RATIONAL BASIS FOR DETERMINING THE DESLUDGING INTERVALS OF SEPTIC TANKS

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ABSTRACT

Ability to determine appropriate desludging intervals will go a long way in maintaining septic tank effluent standards. A relationship between decline in detention time and sludge level was derived and then combined with an already existing empirical sludge accumulation equation. Next, the decline in suspended solids removal efficiency was equated to the decline in detention time. Hence an expression was obtained which relates sludge depth to septic tank effluent suspended solids. Using data from literature, charts were produced which can aid a designer in selecting appropriate detention time and desludging intervals for septic tanks. Results obtained show that a septic tank does not necessarily have to be desludged when sludge reaches one third of the tank's depth. The depth at which desludging should be done may be less or more depending on the required effluent suspended solids concentration.

KEYWORDS: Septic tank, sludge, effluent, wastewater.

1. INTRODUCTION

The septic tank is an enclosed receptacle designed to collect wastewater, segregate settleable and floatable solids (sludge and scum), accumulate, consolidate and store solids, digest organic matter and discharge treated effluent (Bounds, 1997). The structural requirement of the septic tank is that: the septic tank including all extensions to the surface shall be watertight to prevent leakage into or out of the tank. It shall be structurally sound and made of materials resistant to corrosion from soil and acids produced from septic tank gases (Kansas State Department of Health and Environment, 1997). A cursory inspection of the septic tanks in Nigeria will reveal that most of them do not meet this requirement as contractors use inferior materials in a bid to maximize profit. Even in the United States, Bounds (1997) reported that although most regulatory authorities require water tightness, enforcement is almost non-existent.

The design volume of a septic tank is usually based on the liquid retention period and the desludging interval, which usually varies from three to five years (Seablom, 2003). Because of the absence of enforcement of septic tank effluent standards in Nigeria, most people wait until their septic tanks are overflowing with sludge or until sewage begin to back up to their water closet before they think of desludging. This practice results in the failure of the soil absorption system. Retention time is the time provided for solids to separate from the wastewater and thus to be retained in the septic tank. Inadequate retention time results in a higher level of suspended solids in the septic wastewater being sent to the drain field or soak away system. Studies have shown that the overall efficiency of septic tanks is a function of detention time. Rahman et al (1999) recommended detention time as high as five days for septic tanks receiving only sewage from the toilet. Overuse of the system can lower retention time in the tank, and causing unclarified sewage to leave the tank. Overflow of sludge and scum into the absorption field can directly clog the soils or can lead to the over stimulation of the biomat, leading to a reduction in transmission of the effluent into the soils (Canter and Knox 1985). A problem occurs when the sludge in the tank builds up over time and the scum layer gets thicker until the two meet in the middle. When this happens there is no capacity left to allow the minimum 24 hours of retention time and no room for the clear effluent to be produced. The treatment quality of the tank is greatly diminished and the sludge and the scum start to get into the second chamber and then into the leaching pipes. Excess solid particles leaving the septic tank plug up the leaching pipes and then there is no adequate distribution of the effluent and no proper treatment of the waste in the drain field. Wilhelm et al. (1994) noted that the septic tank itself is a zone of redox reactions catalyzed by micro-organisms. Since domestic wastewater is composed mostly of organic matter, the micro-organisms first hydrolyze the large organic compounds to simpler ones. . It was also observed that most of the nitrate-nitrogen (NO^{3} -N) in the influent are usually converted to ammonium-nitrogen (NH^{+}_{4} - N) which is usually denitrified in the absorption field while 10% to 30% of the total organic nitrogen is removed by sludge storage.

The objective of this research is to give a systematic approach for choosing the desludging intervals of septic tanks.

2. METHODOLOGY

2.1 Basic Theory

The reasoning applied in the following derivation is that as sludge accumulates in the septic tank, its effective volume decreases. If the design wastewater flow is not altered, then the detention time of the tank will have to decline steadily until it becomes zero when the tank is filled with sludge.

$$\theta = \frac{V}{Q} = \frac{V}{Au} = \frac{lbh}{bhu} = \frac{l}{u}$$

Where θ is the detention time, V is the volume of the tank, Q is wastewater flow, l is the length of the tank, b is the breadth of the tank, h is the height of the tank and u is the flow velocity in the tank

$$\therefore \theta = \frac{l}{u} \Rightarrow \theta u = l \qquad (1)$$

θ and u change as sludge accumulates while l remains constant. Thus differentiating equation (1) above we have

$$\theta du + u d\theta = 0 \qquad (2)$$

$$\text{But } u = \frac{Q}{A} = \frac{Q}{bh} \qquad (3)$$

Substituting (3) into (2), we have

$$\theta d\left(\frac{Q}{bh}\right) + \frac{Q}{bh} d\theta = 0 \quad \Rightarrow \quad \theta \frac{Q}{b} d\left(\frac{1}{h}\right) + \frac{Q}{bh} d\theta = 0$$

$$\text{Hence } -\theta d\left(\frac{1}{h}\right) + \frac{1}{h} d\theta = 0 \quad \Rightarrow \quad -\theta\left(\frac{dh}{h^2}\right) + \frac{1}{h} d\theta = 0$$

$$\Rightarrow \frac{d\theta}{\theta} = \frac{dh}{h} \qquad (4)$$

Integrating, we obtain $\ln\theta = \ln h + C$

At the start of operation, the septic tank has a detention time θ_i and a clear depth h_i which is the same as the design depth.

$$\Rightarrow C = \ln \frac{\theta_i}{h_i}$$

So that $\theta = h\frac{\theta_i}{h_i}$ (5)

Where h = clear space above sludge level at any time. It is the difference between the original depth of tank and the depth of accumulated sludge. That is $h = h_i$ - D

$$\theta = \frac{\theta_i}{h_i}(h_i - D)$$

$$\Rightarrow \theta = \theta_i - D\frac{\theta_i}{h_i} \quad (6)$$

Equation (6) is the equation of decay of detention time with sludge accumulation in the septic tank.

2.2 Decay of Detention Time

It is necessary to know the value of detention time at any given time after the commencement of operation of the septic tank. This can be done by combining equation (6) with the equation (equation 7) of sludge accumulation obtained by Bounds (1995):

$$N_{sc+sl} = 47t^{0.675} \quad (7)$$

Where N_{sc+sl} = volume of sludge and scum in *US* gallons/capita, t = time in years.
If we assume uniform sludge accumulation over the plan area of the tank, we can re-write Bound's equation in terms of sludge depth D.

$$AD = N = 47t^{0.675} \quad (8)$$

$$\Rightarrow D = \frac{47}{A}t^{0.675} \quad (9)$$

A = plan area of the tank.

Substituting equation (9) into equation (6), we have

$$\theta = \theta_i\left[1 - \frac{47}{Ah_h}t^{0.675}\right] \quad (10)$$

Since h_i is the design depth of tank, Ah_i is equal to the volume of tank, thus equation (10) becomes:

$$\theta = \theta_i\left[1 - \frac{47}{V}t^{0.675}\right] \quad (11)$$

Theoretically speaking, the detention time decreases until it becomes zero at the point where the tank is full. We can estimate the time it will take a tank to be filled up with sludge by equating the right hand side of equation (11) to zero.

$$\theta = \theta_i\left[1 - \frac{AT}{V}t^{0.878}\right] \Rightarrow t = \left(\frac{V}{AT}\right)^{\frac{1}{0.878}} \qquad (12)$$

Where V is the volume of tank per capita
Equation (12) is the same as Bounds' expression for sludge accumulation.

2.3 Desludging Interval

Instead of basing the desludging interval of septic tanks on the length of time it will take sludge to accumulate up to one third of the tank's volume, a better reasoning will be to base it on the relative amounts of suspended solids in the influent and effluent. We can obtain an expression to this effect by considering the loss in the efficiency of suspended solids removal as detention time decrease. The decline in the suspended solids removal efficiency of the tank can be related to the decline in detention time; percentage decline removal of suspended solids removal = percentage decline in detention time.

$$\frac{S_0 - S_i}{S_0} - \frac{S_0 - S}{S_0} = \frac{\theta_i - \theta}{\theta_i} \qquad (13)$$

S_0 = Suspended solids concentration of septic tank influent, S_i = Suspended solids concentration of septic tank effluent at the start of operation, S = Suspended solids concentration of septic tank effluent at any time after commencement of operation, θ_i = Initial detention time of septic tank, θ = Detention time corresponding to effluent suspended solids concentration S
Simplifying, we have:

$$S - S_i = \frac{\theta_i - \theta}{\theta_i} S_0 \qquad (14)$$

Substituting equation (6) in equation (16) we have:

$$S - S_i = \frac{\theta_i - (\theta_i - D\theta_i / h_i)}{\theta_i} S_0 \qquad (15)$$

$$\frac{D}{h_i} = \frac{S - S_i}{S_0} \qquad (16)$$

3. RESULTS AND DISCUSSION

Figures 1 to 6 show that detention time decreases with time of use and that the more the number of people using the tank the more rapidly the detention time will diminish. The result of this study shows that the 24 hour detention time recommended by the Nigerian Public Works Department (PWD) of 1949 is grossly insufficient for optimum performance. Rahman et al (1999) suggested that PO_4, NO_3, and FC removal efficiencies of septic tanks diminished, probably due to a lower detention period and higher initial values of these parameters. They also found that better quality with respect to faecal coliform could probably be achieved with a higher detention time. Obviously maintaining sufficient particle residence time in the septic tank improves the overall quality of the effluent which will in turn enhance soil infiltration rate. This means that soakage pits would require less area and would perform well. Using a detention time of 24 hours in all cases may result in frequent desludging if effluent standards are to be maintained.

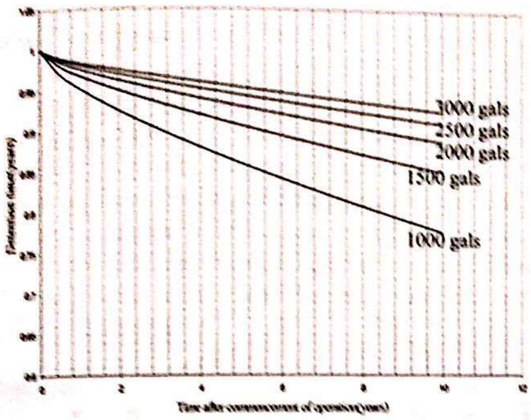

Fig 1: Graph of Decay of Detention Time Versus Time for different capacities for single occupancy

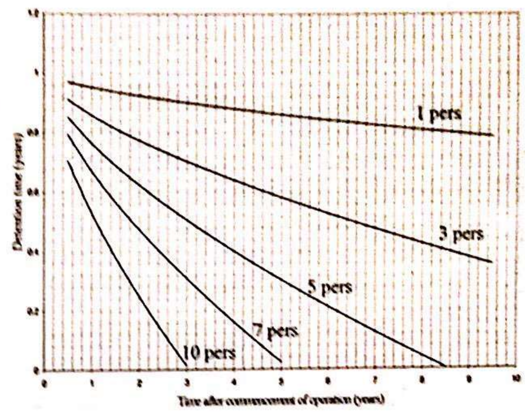

Fig 2: Graph of Decay of Detention Time Versus Time for different occupancies for 1000gals capacity tank

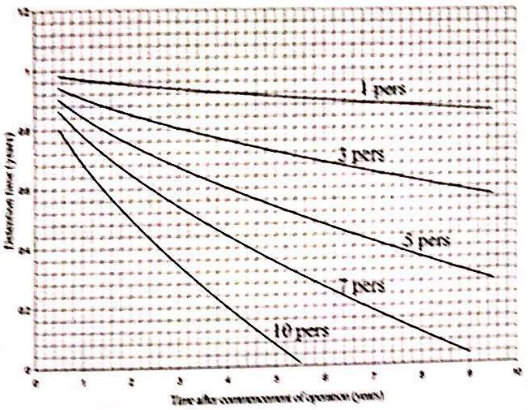

Fig 3: Graph of Decay of Detention Time Versus Time for different occupancies for 1500gals capacity tank

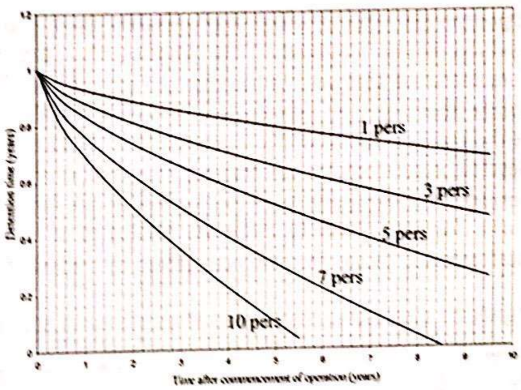

Fig 4: Graph of Decay of Detention Time Versus Time for different occupancies for 2000gals capacity tank

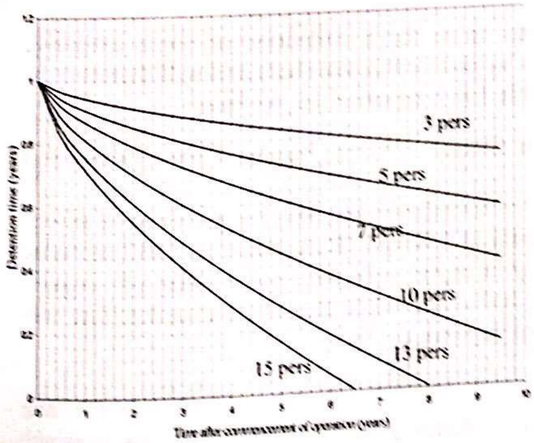

Fig 5: Graph of Decay of Detention Time Versus Time for different occupancies for 2500gals

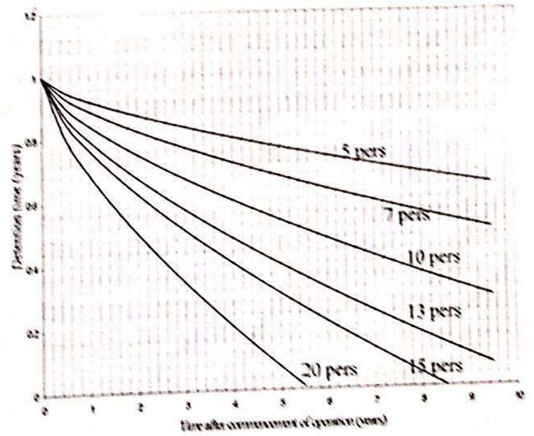

Fig 6: Graph of Decay of Detention Time Versus Time for different occupancies for 3000gals

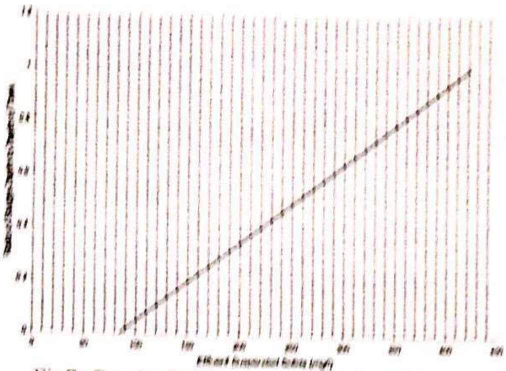

Fig7: Graph of effluent suspended solids versus sludge accumulation for unfiltered effluent

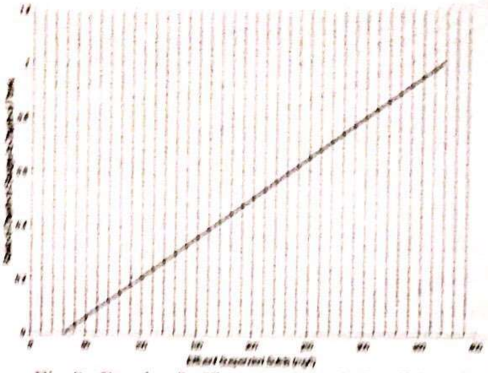

Fig 8: Graph of effluent suspended solids versus sludge accumulation for filtered effluent

Equation (16) can be more appropriately used in septic tank design to obtain the level of sludge at which desludging is required. This implies that the designer must fix the maximum suspended solids concentration that will be discharged into the soil absorption system. Given a desired limit of suspended solids discharge (S) into the soil absorption field and knowing the influent and effluent suspended solids at the start of operation, a more realistic desludging level can be computed for any septic tank of a given depth h_t instead of the generalized one third of the tank's volume. This has the advantage of ensuring strict control over the quantity of suspended solids discharged and also that the soil absorption field is protected from clogging resulting from the discharge of excessive solids from the tank. Table 1 shows the average performance of septic tanks as studied by various researchers.

Table 1: Average performance of septic tanks studied by various researchers

Source	Influent SS (mg/l)	Effluent SS (mg/l)	% SS Removal
Bounds (1997)	338	84 (unfiltered)*	75
Bounds (1997)	338	30 (filtered)**	91
Thammarat	640	185.6	71
Pepple (1998)	-	75	-

* *Effluent from septic tank without effluent filter* ** *Effluent with biofilter attached to effluent pipe.*

The data from Bounds (1997) was obtained as the mean value for a collection of some extensive experiments carried out on the performance of septic tanks by different researchers and will therefore be adopted in this study. Substituting the adopted data from table 1 into equation 16, we have $\frac{D}{h_t} = \frac{S-84}{338}$ for unfiltered effluent and $\frac{D}{h_t} = \frac{S-30}{338}$ for filtered effluent. Figures 7 and 8 show that effluent suspended solids is not only influenced by sludge accumulation but also the presence of filters. Figures 7 and 8 show that if a designer specifies a maximum of 150mg/l (Ronayne et al, 1982 recorded 146mg/l) suspended solids in the septic tank effluent, then a septic tank with outlet filter will require desludging when sludge accumulation reaches 0.36 of the tank depth while that without outlet filter will require desludging when sludge accumulation reaches 0.2 of the tank depth.

Alternatively a designer may decide to fix the desludging interval when the detention time of the tank reaches a particular minimum value. If this is the case the desludging interval can directly be obtained from any of figures 1 to 6 depending on the volume of the tank and number of users, interpolating where necessary. He may also use equation (11) to this effect.

4. CONCLUSION

All septic tanks should not be designed for a detention time of 24 hours and desludging must not always necessary follow the one third tank volume sludge accumulation specification. The designer should be able to know whether his chosen detention time will maintain the desired efficiency with regard to suspended solids removal efficiency and for how long. It is therefore more practical to base desludging interval on suspended solids removal efficiency. If a tank is filled with sludge up to one third of its volume but still performing within the minimum efficiency specified, then there is no need for desludging yet. This approach will ensure that the drainfield is protected from clogging thereby extending the life span of the entire system.

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