DETERMINATION OF FLOC VOLUME CONCENTRATION IN FILTER BEDS BY USING NEW METHODS

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ABSTRACT

Hudson Method is a traditional method for determining average specific deposit (σ_{av}) and floc volume concentration in filter beds. In this research, two head loss development equations (Shektman and Camp) were used for determining σ_{av} and FVC in the filter beds instead of Hudson Method. Results are compared with previous published results of other researchers, which show good agreement.

Three equations were obtained for determining specific deposit (σ) as a function of head loss in the filter beds.

Keywords: Filtration, Filter media, Floc volume concentration, and Head loss equation.

INTRODUCTION

Water is a vital ingredient of life. A growing demand for fresh water, as communities and industries grow and new industries develop, has produced shortages in many areas around the world [1]. Although water is normally considered as H_2O and is a naturally occurring substance, but all waters containing varying amounts of other materials [2]. Natural waters are rarely of satisfactory quality for human consumption or industrial use and nearly always need to be treated. The level of treatment required will depend on how acceptable or 'pure' the natural water is [3] and [4]. It to be used for a public water supply must be drinkable. Potable water should not be chemically pure, because water devoid of dissolved and suspended matter is both unpalatable and unhygienic [5].

Water treatment involves the removal from water for constituents detrimental to a specific use [6]. In order to purify water it is generally necessary to combine a number of basic processes, which may be physical, chemical or biological in character. The three basic types of treatment processes are:

1- Physical processes which depend simply on physical properties of the impurities; typical examples of this type of process are, screening, sedimentation, filtration, and gas transfer.

2- Chemical processes dependent of the chemical properties of an impurity or which utilize the chemical properties of added reagents.
3- Biological processes which utilize biochemical reactions to remove soluble or colloidal organic impurities [2] and [7].

Screening of water removes larger suspended solids from water, and sedimentation following chemical coagulation removes most of the residual suspended matter, however, there will still remain some fine floc particles and other suspended matter [8]. Filtration is used to separate non settleable solids from water and wastewater by passing it through a porous medium; the most common system is filtration through a layer bed of granular media, usually a coarse anthracite coal underline by a fine sand [9], [10], [11], and [12]. Filtration also aids in the removal of color, tastes ...etc. [13]. In this process, a greater part of the suspended matter, which is not removed in the sedimentation unit, can be removed in the pores of the filter media. At the beginning of the filtration process, nearly all of the floc particles pass into the bed. As the flocculated matter lodges between the filter media beneath the surface, the free void area is reduced, and the bed offer resistance to the flow of the water. The rate of flow increases the larger openings and lessens through the smaller and partly clogged the openings. As a result many of larger passageways remain nearly free of deposit material [14]. Removed particles are lodged in the upper layers of the filter bed in conventional filters. As filtration process progresses, the accumulated matter tend to penetrate to deep layers of the filter bed, Figure 1 [14]. When impurities reach the under drain system or a limiting head loss occurs across the filter bed; the filtration phase must be terminated, Figure 2 [7], [15], and [16]. The impurities in improperly coagulated water may penetrate too far into the bed and can be flushed through before being trapped, causing a turbid effluent [17].

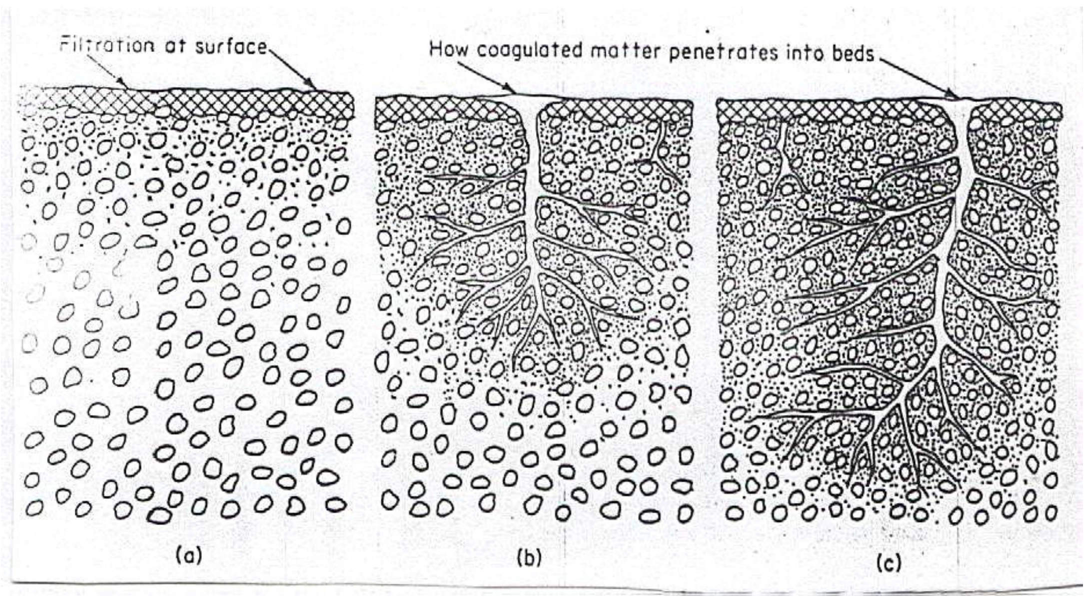

Figure 1: Sketches showing what takes place in a filter bed [14].

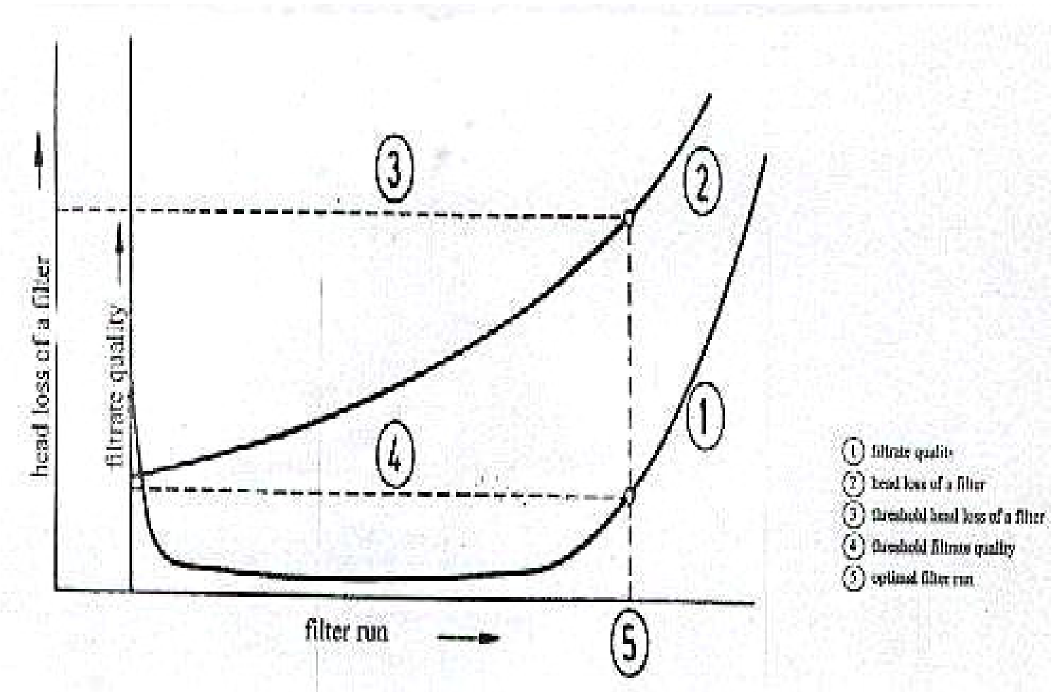

Figure 2: Filtrate quality and head loss at the filtration [7], [15], and [16].

Several researchers work in purifying water, especially in filtration; Mohammed 1989 tried to compare the performance of the traditional and dual media filters [18]. Al Ghabban 1996 wrote a thesis entitled mathematical modeling and computer analysis in filtration [19]. The goals of Al-Anbari study are optimum water production conditions of pre filtration (mixing and sedimentation units) and comparative studies of high – rate filtration units [20]. A pilot – plant constructed by Aziz 2000 and used in New Arbil water treatment – plant, one hundred filter runs conducted on this pilot – plant and compared his results with the treated water of New Arbil water treatment – plant [21]. A limnological study on the water treatment plant at Ifraz station in Arbil City performed by Al–Naqishbandi 2002 [22]. Ganjo et al tried to reuse of wastewater of Arbil City for irrigation purpose by using certain type of filters [23]. This type of research (using new methods for determination of σ_{av} and FVC) not performed by previous researchers.

Application of the head loss development formulae in the filter bed gives an idea about accumulation of the deposits (σ) in each layer of the filter bed, depth of penetration and average specific deposit (σ_{av}) in the filter bed.

Floc volume concentration (FVC) value depends on σ_{av}, depth of penetration, filtration rate and length of filter run [18] and [20].

Conventional method depend on Hudson equation for determination of FVC; but this method is tedious and time consuming and may result in errors. Therefore some new equations like Shektman and Camp equations were used in this research which is easier for obtaining accurate results quickly. Results of traditional method and new methods were compared and statistical analysis such as correlation coefficient and t-test were used for comparison. Results showed good agreement. Several conclusions were outlined as the result of this research.

THEORY

I) Specific deposit (σ)

σ is a dimensionless term is defined as the volume of the deposit per unit volume of the filter media [18] and [20]. It is one of the most needed parameter for determination of FVC of a clogged media. At any time during filtration process and for each layer of filter bed; σ can be determined as:

$$\sigma = \in_o - \in_t \tag{1}$$

Where,

$\in_o$ is initial porosity

$\in_t$ is porosity at time (t)

II) Average specific deposit (σ_{av})

When data are obtained from a filter having pressure taps at various depths below the surface of the filter bed, the value of σ for each layer can be calculated by using one of the head loss equations, such as Hudson equation [18] and [24].

$$\frac{H_t}{H_o} = C\frac{(1-\in_t)^2}{\in_t^{\ 3}} \tag{2}$$

where

H_t is head loss at time (t)
H_o is initial head loss
C is proportionality constant
σ_{av} for the clogged depth of the filter bed can be calculated as follows:

$$\sigma_{av} = \frac{\sum(\Delta L * \sigma)}{\sum \Delta L} \tag{3}$$

where, ΔL is depth of layer in the filter bed.

III) FVC

The value of σ in each layer can be converted to volumes of floc in the filter media. The occupied volume in the filter bed by suspended matter represented by FVC, which is calculated by dividing volumes of floc by the volume of water filtered, in volume per million [18].

$$\text{FVC (vpm)} = \frac{\text{Volume of filter bed occupied by deposits}}{\text{Volume of filtered water}} \qquad (4)$$

$$\text{FVC (vpm)} = \frac{\text{Volume of filtered water}}{\text{Depth of penetration * Length of filter run * Filtration rate}} \qquad (5)$$

vpm = volume per million

CALCULATION PROCEDURE

FVC value depends on: 1) initial porosity of the filter bed and porosity at any time during running of the filter, 2) initial head loss and head loss at various depths below the bed surface during filtration process, 3) the head loss development equation used, 4) depth of penetration of deposited matter in filter media, 5) thickness of filter bed layer(height between two subsequent manometer tubes), 6) length of filter run, 7) filtration rate, 8) cross-sectional area of the filter bed.

To calculate FVC, many researchers have followed the following steps [18] and [20]:

Step 1**:** (Using Hudson equation):

Determination of C value from equation (2)

C value is determined at t = 0, assuming at $t = 0$, $\in_t = \in_o$ and $\frac{H_t}{H_o} = 1$

Step 2:

Log $\frac{H_t}{H_o}$ is determined as follows:

1- Assume values for porosity at time ($\in t$), $\sigma = \in_o - \in_t$

2- $\frac{H_t}{H_o}$ is determined by substituting $\in_t$ and C values in equation 2.

3- Log $\frac{H_t}{H_o}$ is then determined

Repeating steps (1 to 3) to calculate values of H_t/H_o for different values of $\in_t$.

Step3:

Plotting log $\frac{H_t}{H_o}$ versus specific deposit (σ) calculated in step 2.

Step 4:

The average specific deposit σ_{av} for a certain filter run is determined as follows:

1- From value of H_t/H_o for each layer in the filter bed, log H_t/H_o is calculated.
2- From step 3, the value of (σ) for each layer is found from its value of log H_t/H_o.
3- Determination of $\sum(\sigma.\Delta L)$ for the filter bed.
4- Calculation of (σ_{av}) from equation (3).

Step 5:

Calculation of FVC from equation (5).

HEAD LOSS DEVELOPMENT EQUATIONS

Generally, head loss development equations depend on: 1) initial porosity of filter bed, 2) porosity of filter bed during filter run, and 3) specific deposit. Several equations, which relate the development of head loss to the amount of material removed by filter, had been proposed [18]; between these equations, Shektman and Camp are two equations were used in this research for determining FVC.

1- Shektman equation [18]:

$$\frac{H_t}{H_o} = \frac{1}{[1 - \sqrt{(1 - \frac{\in_o - \sigma}{\in_o})}]^2}$$

2- Camp equation [18]:

$$\frac{H_t}{H_o} = (1 + \frac{\sigma}{1 - \in_o})^{4/3}(1 - \frac{\sigma}{\in_o})^{-3}$$

RESULTS AND DISCUSSION

Two different head loss equations were used in this work as new methods (Shektman and Camp equations); therefore, two different values of σ_{av} and FVC are obtained. Data published by Mohammed (1989) Al-Anbari (1997), and Aziz (2000) are used in this work.

FVC values obtained from the new methods are compared with those reported by Mohammed (1989), Al-Anbari (1997), and Aziz (2000) in Table (1).

Table (2) shows correlation between computed values of FVC and those obtained by the mentioned researchers.

Table 1: σ_{av} and FVC for conventional and new methods

No.	Researcher	Length of filter run (hrs)	Filter bed depth (cm)	Filtration rate (m\h)	Hudson Method (Traditional Method)			New Methods			
								Shektman equation		Camp equation	
					Depth of Pent. (cm)	σ_{av}	FVC (vpm)	σ_{av}	FVC (vpm)	σ_{av}	FVC (vpm)
1	Mohammed (1989)	12	50	5	34	0.1490	844.33	0.1190	875.72	0.1150	846.36
2		9	50	7	34	0.1369	739.05	0.1320	710.11	0.1340	721.43
3		6	50	9.93 1	34	0.1194	681.2	0.1180	671.25	0.1120	636.90
4		3.5	40	5	14	0.1471	1176.68	0.1420	1320.85	0.1380	1291.51
5		2.667	40	7	14	0.1582	1186.6	0.1490	1485.90	0.1570	1570.10
6		2.5	40	9.93 1	40	0.0728	1174.9	0.088	1777.80	0.0590	1192.19
7	Al-Anbari (1997)	10	48	5	-	0.1110	1210.6	0.116	1161.37	0.116	1160.60
8		10	60	5	-	0.1022	1001.3	0.104	1148.56	0.092	1016.77
9		10	60	5	-	0.1143	1029.28	0.109	979.40	0.113	1012.65
10		10	60	5	-	0.1195	1081.46	0.110	987.08	0.124	1120.11
11		10	48	7.5	-	0.1070	670.40	0.113	829.43	0.111	812.56
12		10	60	7.5	-	0.0970	607.18	0.116	696.76	0.108	856.47
13		10	60	7.5	-	0.1020	631.30	0.109	652.46	0.109	654.78
14		10	60	7.5	-	0.1070	672.2	0.100	733.14	0.103	751.70
15		10	60	9	-	0.0910	479.28	0.120	601.22	0.115	576.30
16		10	60	9	-	0.0951	517.3	0.102	679.85	0.103	688.95
17		10	60	9	-	0.1012	593.5	0.113	564.88	0.127	635.69
18	Aziz (2000)	13	40	6	32	0.072	295.38	0.099	303.90	0.072	222.21
19		16	40	7	16	0.139	198.57	0.135	192.94	0.135	192.94
20		19.50	40	9	40	0.065	147.01	0.177	88.04	0.212	99.35
21		30.16	50	6	20	0.1158	127.98	0.229	50.93	0.282	62.58
22		23.58	50	7	20	0.196	237.49	0.111	331.42	0.092	273.87
23		22.75	50	9	28	0.114	155.90	0.186	75.32	0.218	87.91
24		34.34	60	6	60	0.0819	238.50	0.096	273.273	0.068	193.94
25			60	7	50	0.0576	194.35	0.110	164.224	0.094	141.03
26		19.34	60	9	60	0.049	170.28	0.137	80.203	0.139	81.397
27		16.25	70	6	70	0.104	749.54	0.139	697.113	0.144	720.021
28		47.5	70	7	70	0.084	176.42	0.098	20`2.65 6	0.073	150.759
29		33.41	70	9	70	0.110	255.38	0.113	259.454	0.097	220.902

Table 2: Correlation coefficient of FVC values

No.	Data	Correlation of traditional FVC values with	
		Shektman equation	Camp equation
1	Mohammed (1989)	0.9428	0.9460
2	Al-Anbari (1997)	0.9456	0.9664
3	Aziz (2000)	0.9482	0.9820

Results show that the correlation coefficient between FVC results and those recorded by Mohammed (1989) using Shektman and camp equations are 0.9428, and 0.9460, respectively. This coefficient when compared with Al-Anbari (1997) results is 0.9456 for Shektman and 0.9664 for Camp equation. According to results obtained by Aziz (2000), the correlation coefficient is equal to 0.9482 and 0.9820 for Shektman and Camp equations, respectively.

Results of t-test for FVC values obtained from the new methods are shown in Table (3) which shows a good agreement with those values reported by Mohammed (1989). According to results recorded by Al-Anbari (1997), there is no difference between the two methods when Shektaman and Camp equations are used. No variation is observed between FVC recorded by Aziz (2000) and FVC values obtained from the Shektman equation.

Table 3: t-test of FVC values

No.	Data	t- test (table)	t- test calculated	
			Shektman equation	Camp equation
1	Mohammed (1989)	2.571	-0.1377	-0.5252
2	Al-Anbari (1997)	2.228	-1.734	-2.268
3	Aziz (2000)	2.201	1.184	4.279

CONCLUSIONS

1- Accurate results are obtained quickly (eliminating steps 1 to 3 in calculation procedure) using new methods, Shektman and Camp equations.

2- Shektman equation for determination of FVC can be used instead of Hudson equation (traditional method).
3- Three equations were obtained for computing (σ) values directly instead of the conventional method, as follows:

***A-Hudson equation*:**

I) $$\sigma = 0.0027(\log\frac{H_t}{H_o})^3 - 0.043(\log\frac{H_t}{H_o})^2 + 0.226(\log\frac{H_t}{H_o}) - 0.0006$$

for sand with E.S. of 0.42,

II) $$\sigma = 0.0029(\log\frac{H_t}{H_o})^3 - 0.0435(\log\frac{H_t}{H_o})^2 + 0.2209(Log\frac{H_t}{H_o}) - 0.0005$$

for sand with E.S. of 0.4032,

III) $$\sigma = 0.0025(\log\frac{H_t}{H_o})^3 - 0.0427(\log\frac{H_t}{H_o})^2 + 0.2322(Log\frac{H_t}{H_o}) - 0.0006$$

for sand with E.S. of 0.44,

B- Shektman equation:

$$\sigma = 0.0542 \ln\frac{H_t}{H_o} + 0.0395$$

C- Camp equation:

$$\sigma = \in_o \left[1 - \sqrt{\frac{H_0}{H_t}}\right]^2$$

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