Fluidized Bed Gasifier Design

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Abstract: A "fluidized bed reactor" (FBR) is a kind of reactor system that may be utilized to conduct a number of chemical processes with multiple phases. A fluid is pumped thru a solid concentrated material in the reactor (generally a catalyst probably formed as small spheres) at sufficiently high speeds to suspend substance and allow it to function as a fluid. The paper discusses aboutfluidized bed in waste water treatment.Application of fluidized bed reactor in treatment of waste such as municipal waste water in order to treat sewage, landfill leachate in order to remove COD, ammonia which affects environments and rendering waste along with proper analysis and results is also discussed. Importance of primary clarifiers and secondary clarifiers are presented in the paper.

Keywords: Bio-reactor, fluidized bed, wastewater, landfill leachate, rendering waste

1. INTRODUCTION:

In "fluidized bed gasifiers",biomass is poured into chemically inactive bedmade of fluidized substances such as coal, char etc. Fuel is subjectedwithin fluidized system above the bed or withinthe bed, in reference tofuel size and density in addition to bed velocities effects[1]. Undersimple operation, the media within the bedis maintained between 551°C-1001 °C temperature range.On subjecting fuel at this temperature range, reactions of dryingfollowed by pyrolysis occurfastly, exhibiting fuel gaseous portion at lower temperatures. The remaining char gets oxidizedin bed for providing a source of heat to dry and devolatize reactions. "Fluidized bed gasifiers" are better as compared to the dense phase reactors as more heat is produced by them in less duration due to excoriation phenomenon between biomass and chemically inactive materials, under high (810–1005 ºC) temperature of bed.Therefore, gasifier functions asbed of particles of sand that is hot which is further agitated ccontinuously by air. Distribution of air is done by nozzles installed within the bed bottom[2].

Feedstock particles are suspended by the "fluidized bed gasifiers" in a gas that is rich in oxygen thereby making the resultant bed to perform as fluid within the gasifier.These gasifiers involve back-mixing, and efficiently mix feed coal particles with coal particles already undergoing gasification[3].

Design configurations and ash conditions differ in these gasifiers for improvement of char utilization. In reference to fluidity degree and height of bed, these gassifiers are also addressed as"circulating fluidized bed". Fluidized bed gasifier contains vertical, cylindrical, refractory-lined vessels and bottom ash cooling systems[4].

Fine dry coal (<9 mm) is incorporated at lower portion of gasifier as well as at fluidized utilizing oxidant and steam reactors. Heat & mass transfer is promoted by proper mixing of oxidant with feed.

The duration of residencewithinthe gasifier is explicitly inorder of 10-100 sec. but can exceed if the feed experiences high rate of heating when subjected to the gasifier.

The problems in these beds is the differential ashcharactertics in order to mix feed of coal in a proper way thereby maintaining same characteristics in a well possible way.

Steam along with gas are utilzed in these reactors in an average amount during gasification. Further, it is operated at atmospheric pressure, thereby usually suitable for small volumes.

The two major types forthese gasifier technology are "High Temperature Winkler (HTW)" and "Kellogg Rust Westinghouse” gasifiers. These technologies are yet not been applicable on large scale for number of reasons, that involve lower volume throughput, higher operation rate, lowerconversion of carbon, larger charrecycling, and agglomeration problems of ash[5].

The simple design of singlefluidized bedsenables them very attractive for gasificationon biomass. The gases exhibited through fluidized bed gasifier vary majorly in reference to several parameters. Fuel moisture, bed temperature, bed depth, gasification rate, bed particle size, char re-injection, air temperature and location of fuel inlet allaffect the gas composition[6].

In the presence of oxygen, some part of solid C andalmost all hydrocarbon vapours are oxidised. Moreover, solid particles are removed and carbon particles that are not burned are sent back to the bed which is further oxidized thereby reducing the temperature of the gas to a desired level. Biomass pyrolysis is very fast and initiates at the same temperature at which the temperature of the bed is maintained.

The procedure of fluidized bed is different from all biomass gasifiers in terms of capability and moisture content along with ash content.

The fluidized bed gasifier has an air distribution plate and has two functions. It serves as a support to the bed material and also has nozzles or air caps that allow air to flow into the reactor. Below the air distribution plate is the plenum zone where initial combustion is performed for gasifier start-up purposes[7]. The by-products of combustion flow through the air distribution plate and into the gasifier, heating up the bed material and the reactor walls until a certain temperature is reached. Fuel feeding will commence once the required temperature is reached and the initial combustion process is halted.

Fluidized bed gasifier is more flexible in the selection of fuel type. It can gasify various types of biomass without much difficulty and has high carbon conversion rates as well as high heat transfer rates which enable this system to handle a larger quantity and lower quality of fuels. This gasifier handles smaller fuel particle size as compared to the fixed bed gasifier.

In a fluidized bed gasifier, the hydrodynamic phenomena cause turbulent mixing in which there is a consistent mixture of new particles blended with the older, partially and fully gasified particles. The turbulent mixing also enhances uniform temperatures throughout the bed[8].

Due to their ability to accomplish high heat and mass transfer rates, fluidized bed gasifiers are considered promising for biomass thermochemical conversion in large scale applications. Such processes are leading to a high conversion rate and more tolerance towards the feedstock feeding when compared with the fixed bed[9]. Fluidization is a process similar to liquefaction through which solid particles in a bed are transformed into a fluid-like state through suspension in a gas or liquid. Fluidization is used in a wide range of applications including pyrolysis, gasification and combustion of a wide range of feedstocks including biomass.

In gasification, the efficiency of fluidized bed gasifiers is approximately five times thanthat of the fixed bed gasifiers. As a result of high mixing rates, in contrast to fixed bed gasifiers, there are no different reaction zones in a fluidised bed gasifier[10]. Also, fluidized beds have been confirmed to be among the most appropriate approaches for thermal conversion of different kinds of biomass fuel because it provides a sufficient heat and mass transfer for the reactants. There are three types of fluidised bed gasifier which are classified as follows.

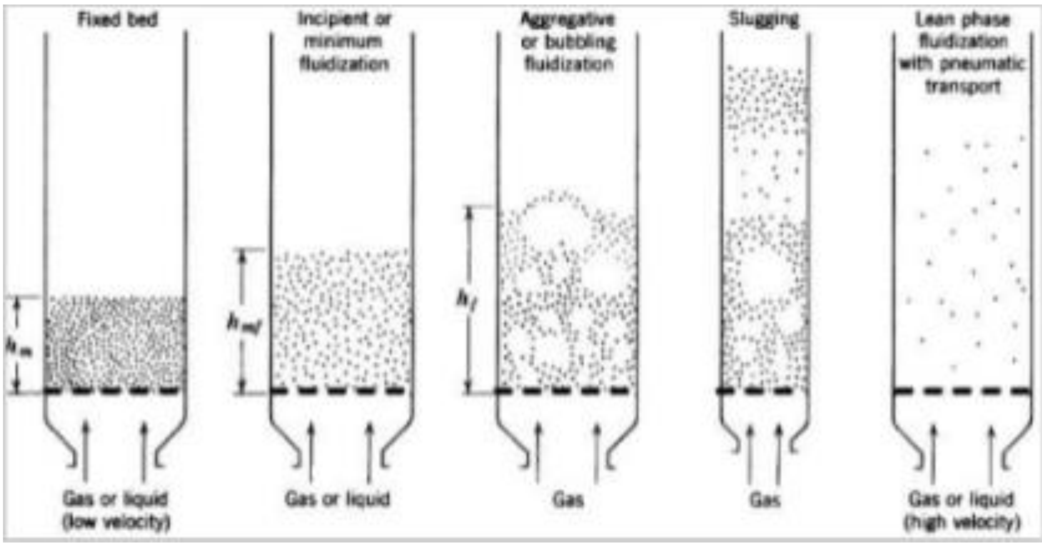

Fig.1.Mechanism of Fluidized Bed Reactor

1. Applications of fluidized bed reactor:

a) Landfill Lechate:

Break down of "organic waste" by group of bacteria forms "landfill leachate" that are further mixed with water leading to production of increased concentrated solution of COD, and NH3 as well as other pollutants[6], [11]–[13].Due to its toxic nature, the effective treatment of "landfill leachate" is of great importance. Increased concentrations of COD, NH3, and air pollutants, found in the leachate, along with the other contaminants, will severely contribute to global warming if not treated appropriately and removed.Additionally, leachate's low C:N makes treatment challenging by biological process. As discharge limit increases, traditional biological treatment combines with the chemicals as well as physical methods might no longer be sufficiently effective forleachate treatment from landfill[14].

Besidesbeing used as a way of treating "municipal waste water (MWW)", the fluidized bed bioreactor is effective in treatment of leachate from landfill. The incorporation of aerobic versus anaerobic environments into single application makes it an acceptable candidate for achieving higher care levels.The fluidized bed system's physical function was the same as Municipal waste water treatment process[15]. In the accelerated fluidization process, the anaerobic riser worked and aerobic bummer operated under the standard regime. The fluidized bed was not used with particle diffusion for leachate therapy.The pilot-scale reactor was checked for leachate at different accelerations and related “High retention times (HRTs)”. Table 1 displays use of tripleflow rates along with their loading amounts. Table 2 displays quality of influent and effluent in leachate.

Table 1: Operating Conditions of the Fluidized Bed Reactor

Parameter	**Column**	**Phase I**	**Phase II**	**Phase III**
Influent (L-d^{-1})	-	650	720	864
Avg. OLR [kg(COD)-(m^3.d)$^{-1}$]	-	1.9	2.15	2.6

EBCT (d)	Aerobic	0.43	0.38	0.32
	Anoxic	0.12	0.11	0.09
HRT (d)	Aerobic	0.89	0.81	0.67
	Anoxic	0.27	0.25	0.21
SRT (d)	Aerobic	26	21	18
	Anoxic	18	17	13

Table 2: Quality of influent-effluent in leachate

Parameter	**Influent**	**Effluent**		
		Phase I	**Phase II**	**Phase III**
SCOD	1022	145	155	247
TCOD	1260	199	200	305
NH_4-N	364	35.9	36.5	55.7
VSS	165	36	36.5	42
TP	6.1	2	2	1.6
NO_3-N	3.2	59	61.1	61.2

It is observed that fluidized bed reactor showed very low yields. For phase ranging from I to III, the yield of 0.15, 0.17 and 0.19 "g(VSS)•g(COD)–1" respectively; that is same as obtained wherein "municipal waste water" was treated. In the second phase, it is observed that the COD, N, and P was removed efficiently with removal efficiencies of 90%, 85% and 80% respectively. Figure 2 is diagrammatic representation of landfill leachate. The diagram represents applications of treated landfill leachate in various sectors such as agriculture and environment thereby reducing toxicity produced from such effluents.

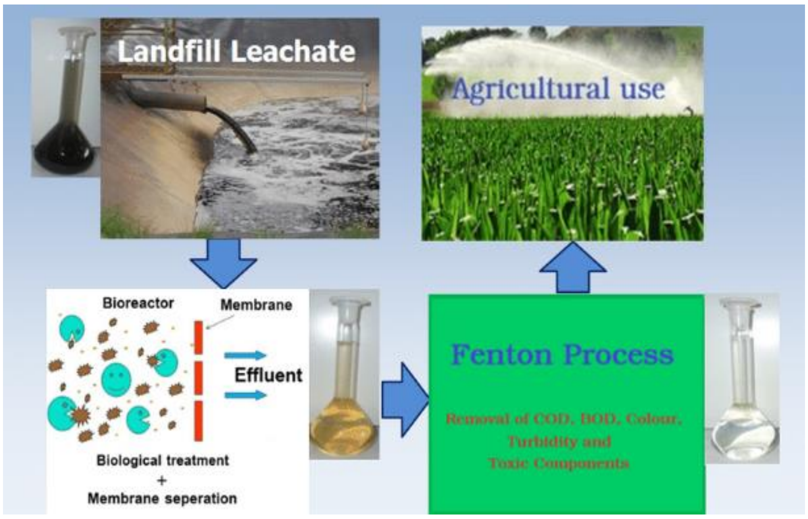

Fig.2. Applications of Landfill Leachate

2. Rendering Waste:

The wastewater with high-strength which is treated with the fluidized bed is knownas the rendering of wastewater. Rendering arises from either the agriculture or food manufacturing industries; it is created by mixing organic waste together just to form waste discharge with high levels of organic as well as nutrients.Rendering sewage, like all heavy-strength wastewater, must meet some levels of effluent value before it is dumped into the urban sewers.To conduct study on rendering waste, fluidized bed was used and results were analysed by carrying three phase analysis with different influents flow and OLRs. Excellent performance of fluidized bed is observed for the treatment of rendering waste as summarized in table 3. In first phase, efficiency of fluidized bed in removal of COD is found to be 92% and N removal efficiency observed is 80%. The solid yields were found to provide a yield of 0.12 g(VSS)•g(COD)–1.

Table 3. Rendering Treatment Operational Parameters

Parameters	Column	Phase I	Phase II	Phase III
Influent flow	-	3	2	1.5
HRT	Anaerobic Aerobic	9.5 39.9	12.5 53	19 80
SRT	Anaerobic Aerobic	2 3.5	4.9 7.5	22 33.4
EBCT	Anaerobic Aerobic	6 15	8 19	12 29.2
OLR	-	14	10	8

2. RESULT &CONCLUSION

The fluidized bed has shown its excellent ability to treat MWW. COD removal efficiencies of 90% and N and P removal efficiencies of 85% and 80% respectively were achieved.

Moreover, increased contact between substrates and biofilm, handling of higher solids were also observed as compared to the conventional methods.Since fluidized bed has been able to treat unclassified primary control, primary clarification can be completely by-passed by the dominant, removing the need for principal clarifiers and thus reducing capital expenditure. Generally, with shorter retention periods, the fluidized bed is able to treat larger quantities of sewage than its traditional counterparts.The fluidized bed has longer storage time for storing solids which often results in decreased yields of effluent. If the concentration exceeds than the discharge requirements, low levels of solids in the wastewater stream may theoretically reduce necessity of secondary clarifiers.

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