Bio-Filter Reactor Scale-up

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PURPOSE

Team Maji Purpose Statements

1) To scale up the bench scale bio-filter reactor developed by the Column Group
2) To design a bio-filter reactor capable of processing 1000 liters of raw water per day
3) To develop an effective educational program that will address the construction, maintenance and utilization of the filter

BACKGROUND

Bio-Filter Reactor – Lab Scale

Seven bio-filter reactors were designed and built in analogous proportions.

Three distinguishable layers of packing material:
- Base layer – pea gravel
- Second layer – coarse sand
- Final layer – fine sand

Testing

To test the effects of system performance utilizing varying qualities of packing material:

- Three reactors (A, B, C) contain non-Industrially processed, manually washed fine sand
- Four reactors (D, E, F, G) contain industrially processed fine sand

To test the disinfection capability of ACX, a copper alloy (Huanga et. al. 2008) developed by Aqua Clara:

- Six bio-filter reactors (A, B, C, D, E, F) – 20 g ACX distributed throughout the initial 2 cm of the fine sand layer
- One bio-filter reactor (G) – no ACX

Material Layer Height (cm)	Bio-filter Reacotor						
	A	B	C	D	E	F	G
Pea Gravel (1.27 cm)	8	8	8	8	8	8	8
Coarse Sand (0.8-1.2 cm)	5	5	5	5	5	5	5
ACX in Fine Sand	2	2	2	2	2	2	0
Fine Sand	32	32	32	32	32	32	34
Wash Quality	Manual	Manual	Manual	Industrial	Industrial	Industrial	Industrial
Total Packing Height	47	47	47	47	47	47	47
Final Water Height	52	52	52	52	52	52	52
Initial Water Height	66	66	66	66	66	66	66
Note: All heights reference the bottom of the container as the datum.							

Table1: Bio- Filter Reactor Material Layer Heights

Figure 1: Lab Scale Bio-Filter Reactors

For 11 weeks, Wabash River water (2.5L) at room temperature was applied daily to each bio-filter reactor.

The bio-filter reactor flow rate was calculated and the influent and effluent water was analyzed for:

- Temperature
- Dissolved Oxygen
- pH
- E. coli
- Turbidity Levels
- Viable Coliform Bacteria

CURRENT WORK

It was determined that a cylindrical, 5000L tank, constructed from HDPE plastic, would be able to effectively house the packing material and to process the daily raw feed water flow rate of 1000L. The tank comes with a lid that will prevent contaminants from reaching the water and from disturbing the bio-layer of the filter.

Schematics:

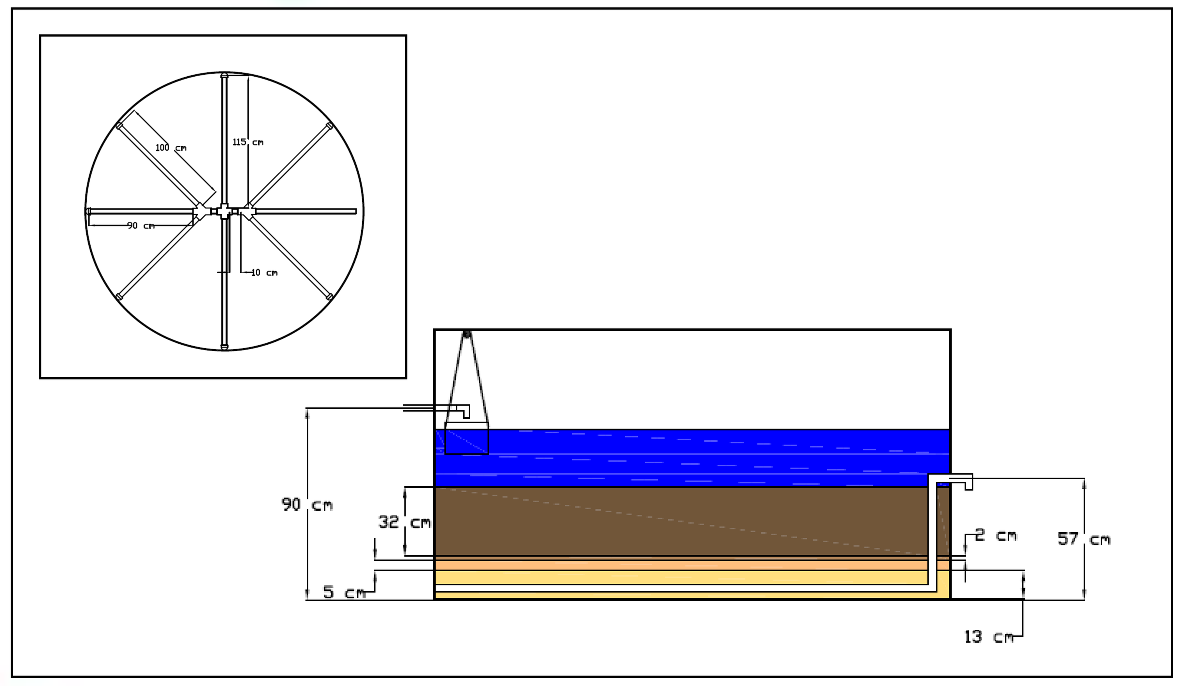

Figure 2: (Left) Schematic of the piped collection system at the bottom of the reactor (Right) cross-section, side view of proposed Bio-Filter Reactor

Bulk Materials List	Quantity (Metric Ton or Tonne)	Estimated Cost per Tonne ($/tonne)	Total Costs (USD)
Pea Gravel	1.06	$10.00 (USD)	$10.60
Coarse Sand	0.5	$10.00 (USD)	$5.00
Fine Sand	3.07	$10.00 (USD)	$30.70
Total Bulk Material Cost			$46.30

PVC Material List	Quantity	Estimated Cost per unit	Total Cost (USD)
1.5 inch PVC (meter)	8.5	$2.79 (USD/Meter)	$23.70
1-1/2 Inch Four-Way Cross Fitting	1	$2.50 (USD)	$2.50
1-1/2 Inch Double Wye Fitting	2	$3.00 (USD)	$6.00
1-1/2 inch End Caps	7	$0.60 (USD)	$4.20
1-1/2 inch 90° Elbow fittings	3	$3.00 (USD)	$9.00
PVC Pipe Cement	1 Container	$5.00 (USD)	$5.00
Caulk Dispenser	1	$3.00 (USD)	$3.00
Waterproof Caulk	1	$5.00 (USD)	$5.00
Estimated Total PVC Material Cost			$58.40

Table 2: Bulk Materials List with Estimated Cost
Table 3: PVC Material List with Estimated Cost

Bio-Filter Reactor

The bio-filter reactor operates under plug flow conditions as determined by the Column Group. This allows the scale-up design to be linear, that is, the heights established in Table 1 are fixed, while the surface area of the lab scale bio-filter reactors scale linearly with the larger unit show schematically in Figure 2.

Water Flow

Kesses Reservoir water is pumped to the bio-filter reactor utilizing an existing pump on site. Water enters the reactor and is initially fed into the container suspended between the feed line and the top of the filter packing material (seen in Figure 2). This container serves primarily to absorb the water impact and mitigate the destructive effect on the biologically active layer. Upon reaching the processing capacity of 1000L, the raw water feed to the bio-filter reactor is turned off, and the water is allowed to pass through the filter. The purified water is collected at the bottom of the bio-filter reactor through a piped collection system. The existing head pressure is used to push the purified water through the piped collection system to the clean water collection tank located adjacent to the bio-filter reactor.

Education

Using basic concepts of biology, hygiene and filter technology, Team Maji is developing a collection of educational materials regarding the relationships between the user, water and reactor.

The intent of educational material development is to demonstrate:
- the relationship between water and health
- the indicators of water quality
- the capability of the bio-filter reactor to meet the water quality requirements necessary for safe consumption
- the activities that lead to contamination of water

The informational material is intended:
- to be easily understood and taught to the local people, especially children
- to connect with individuals of varying educational background
- to clearly show the connection between health and water

FUTURE WORK

Short-term:

May 9th to 14th the team will:

- Construct the filter at St. Catherine Girls School in Eldoret, Kenya.
- Present educational program addressing the construction, maintenance and utilization of the filter
- Collect water samples and data on the water quality of the Rift Valley

Long-Term:

Purdue University student will continue to develop a partnership with Moi University in Eldoret, Kenya. This will result in:

1) Continued monitoring of the aforementioned system by Moi University graduate students
2) Continued design refinements to apply this system, with the addition of a hollow fiber filament, to a medical facility setting
3) Scale-up the system to meet the original 4000 liters of raw water per day

CONCLUSIONS

Team Maji recognizes that this is the first step to establishing a partnership between Purdue University and Moi University. The technical feasibility and system design are relatively simple portions of the project scope as compared to establishing an open collaboration between Purdue University, Moi University and Aqua Clara International. Establishing a closer partnership with the aforementioned stakeholders will eliminate the complications that have arisen in this phase of the design process.

REFERENCES

Huanga, Hsin-I, et. al. *In vitro efficacy of copper and silver ions in eradicating Pseudomonas aeruginosa, Stenotrophomonas maltophilia andAcinetobacter baumannii: Implications for on-sitedisinfection for hospital infection control*. Water Research 42 (2008). pp.73 – 80.

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