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Effect of variation in solid bed height on the pressure distribution during gas fluidization of solids

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Abstract

The present work has been to investigate the effect of increase in the static bed hieght of the solids *on the pressure distribution* during *gas fluidization of solids in a stationery* pool of *liquid. The experimentations have been performed on a standardized experimental setup. Results show that increase in the solid bed height also increases the pressure drop across the bed. The pressure distribution along the axis of the fluidized column decreases with the increasing bed height.*

Keywords: Fluidization, Bed height, Pressure distribution, Stationary liquid.

Introduction

Epstein[1] suggested three different types of fluidization modes for Gas- Liquid – Solid fluidization. Those are concurrent, counter current and stationary liquid mode. Numbers of research work have already published in the field of concurrent and counter current fluidization. However, for stationary mode of Gas- Liquid-Solid fluidization research work are scarce. The present work has been undertaken with an objective to find out the effect of variation in the solid bed height over the bed pressure distribution during the fluidization of solids using the gas medium selected as air in the stationary liquid (or liquid with zero velocity). The pressure drops during fluidization within the column have been experimentally measured using manometer at four different heights on the axis of the column for different flow rates. The ranges of experiments are shown in the following table.

Table-1: Experimental range of parameters.

Parameter	Range	Level
Flowrate	0-45 lpm	0, 7.5, 15, 30, 45 lpm
Solid bed height	10-30 cm	10, 20, 30 cm
Liquid height	40-60 cm	40, 50, 60 cm
Solid	3	Coal, Peanut, Stone
Size of Material	3	2, 4, 6 mm
Liquid	3	Water, Kerosene, Turpentine
Height of pressure tapping	4	0, 25, 50, 75 cm

Related work: In year 1961, Davidson[2] presented a theory named as Isolated Bubble Model for the pressure distribution in fluidized beds. As per this model the pressure distribution in fludized bed is unaffected by the motions of the particles in the fluidized bed. In the year 1981, Maruyama[3] and co-workers defined the critical velocity of gas in a bubble column by measuring the pressure distribution. They mentioned in their work that the pressure gradient can be expressed as the total sum of gravitational, acceleration and frictional pressure drop for two phase flow. In 1989, Fan[4] published a standard reference book in the feild of fluidization having title Gas-Liquid-Solid Fluidization Engineering. According to him the axial pressure distribution has linear behaviour in fluidized bed and freeboard region above the bed. Further, he also written that the solid bed height in the fluidized can also be defined using the pressure measurement. For liquid solid pressure distribution Fan given a correlation as following

$$\frac{dp}{dz} = (1 - \varepsilon_l)(\rho_s - \rho_l)$$

Above equation shows the linear relationship in the fluidized bed region. According to Fan[4] the expanded bed height can also be determined by the intersection of a linear pressure profiles in the freeboard region and fluidized bed region. In the year 2003, Naoko Ellis[5] shown in his research work that prediction of the expanded fluidized bed height is possible using axial pressure distribution. In the same year 2003, Yang[6] published the Handbook of Fluidization titled as "Handbook of Fluidization and Fluid Particle System" in which he quoted about the Davidson model and interpreted further as the installation of the baffles in the fluidized bed can significantly affect the pressure distribution in the fluidized bed. He also described the technique for measuring the pressure distribution along the bed by multiple pressure sensors on the column wall. Yang[6] had given the description for mounting the pressure taping on the wall of the fluidization column. In the year 2005, Cui[7] conducted study on the Hydrodynamics of the bubble column at higher pressure using direct numerical simulation technique. He conducted three-dimensional simulation study for the propagation of acoustic standing waves between two transducers in square shaped column under the presence of water. He found that due to the presence of bubble in the fluidized bed the uniform pressure field can be replaced by axially symmetric pressure distribution. This symmetric pressure distribution can be identified by the concentric patterns of the acoustic waves in the cross-sectional area. As per Yang[8] et alpressure distribution in the liquid solid suspension is directly affected by the fluid motion and solid concentration. Yang[8] also mentioned that in the year 1992, Raghunatha and co-workers also performed the similar research work. Kumar[9]and researchers worked on the pressure analysis for spherical type food material and on the terminal velocity[10]. In the year 2015, Heino[11] written in his master's thesis that axial pressure distribution has linear behavior in the fluidized bed. The height of the bed can also be defined using the pressure measurements. Kumar[12]and co-workers found the effect of material size on the pressure drop during gas fluidization of solids in stationary liquid pool.

Methodology

Experimental set-up: Schemetic of the experimental setup is shown in the following figure.

A vertical cylindrical column of acrylic having 50 mm internal diameter is used as a fluidized column. The bottom end of the column is connected with the calming section using flanges. A sieve of 2 mm stainless steel is sandwiched between the flanges. The stainless steel sieve is used for supporting the solids of fluidized column. To restrict the sagging of the stainless steel sieve another course sized g. i. sieve having 2 mm thickness is provided for the additional support. The calming section consists of the 10 mm steel balls for uniform generation of the bubble swarms. The calming section is connected with the vertical type non-return valve which ensures no backward motion of the liquid present in the fluidizing column.The air is entered into the column from the bottom of the non return valve. Rotameter is used for the the measurement of the air flowrate in the column. The pressure reading have been taken in the different manometers for the different operating conditions. The process of experimentation has been standardised[13] by using theory of repeatability and reproducibility.

Results and discussion

The experimentations have been performed for different system variables. The results found have been presented in the following graph. The analysis of the graphs clearly indicate that increase in the solid bed height also increases the pressure drop across the column. The reason behind the increase in pressure drop for increasing solid bed height is that increases in the solid bed height increase the loading of the solids in the bed which requires additional air for fluidizing the material present in the column which finally results increase in the pressure drop across the column. Further, with increase in axial height the pressure decreases for all the combination of the system variables. Further, pressure decreases with respect to increase in the height indirection of fluidization. As the fluidizing condition establishes in the system the material present within the bed with increasing be height decreases which ultimately reduces the number of solid particles present in the column at a particular time. The reduction in the count of the solid materials opens several alternative paths for the gas to flow from the solids which ultimately reduces in the pressure along the increasing height of the fluidized column.

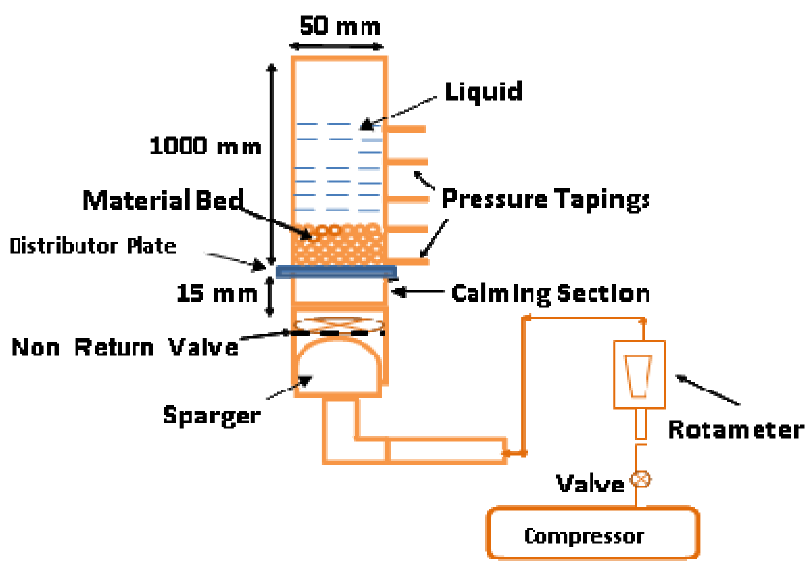

Figure-1: Schematic diagram of the experimental set-up.

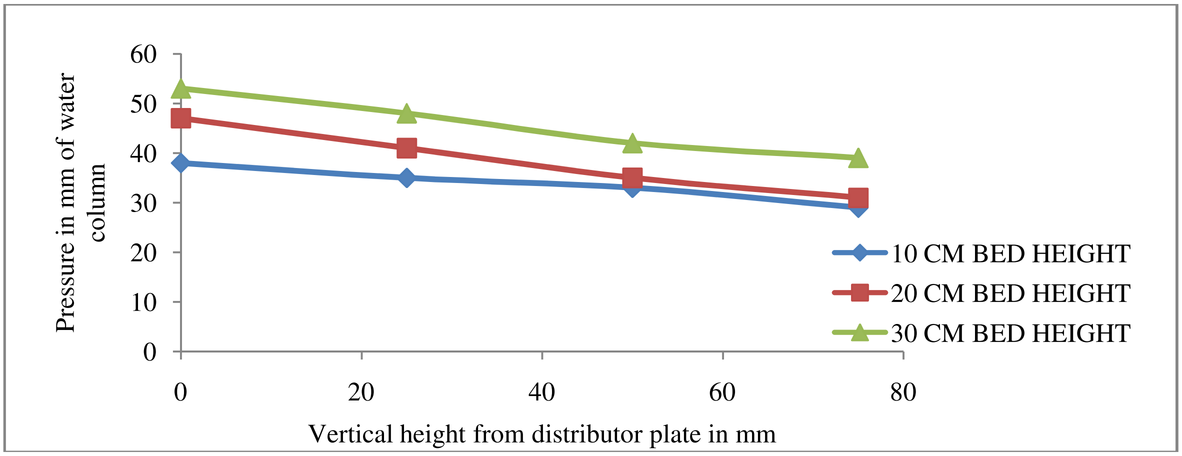

Figure-2: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid - water, d_p= 2 mm, h_l= 0.4 m, Q=7.5 lpm].

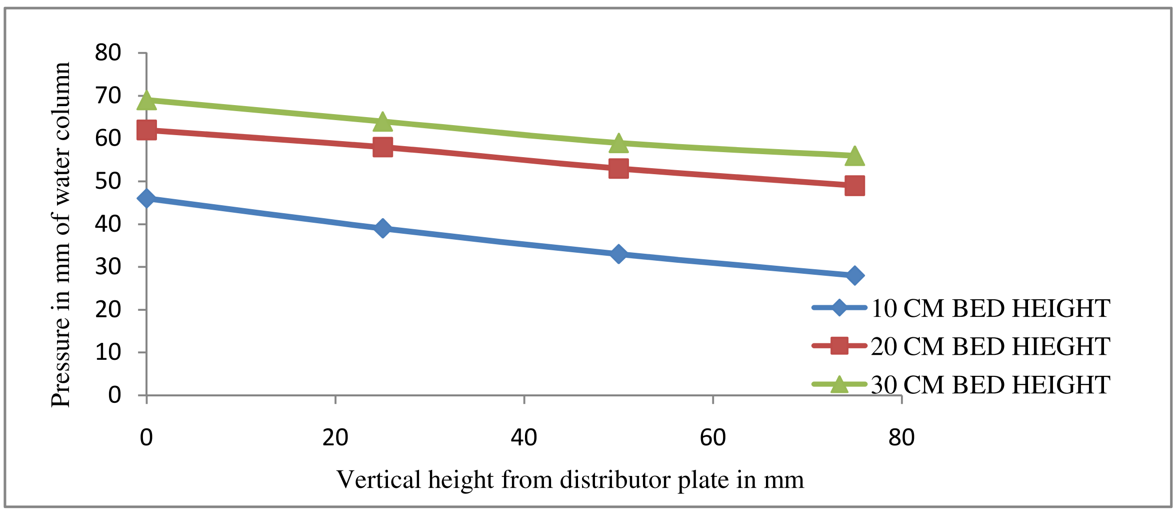

Figure-3: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid - water, d_p= 2 mm, h_l= 0.4 m, Q=30 lpm]

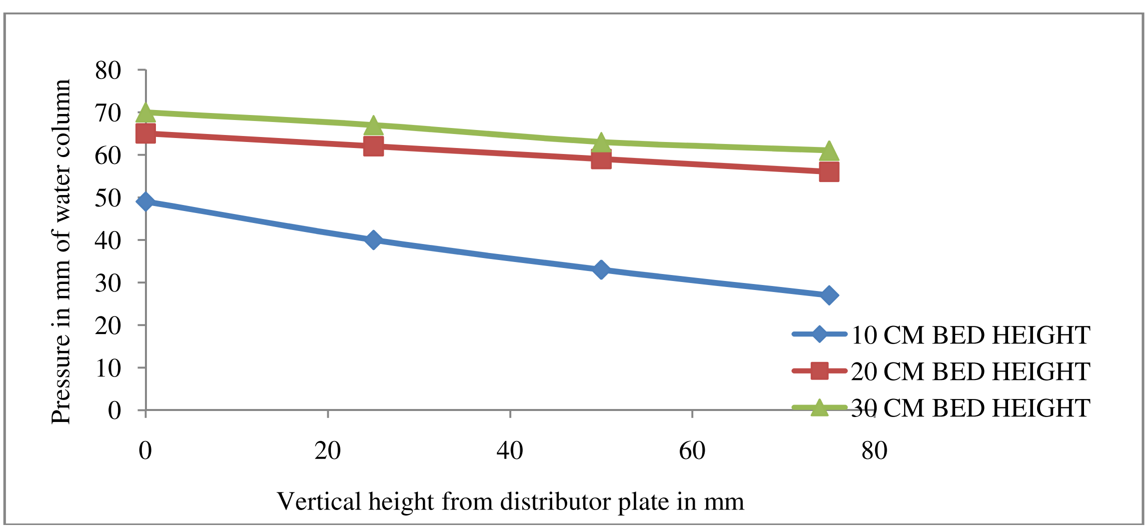

Figure-4: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid - water, d_p= 2 mm, h_l= 0.4 m, Q=45 lpm].

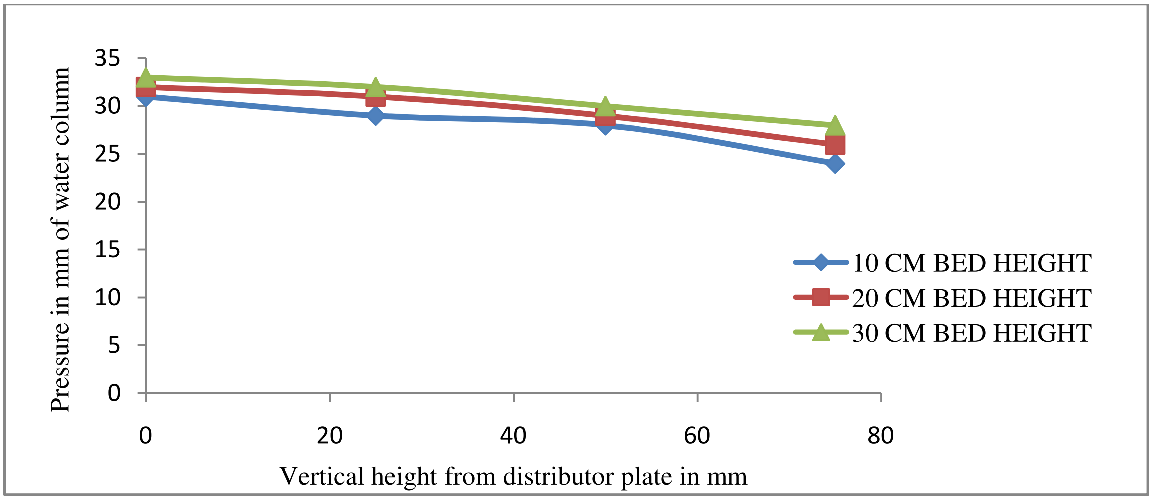

Figure-5: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid turpentine, d_p= 2 mm, h_l= 0.4 m, Q=7.5 lpm].

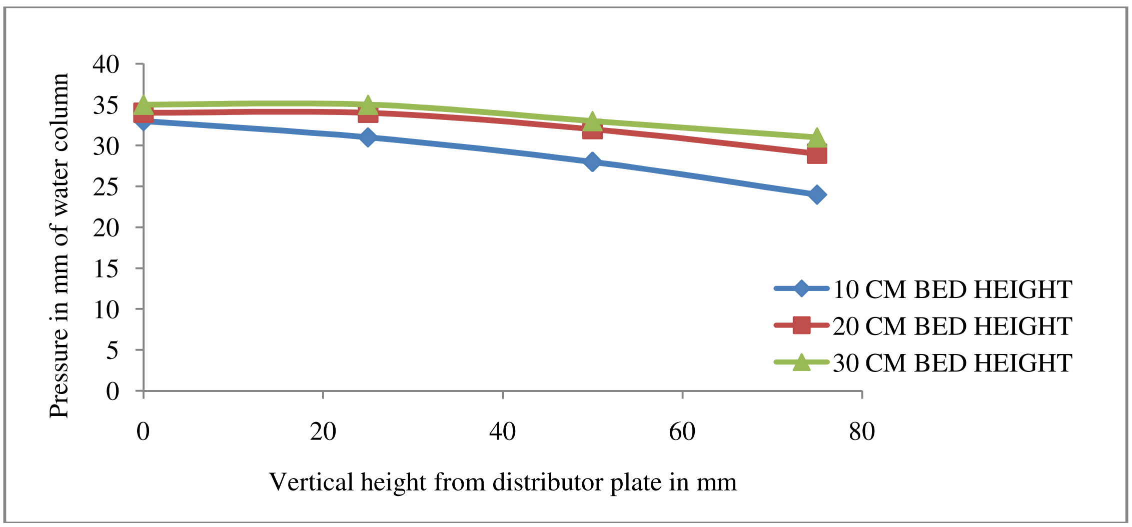

Figure-6: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid turpentine, d_p= 2 mm, h_l= 0.4 m, Q=15 lpm]

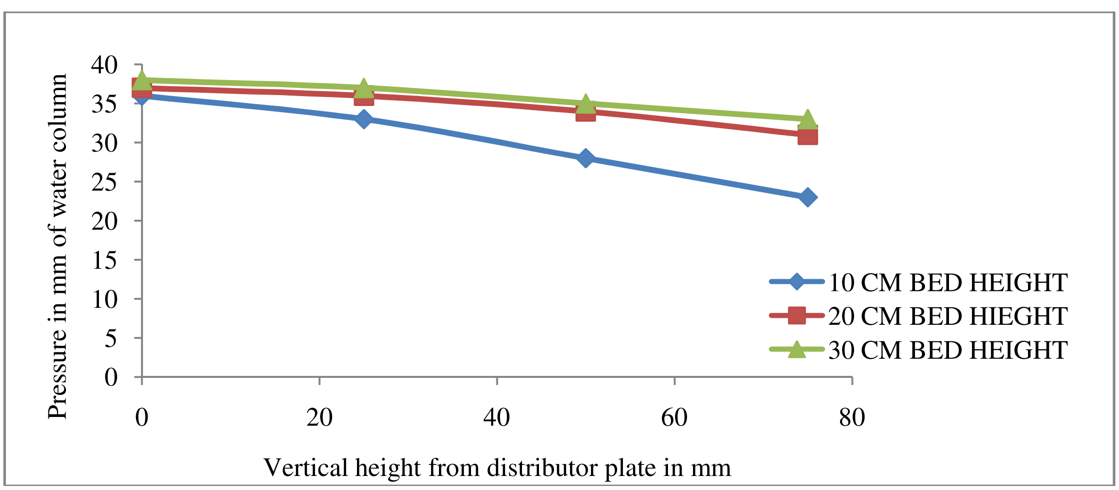

Figure-7: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid turpentine, d_p= 2 mm, h_l= 0.4 m, Q=30 lpm]

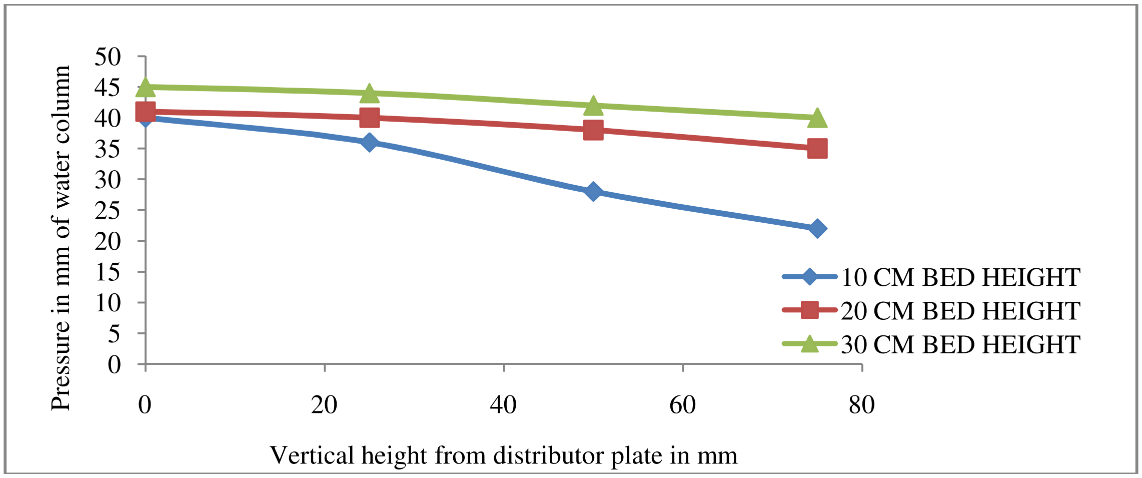

Figure-8: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid turpentine, d_p= 2 mm, h_l= 0.4 m, Q=45 lpm]

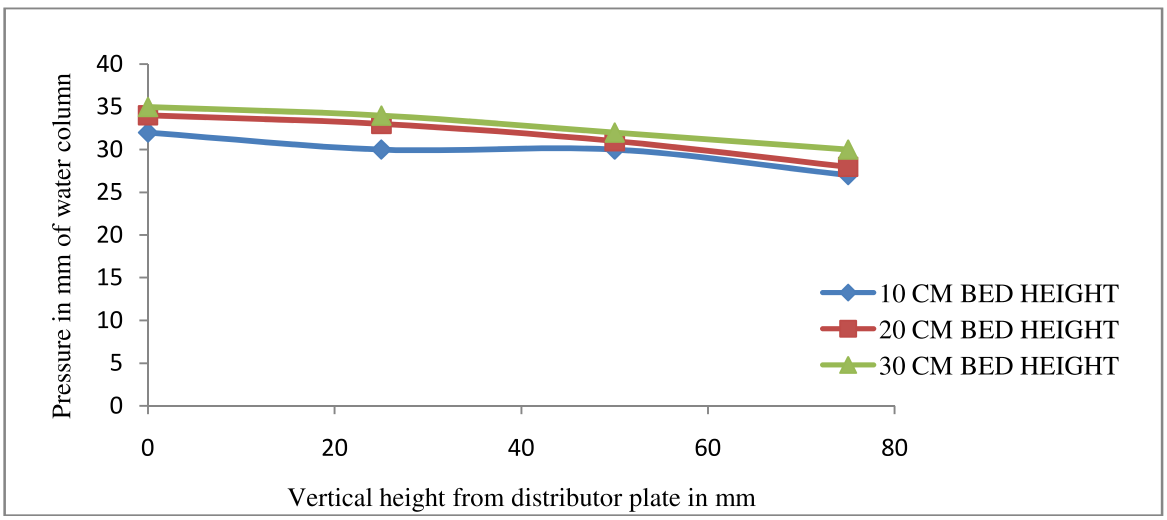

Figure-9: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid – kerosene, d_p= 2 mm, h_l= 0.4 m, Q=7.5 lpm]

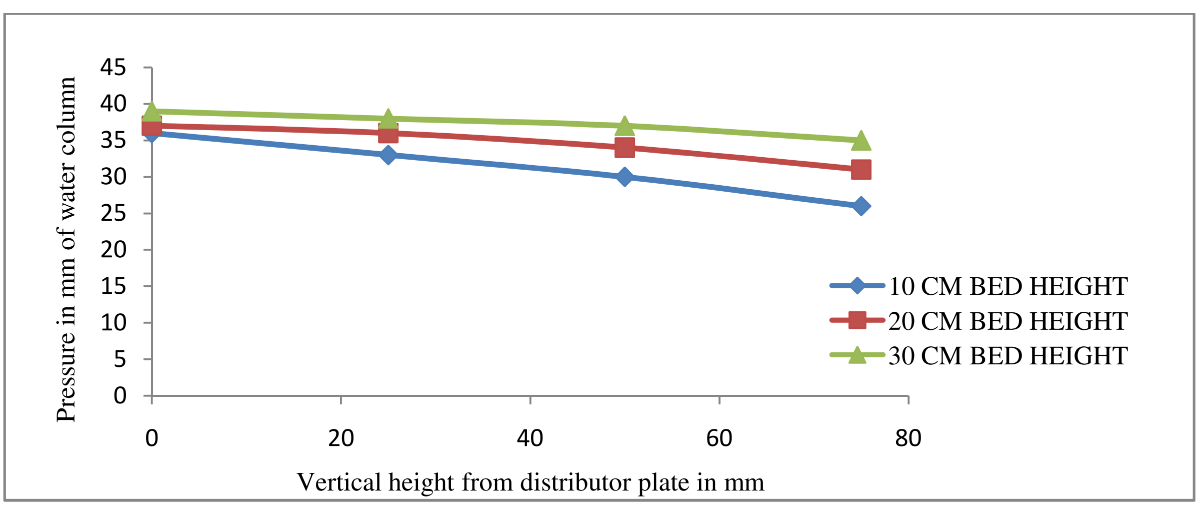

Figure-10: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid – kerosene, d_p= 2 mm, h_l= 0.4 m, Q=15 lpm]

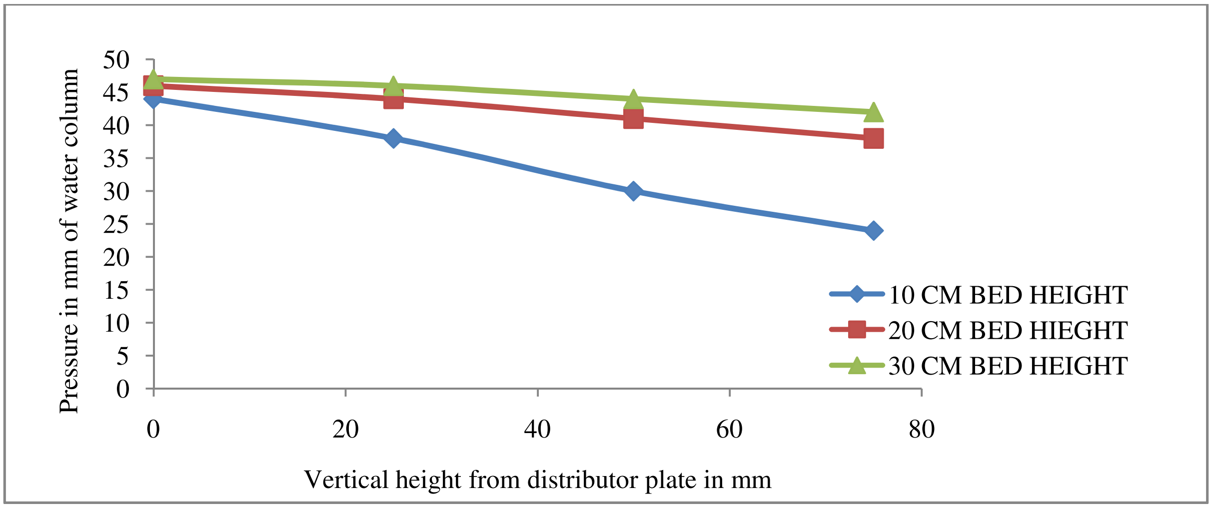

Figure-11: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid – kerosene, d_p= 2 mm, h_l= 0.4 m, Q=30 lpm]

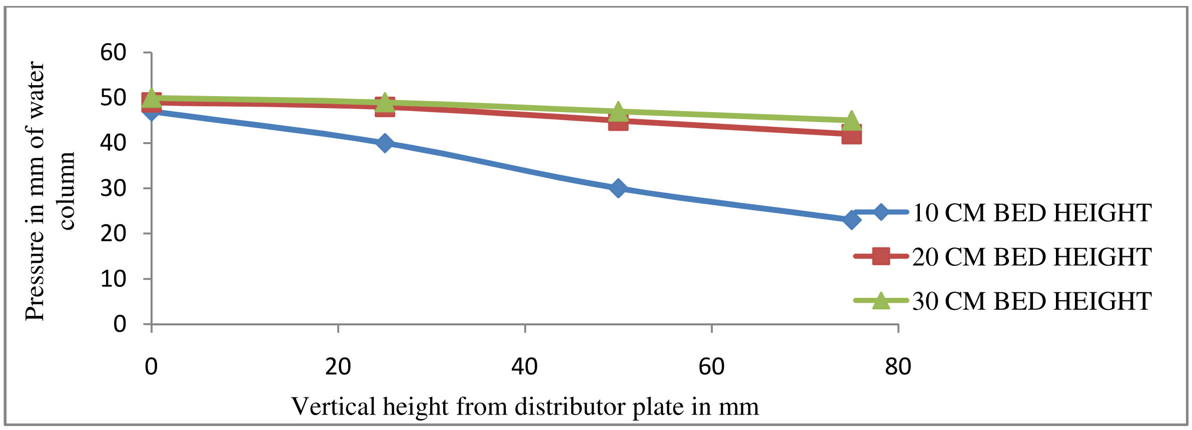

Figure-12: Variation of pressure distribution with vertical height for different solid bed heights [solid - coal, liquid – kerosene, d_p= 2 mm, h_l= 0.4 m, Q=45 lpm]

Conclusion

The numerous experiments have been performed for relating the pressure distribution with solid bed height in static position. The final outcome of the present work shows that changestatic bed height of the solids is directly proportional to the pressure drop across the column and pressure distribution reduces with increasing bed height in the vertical direction. For the same material, size, flow rate and initial static bed height of solids the pressure drop for the water is maximum, relatively lesser for kerosene and minimum for the turpentine.

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