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Linear Modeling with Surface Area and Diameter of Hydro - anthracite Multimedia Filter in Water Treatment Processing

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Abstract: *Filter media are prepared materials that allow the passage of raw water with polluted, suspended organic and inorganic particles through them with significant retention of the pollutants. They are selected based on the desired physical characteristics, such as specific size, gravity, and particle sizes. The case study of hydro anthracite as a single multimedia filter with the merits of physical stability, excellent chemical resistance, and durability was simulated with lentech multimedia web-based calculator to model the interaction of its surface area ($y= 0.555x + 0.0008$; $R^2 = 0.9999$) and diameters($y=0.0176x + 0.0008$; $R^2=0.9992$) at a precise flow rate by the filtrate from 1 to 20 m^3 per hour. The predicted and actual flow rate, surface area, and diameter of the filter is 10.5 ± 5.92 m^3/hour, 0.58 ± 0.33 m^3, and 0.19 ± 0.10 m respectively. This implies the model can be adopted in the process performance and optimization of water treatment with hydro anthracite as a multimedia filter.*

Keywords: Multimedia filter, water treatment, hydro anthracite, surface area and diameter**.**

1.0 INTRODUCTION

Filtration across a structured system of granular materials has been the most common technique of eliminating non-settleable solids in wastewater treatment. Some certain particles in water bodies are too tiny to be expelled through ordinary sedimentation techniques as microorganisms, suspended organic matter, and precipitated flocks are extracted effectively by filtration. The separation of particles is conducted as the particles establish physical interaction with the filtration medium surface [1]. As these unwanted particles migrate along with the filter, they are intercepted with eliminated by sedimentation and bind to the surface of the medium due to momentum that induces the larger particle to stick to the pore. Meanwhile, the performance of the filtration is significantly enhanced by the coagulation of the particles before the process as the change in the charge of particles amplifies the aggregation of the particles with a decrease in the force needed to precipitate particles around the filter material [1**].** Multimedia filters are getting common and noteworthy in advanced wastewater management as pressure or open gravity filters having more than a medium component [1]. They are more prevalent in modern wastewater treatment in recent times with their successful outcomes [1]. In general, multimedia filter beds encompass sand, garnet, anthracite, activated carbon, and coarse sand [1]. The media is characterized by further properties than particle removal with longer purification cycles, better filtration rates, and the capacity to treat water of high turbidity. This presents a filter for the recovery of solid particles with a larger portion of sufficient pore volume that is situated at the upper part of the system in the single-medium filter, whereas the pore volume is expanded deep within the filtration system with the multimedia filter. They are often considered as deep bed filters with to the deep ingestion of precipitated flocs [1]. Due to the short process cycles, one medium filter is seldom applied in advanced wastewater treatment. The multimedia filters stand the advantage of being used in tertiary wastewater treatment concerning their available active pore volume required for floc collection and filter cycle. The number of suspended particles in terms of grain, organic matter, and microorganisms are theoretically and significantly treated by a Multi-Media Filter. However, incoming wastewater with a high degree of suspended particles may lead to a drop in high pressure with a decrease in the efficiency of the downstream filtration systems [2]. Fundamentally, with the density index (SDI) value of more than 3 and turbidity of more than 0.2 NTU, multimedia filters are recommended to avoid premature fouling [3].Typically, a Multimedia Filter comprises three media layers as hydro anthracite, garnet, and sand, with a non-filtering gravel supporting layer [3]. The variations in size and density have sustained the wide uses of these media materials. Technically, the bigger and the lighter anthracite coal with the smaller garnet occupy the base of the filtration system. The configuration of filter media enables the biggest particulate matter to be withdrawn at the upper part of the media layer, with deep retention of the lesser particulate matter in the media. This empowers the entire bed to operate as a membrane that provides for much-prolonged filter response time between reactivation and more effective removal of particles [3]. An active multimedia filter can eliminate particles from 15 to 20 microns with a coagulation process that further remove particles to 5-10 microns[3] through inducing the particles to merge forming particles massive enough to be filtered. For a multimedia filter, the optimal service flow is about 3-7 g/ min. / square foot. Faster flow speeds will stop contaminants from attaching to the media structures and as well dislodge already accumulated particles [3]. The separation of turbid particles from the incoming wastewater through the filter causes a significant pressure decline throughout the bed with the elevated turbidity levels across the filter. Consequently, a

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backwash will finally be conducted for the Multi-Media Filter to decongest the bed. Technically, the backwash is initiated as the differential pressure attains 10 psi around the bed and if the feed's turbidity spikes by 10 percent [3]. Meanwhile, acceptable pressure reduction across a fresh multimedia filter varies from 3 to 7 psi. Backwashing allows active reverse of the water flow through the Multi-Media Filter bed in eliminating the suspended particles that are stuck around the bed. Loosening the whole Multi-Media Filter bed allows the particulate matter to be evacuated from through the top section of the vessel with the backwash water as the supporting medium will assist to uniformly disperse backwash across the bed. To raise the media bed adequately devoid of displacing any media from the top of the filter, an ideal backwash rate of 12 to 15 gpm / sq ft is required [3]. Filters attached to the backwash outlet are designed with a flow regulator which manages this movement rate with the seasonal variations in water temperature. After several years of operation, the jagged edges with the sand and other media will be rounded with a decrease in their filtration capacity and logically should be substituted. Hydro -anthracite is a lump of black, shiny, and hard mineral coal with a high carbon content of 95% from a gradual process of plant conversion with temperature and pressure effects [4]. Fortunately, as dual media filters, hydro-anthracite can alone be adopted for water filtration and with different sand sizes as Its peculiar shape and density make it more effective to filter, making it the ideal medium for drinking water, processed water, pool water, wastewater, industrial water and urban water filtration[5]. Due to the distinct variations in densities, these media are mostly selected for use as the simplest filtration media per unit volume, followed by sand, and garnet is hydro anthracite [6]. The theory supporting the use of media with differential masses is that the lightest media with the largest hydro-anthracite particles will automatically balance during backwashing as the medium-sized sand media will sink at the center, while the heaviest media with the smallest grenade particles will fall to the bottom. Locking pollutants in this direction enables the effective separation of turbidity and longer run periods between cycles of backwash [6].However, a normal filter that removes particles up to 25-50 microns in size, relative to a multimedia filter that is capable of expelling particles to 10-25 microns at a higher differential pressure is responsible for pushing particles very deeply into the media bed without being removed by backwash [6]. Hence the debris embedded inside the filter would induce shorter filter runs and elevated differential pressures over time. Filter backwash can include air blowing around the filter to disengage the packed dirt and water drain down the backwash cycle. Upstream of the filter, flocculants, and coagulants can be employed to induce the tiny particulate matter to form particles big enough to be extracted by agglomeration as these allow the filter to be subsequently effective [6].The merits of multimedia filtration are ordered porosity, the ability to retain a larger quantity of suspended particles, longer operational periods, and high quality, filtered water at much faster rates [7]. The surface areas of the hydro anthracite multimedia filter from the filter bed speeds input were modeled and evaluated with the standard filter bed speed limits.

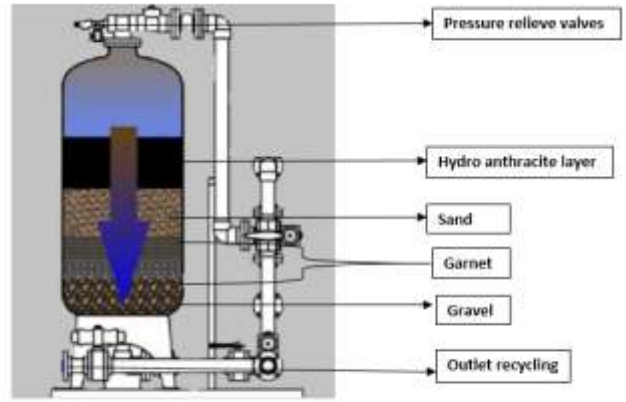

Figure 1. A typical hydro anthracite based multimedia filter system

Table 1. Selected properties of hydro anthracite

Property	Value
Colour	Black
Hardness	2.75 – 3.00 Mohr's scale
Relative density	1.3-1.4
Uniformity Coefficient	1.5-1.7
Carbon Content	79-89%
Specific gravity	1.6-0.05 g/cm^3
Effective size	1.2 -2.4 mm
Bulk Density	850kg/m^3

2.0 METHODOLOGY

Web based multi-media filtration simulator estimates the surface area and diameter of a round multi-media filter (hydro-anthracite) by computing the filter bed speed of 17.5 meter per hour with the liquid (water) flow of 1 to 20m^3 per hour.

3.0 RESULTS AND DISCUSSION

Table 2. Modeled values for hydro anthracite multimedia filter for water treatment

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Flow (m^3/hour)	Surface area (m^2)	Diameter (m)
1	0.06	0.02
2	0.11	0.04
3	0.17	0.05
4	0.22	0.07
5	0.28	0.09
6	0.33	0.11
7	0.39	0.12
8	0.44	0.14
9	0.50	0.16
10	0.56	0.18
11	0.61	0.19
12	0.67	0.21
13	0.72	0.23
14	0.78	0.25
15	0.83	0.27
16	0.89	0.28
17	0.94	0.30
18	1.00	0.32
19	1.06	0.34
20	1.11	0.35

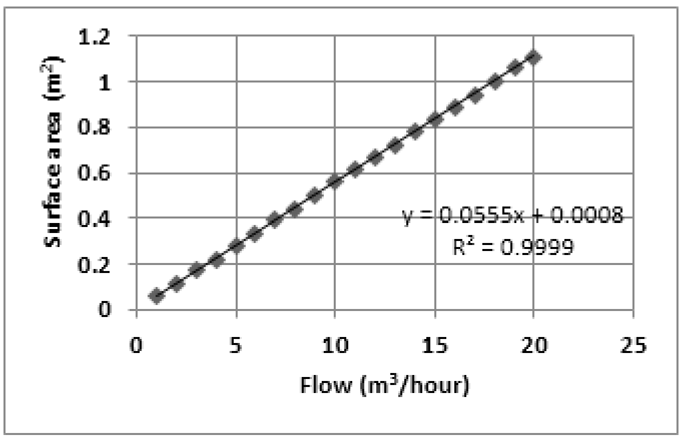

Figure 2. Simulated surface area against the corresponding flow rate

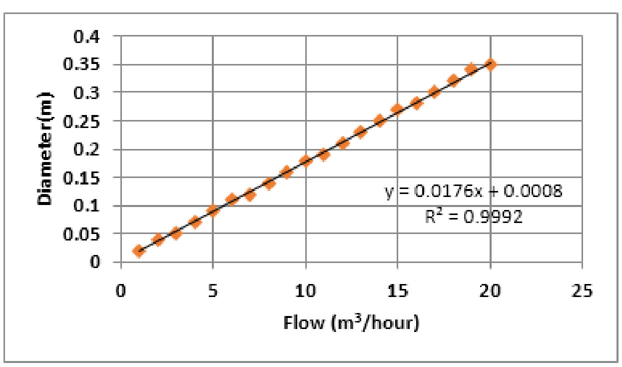

Figure 3. Simulated diameter against the corresponding flow rate

Table 3. Statistical analysis

Descriptive statistics	Multimedia filter parameters		
	Flow rate (m^3/hr.)	Surface area (m^2)	Diameter (m)
Mean	10.50	0.58	0.19
Standard deviation	5.92	0.33	0.10
Standard error	1.32	0.07	0.02
Kurtosis	-1.20	-1.20	-1.22
Range	19.00	1.05	0.33
Maximum	20.00	1.11	0.35
Minimum	1.00	0.06	0.02
Shapiro wilk p-value	0.55	0.53	0.47
Actual average value	10.5 ± 5.92	0.58 ± 0.33	0.19 ± 0.10

The predicted surface area and diameter of hydro anthracite multimedia filter concerning the output flow rate per hour is presented in table 2. Subsequently, the evaluated values of the filter surface area in relationship with the defined flow rate were established by the model y= 0.555x + 0.0008 at R^2 = 0.9999 (Figure 2) and between the diameter of the filter and the same flow rate as y=0.0176x + 0.0008 at R^2=0.9992. Hence the performance in terms of surface area and the diameter of the hydro anthracite filter is directly proportional to the corresponding flow rate of the filtrate through the media. The media activity is however anticipated to be efficient to the point of backwashing as the organic and inorganic contaminants would have deactivated the intrinsic adsorbing structures around the filter. This implies that the efficiency of the filter can be estimated before and after the treatment as sedimentation is not necessary.
However, water samples with remarkably low particulates components and pollutants are easily treated with filtration compared to the forms with a high level of microorganisms (pathogens) that will demand an additional disinfection approach. Additionally, selective statistics computed the precise and average values of the flow rate of the filtrate, the surface area of the filter, and the diameter at the same environmental conditions (Table 3). Importantly, the Shapiro Wilk p-value declares perfect uniformities amongst the three categories as their individual p-values are greater than the statistical alpha value (0.05).

4.0 CONCLUSION

Processed, natural and activated filters are widely adopted in water treatment, potable water purification, and remediation. Therefore, Hydro anthracite filtration matrix offers a safe, secure, and sustainable filter layer that inhibits overflow with the capacity to hold particles more accurately than regular filter sand. It has been established to be suitable for practical wastewater treatment by virtue of its mechanical and chemical resistances. Anthracite's application spans beyond filtration, while in multi-media water treatment systems it is undoubtedly the best feasible product. Therefore, applicable technological modelling with hydro anthracite multimedia treatment plants is mandatory to the advantage of process design in water pretreatment technologies.

Conflict of interest: No

5.0 REFERENCES

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