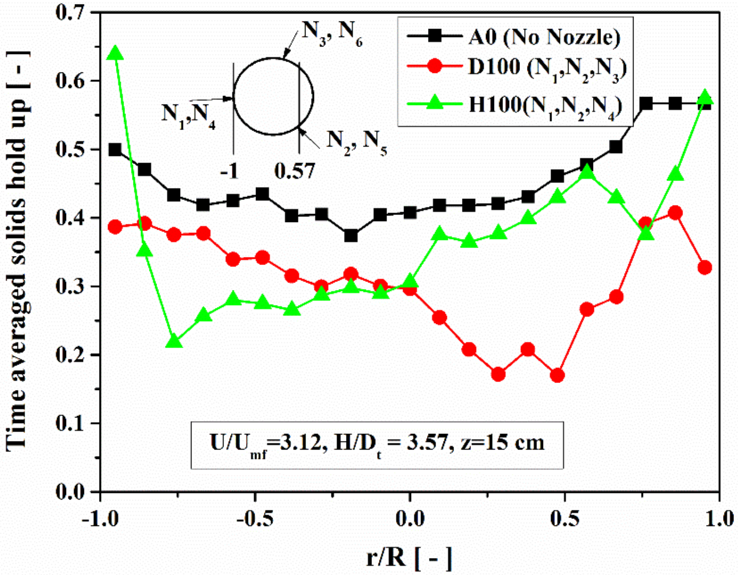


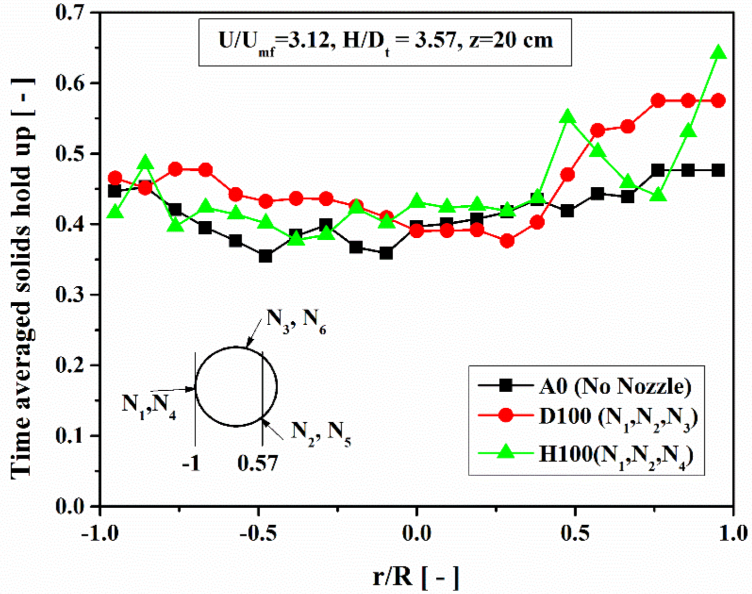


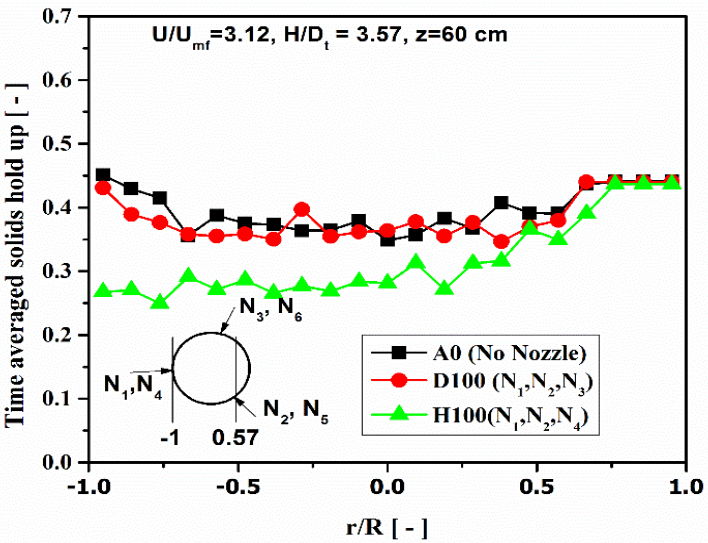
- **The behavior of the bed changes significantly when nozzles are placed at different axial locations.**
- **For low nozzle injection velocity, interaction between nozzle gas and fluidizing bubble take place below the nozzle injection plane for all the cases.**
- **When nozzles are placed at different axial location then at injection plane solid fraction profile becomes more uniform**
- **Nozzle injection gas bypass increases when nozzles are placed at different planes**

Effect of Number of Nozzles Placed at Different Planes on Solid Fraction for High Nozzle Injection Flowrate

U=1.12 m/s







- For high nozzle injection velocity, decrease in solid fraction is increased below the injection plane for all the cases
- When nozzles are placed at different axial location then for high nozzle injection velocity solid fraction increases at injection plane
- Nozzle injection gas bypass increases when nozzles are placed at different planes

Conclusions

- For single nozzle injection solid fraction increases below the injection plane and decreases above the injection plane which means nozzle gas and fluidizing bubble interaction take place above the nozzle injection plane.
- For single nozzle injection phenomena remains same for all the velocities.
- For three nozzles injection interaction between nozzle injection gas and fluidizing bubble occurs below the nozzle injection plane which significantly reduces the solid fraction
- This severely increases the back mixing of the solids
- It was observed that if the two nozzle were working at the different height (z) at same side, the solid fraction near the injection wall was dropped significantly with increasing the injection flow rate.
- The multiple nozzle injection (their location and configurations) have significant impact on the system locally. Hence these parameters must be considered for designing a reactor

Thank you