Int. J. Environ. Res., 4(4): 825-836, Autumn 2010
ISSN: 1735-6865

Effect of Sludge Initial Depth on the Fate of Pathogens in Sand Drying Beds in the Eastern Province of Saudi Arabia

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Received 25 Sep. 2009; Revised 12 Feb. 2010; Accepted 15 May 2010

ABSTRACT: In order to optimize sludge depth in sand drying beds under the climatic conditions of Saudi Arabia, the effect of initial sludge depth on the fate of pathogens was investigated.The investigation was carried out for one year in Al-Khobar Wastewater Treatment Plant, where initial sludge depths of 10, 15, 20, 25, 30 and 35 cm were implemented. Sludge samples were collected on 0, 1, 2, 4, 7, 14, and 30 days and were analyzed for various types of bacterial species and protozoan and helminthic pathogens.The study showed that the effect of the initial sludge depth in drying beds on the dye-off rate of pathogens under investigation was apparent.Total coliform, streptococci, shigella, salmonella and clostridium were found to survive longer as the sludge initial depth was increased. As an example, the *streptococci* count reached values of 25, 37, 49, 59, 71, and 90 organisms per gram dry weight for sludge initial depths of 10, 15, 20, 25, 30 and 35 cm, respectively.The same trend was also observed for protozoan and helminthic pathogens. For example, the number of *ascaris lumbricoides* after 2 days of drying was 3, 4, 6, 7, 7, and 10 in sludge samples collected from drying beds with initial depths of 10, 15, 20, 25, 30 and 35 cm, respectively.A mathematical representation was formed to describe the pathogens dye-off with respect to time that included the effect of the sludge initial depth. The results indicated that the mathematical representation of the drying beds for individual species was dramatically improved when average values of constants for individual species were used in the model.

Key words: Domestic Sludge, Pathogens, Total Coliform, Fecal Coliform, Protozoa, Helminthes

INTRODUCTION

Sludge dewatering is a physical unit process used to remove as much water as possible from sludge to produce a highly concentrated cake.Dewatering differs from thickening, as the sludge should behave as a solid after it has been dewatered.Metcalf and Eddy (2003) reported more than one reason for the dewatering to be performed. Dewatering of the different types of water from sludge was studied by several investigators such as Robinson and Knocke (1994), Smith and Vesilind (1995), Cantet et al. (1996), Chen et al. (1996), Wu and Huang (1997), and Lajoie et al. (2000). Sludge drying beds are the oldest method of sludge dewatering and are still used extensively in small-to-medium sized plants to dewater sludge.They are relatively inexpensive and provide dry sludge cake.In the recent years, much advancement has been made to the conventional drying beds, and new systems are used on medium- and large-sized plants. Theses variations of the drying beds are (1) conventional sand, (2) paved, (3) wire-wedge, and (4) vacuum assisted.

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Conventional sand beds consist of a layer of coarse sand 15-25 cm in depth and supported on a gravel bed (0.3-2.5 cm) that incorporates selected tiles or perforated pipe under-drain. Sludge is placed on the bed in 20-30 cm layers and allowed to dry. Sludge cake removal is manual by shoveling into wheelbarrows or trucks or a scraper or front-end loader. The underdrained liquid is returned to the plant.The drying period is 10-15 days, and the moisture content of the cake is 60-70 percent. Sludge loading rate is 100-300 kg dry solids per m^2 per year for uncovered beds.Marklund (1993) studied the dewatering of aerobically digested sludge using drying beds. He concluded that larger portions of the moisture could be removed by drainage from thin sludge layers.When the initial sludge layer depth was 350 mm, only one third of the moisture was removed. Al-Muzaini (2003) assessed sludge produced by the Jahra treatment plant.The assessment of the quality of the sludge produced was based on the standards for land application of sewage sludge. Analyses were carried out for

trace heavy metals and bacteria. He reported that the results of the analyses showed that the sludge produced was high in organic matter and sand content but low in heavy metals. Al-Malack et al. (2007) conducted an extensive research in order to determine the microbiological characteristics of municipal sludges produced at three major cities, namely, Qateef, Dammam and Khobar in the Eastern Province of Saudi Arabia. The results indicated that municipal sludge produced at the three cities was not suitable for utilization in agricultural activities due to the high levels of salmonella even after 14 days of drying at Qateef wastewater treatment plant. Dried Sludge samples collected from Qateef, Dammam and Khobar were found to contain salmonella species on the average of 22, 107 and 127 MPN per gram of dried sludge, respectively. O'Shaughnessy et al. (2008) investigated the effects of moisture and temperature on the inactivation rate of fecal coliforms in biosolids and developed a mathematical model to predict their level in biosolids in solar drying beds at any time during the drying process. They reported that temperature and moisture had significant main and interactive effects on the inactivation rate of *Escherichia coli* in biosolids. The results also showed that observed and predicted inactivation rates from the microcosm study correlated well (R^2 = 0.81). The use of different modifications of drying beds in dewatering of municipal sludge was also investigated by Elariny and Miller (1984), Hossam and Saad (1990), Marklund (1990), Nishimura et al. (1994), Yamaoka and Hata (2003), Al-Muzaini (2004), Choi et al. (2005), Zaleski et al (2005), Alkan et al. (2007), Mehrdadi et al. (2007) Achon et al. (2008), O'Shaughnessy et al. (2008), and Yi et al. (2008).

With respect to the survival of pathogens in drying beds, Cofie et al. (2006) investigated the use of drying beds with municipal sludge. They reported that drying beds were found to retain 80 per cent of solids and 100 per cent of helminth eggs. Fars et al (2005) investigated the survival of *fecal coliforms* in activated sludge after dewatering in drying beds. They reported that the treatment of sludge in drying beds appeared to be efficient in eliminating pathogenic micro-organisms such as *fecal coliforms*, *protozoan cysts* and helminth eggs. Plachy and Juris (1995) investigated the survival of eggs of *A. suum* in two sludge drying beds of sewage treatment plants (STP) under different climatic-geographical conditions. They reported that sludge drying beds of both sewage treatment plants showed different survival of eggs. In one of the STPs, a rapid reduction in viable eggs from was reported (from 80.4 to 19.8 per cent). Later this decrease became less rapid and at the end of the experiment, after 240 days only 5 per cent of eggs were viable. In the other STP, the viability of eggs was reduced rather gradually, and after 320 days of exposure 36 per cent of viable A. suum eggs were still recorded.

With respect to the effect of initial sludge depth in drying beds on the fate of pathogens, and up to the knowledge of the author, there is no single work in that direction. Based on that, the main objective of the study is to investigate the effect of initial sludge depth on the microbiological characteristics of the sludge during the drying period.

MATERIALS & METHODS

As proposed, the fieldwork was conducted at Khobar wastewater treatment plant (WWTP) located in Azizia area. The experimental setup was designed by isolating and modifying two sludge drying beds to suit the experimental objectives. The beds were divided equally into six compartments (plots) of 8.3 × 15 m each with a numerical designation of 1 - 6. Plot number six was maintained as a control bed that is identical to the present actual sludge loading practiced in the plant. The existing feed line was connected with individual inlets to be operated independently in order to maintain the desired sludge thickness in each plot. Splash plates were installed in each bed to regulate the flow. For each experiment, six experimental plots were loaded with 10, 15, 20, 25, 30, and 35-cm thickness of sludge. The drying period ranged from 0 to 30 days, which constituted one experimental run. Samples were collected from each plot at time intervals of 0, 1, 2, 4, 7, 14, and 30 days. At the end of each experiment, a five-day period was allowed to prepare the beds for the next set of experiments by removing the residual dry sludge and maintaining a constant sand depth. Two experimental runs were conducted during each season and, therefore, a total of eight experimental runs were carried out during the one-year experimental investigation.

Standard methods were implemented in the sample analysis.It is worth to mention that collected sludge samples were analyzed in triplicates.The following is a brief description of the techniques which were employed in the determination of different microbiological parameters:

Total and Fecal Coliforms:Presumptive lauryl sulfate MPN test followed by BGB confirmed test; direct enumeration by Membrane Filter technique using M-Endo agar.Presumptive positive samples were inoculated in EC medium to confirm quantitatively *fecal coliforms* from total *coliforms.*

Streptococcus sp. :Inoculate samples into azide dextrose broth and incubate at 35°C to observe turbidity for the presence of *Streptococcus sp.* Confirmation was done by streaking PSE agar for brown positive colonies.

Salmonella sp.:MPN method using dulcitol selenite as enrichment media and streak from each tube to brilliant green and xylose lysine desoaycholate agars. Reinoculate colony in triple sugar iron slant and lysine iron agars.

Shigella sp. :Using xylose lysine desoxycholate (XLD) agar for primary isolation of *Shigella sp.* strains and incubate at 35°C for 24 hrs for isolation of red positive colonies.

Clostridium perfringens: Samples were inoculated in clostridium basal media and incubated at 37°C to detect positive black *Clostridium perfringens* colonies.

Helminthic ova: Using zinc sulfate floatation technique all the helminthic types present were identified.

Parasites :Both protozoan and helminthic parasites are expected to be present in the sludge. The main helminthic parasites present as ova of human enteric species are represented by *Ascaris lumbricoides, Enterobious vermicularis, Ancylostoma doudenale, Trichuri trichura, Hymenolepis nana*. The main enteric protozoan parasite include *Entamoeba histolytica.* Two techniques were used for the detection and enumeration of helminthic and protozoan parasites, they were floatation and sedimentation. Sedgewick-Rafter cell was used for quantitative analysis.

Entamoeba histolytica:Suspension were strained through 7-10 μm membrane and resuspended. Sedgewick-Rafter cell was used in enumeration (Concentration Method).

RESULTS & DISCUSSION

Due to the similarity of the results obtained in all sessions, only one set of data will be presented. The effect of initial sludge depth on the survival of total *coliform* in sludge samples collected during the first session is presented in Fig. 1. Generally, the figure shows that total *coliform* count was decreasing, in sludge samples, with respect to drying period. Moreover, the figure demonstrates a trend where total *coliform* was found to survive longer in higher sludge depths.The reason for longer survival of *coliform* bacteria in thicker sludge could be due to penetration of solar heat and radiation, which will be reduced in thicker sludge depths. The results show that sludge samples, collected during that session, contain *coliform* densities ranging between 8×10^4 and 1.1×10^5 organisms per gram dry weight, after 30 days of drying period. Regarding the effect of initial sludge depth on the survival of *streptococci*, Fig. 2 shows that as the initial sludge depth was increased, the *streptococci* would survive longer. By the end of the 30-day drying period, the *streptococci* count reached values of 25, 37, 49, 59, 71, and 90 organisms per gram dry weight, for initial depths of 10, 15, 20, 25, 30, and 35 cm, respectively. The effect of initial sludge depth on the survival of *shigella* in sludge samples is presented in Fig. 3. Generally, the figure shows that *shigella* count was decreasing, in sludge samples, with respect to drying period. Moreover, the results demonstrate a trend where *shigella* was found to survive longer in higher sludge depths. The reason for longer survival of *shigella* bacteria in thicker sludge could be due to the same reasons given above. The results show that sludge samples contain *shigella* densities ranging between 50 and 200 organisms per gram dry weight, after 30 days of drying period. Regarding the effect of initial sludge depth on the survival of *salmonella*, Fig. 4 shows that as the initial sludge depth was increased, the *salmonella* would survive longer. At the end of the 30-day drying period, the *salmonella* count reached values of 15, 25, 35, 35, 50, and 60 organisms per gram dry weight, for initial depths of 10, 15, 20, 25, 30, and 35 cm, respectively. The effect of initial sludge depth on the survival of *clostridium* in sludge samples is presented in Fig. 5. Generally, the figure shows that *clostridium* count was decreasing, in sludge samples, with respect to drying period. Moreover, the results demonstrate a trend where *clostridium* was found to survive longer in higher sludge depths. The reason for longer survival of *clostridium* bacteria in thicker sludge could be due to penetration of solar heat and radiation, which will be reduced in thicker sludges. The results show that sludge samples contain *clostridium* densities ranging between 7 and 45 organisms per gram dry weight, after 30 days of drying period.

Protozoan and helminthic pathogens are of great concern due to their probable effects on the public health. Sludge samples were examined for helminthic and protozoan pathogens such as *Ascaris lumbricoides, Enterobious vermicularis, Ancylostoma doudenale, Trichuris trichura, Hymenolepis nana*, and *Entamoeba histolytica*. The results show that all sludge samples collected from the six different sludge depths, were free from *Enterobious vermicularis, Hy-*

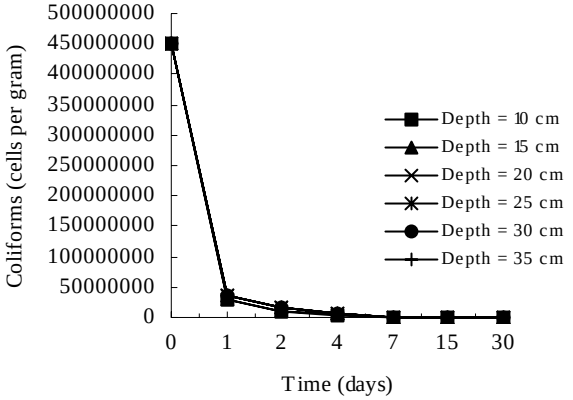

Fig. 1. Coliform Die-off at Different Initial Sludge Depths

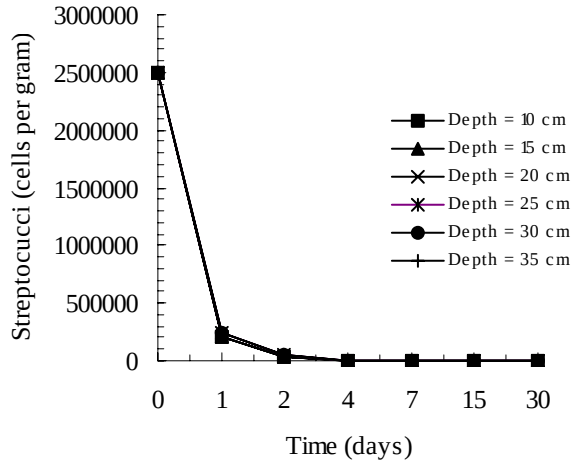

Fig. 2. Streptocucci Die-off at Different Initial Sludge Depths

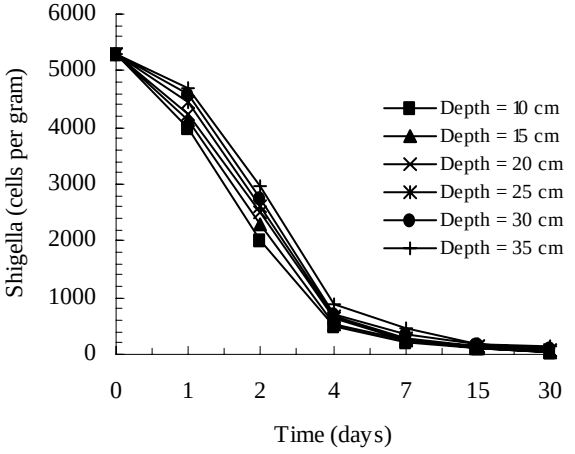

Fig. 3. Shigella Die-off at Different Initial Sludge Depths

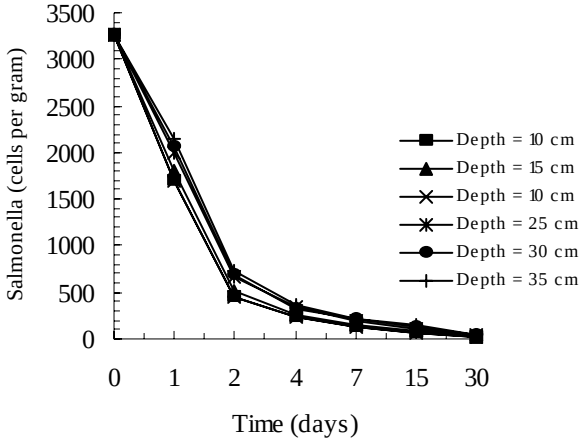

Fig. 4. Salmonella Die-off at Different Initial Sludge Depths

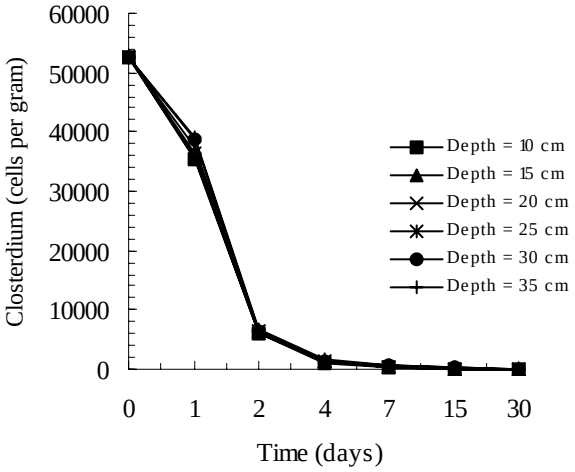

Fig. 5. Closterdium Die-off at Different Initial Sludge Depths

Regarding the effect of initial sludge depth on the survival of *Ascaris lumbricoides*, Fig. 6 shows that those parasites were decreasing with respect to drying period in sludge samples.The figure also shows that sludge samples collected from higher initial depths were containing higher number of *Ascaris lumbricoides*. After 2 days of drying, the number of *Ascaris lumbricoides* was 3, 4, 6, 7, 7, and 10 in sludge samples collected from drying beds with initial sludge depth of 10, 15, 20, 25, 30, and 35 cm, respectively. This can be attributed to the same reasons given on total *coliform*. The figure also demonstrates that the maximum rate of decrease in *Ascaris lumbricoides* was taking place during the first two days of drying. This could be attributed to the fact that water infiltration is maximum at the start of the drying time, which will result in washing out those parasites from sludge solids. Moreover, the figure shows that all sludge samples were free from *Ascaris lumbricoides*, after 30 days of drying.

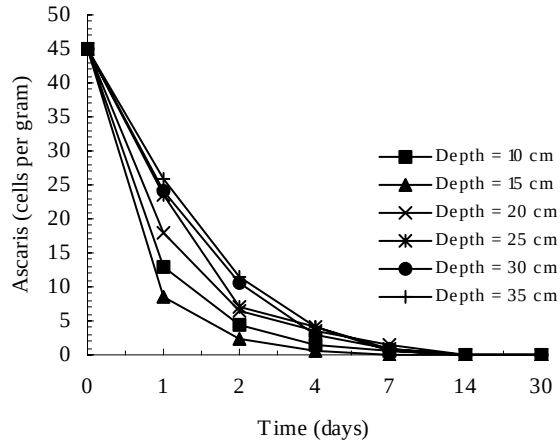

Fig. 6. Ascaris Die-off at Different Initial Sludge Depths

Fig. 7 shows the effect of initial sludge depth on the content of *Trichuris trichura* in sludge samples. The figure clearly demonstrates that as initial sludge depth was increased, the count of surviving *Trichuris trichura* in sludge samples increases, during the first days of drying. Sludge samples collected after two days of drying were found to contain *Trichuris trichura* counts of 1, 2, 4, 4, 5, and 7 when collected from drying beds with initial sludge depth of 10, 15, 20, 25, 30, and 35 cm, respectively. This is attributed to the same reasons given on *Ascaris lumbricoides*. The figure clearly demonstrates that all sludge samples were free from *Trichuris trichura*, after 30 days of drying.

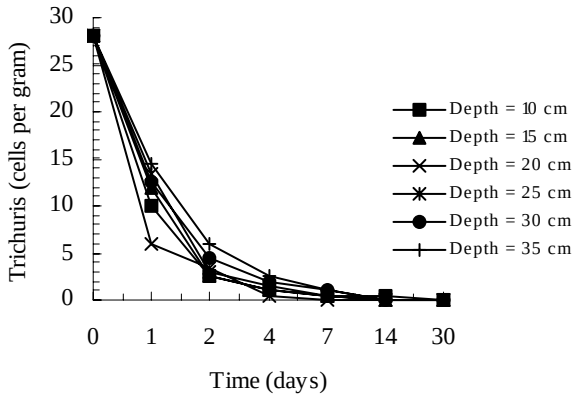

Fig. 7. Trichuris Die-off at Different Initial Sludge Depths

The effect of initial sludge depth on the contents of the protozoan parasite *Entamoeba histolytica* in sludge samples is shown in Fig. 8. As in the case of *Ascaris lumbricoides* and *Trichuris trichura*, the count of surviving *Entamoeba histolytica* was found to be affected by the initial sludge depth. After two days of drying, the *Entamoeba histolytica* counts were 1, 2, 2, 3, 5, and 8 for samples collected from drying beds with initial sludge depth of 10, 15, 20, 25, 30, and 35 cm, respectively. After 30 days of drying, the *Entamoeba histolytica* parasites were not detected in all sludge samples.

In order to best describe the obtained results, statistical analysis was implemented.Table 1 shows mathematical representations of the effect of the initial sludge depth on the fate of microorganisms under investigation.The table clearly shows that there is a general mathematical representation of all depths. The general representation is in the form of:

$$\ln(y) = A - B \times \ln(time)$$

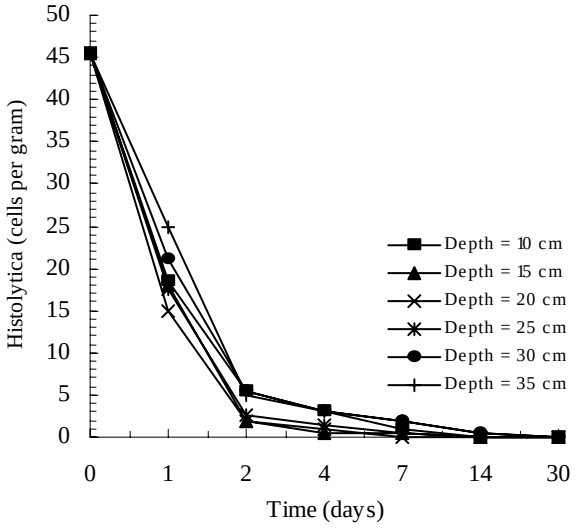

Fig. 8. Histolytica Die-off at Different Initial Sludge Depths

where
y = microorganism / gram of dry sludge
A and B = constants depend on initial sludge depth

The effect of the sludge initial depth on the values of constants A and B is clearly depicted in Table 2. which shows the different range of values and trends of constants A and B for the microorganisms under investigation when increasing the initial depth of the sludge in the drying beds.Generally, the values of constants A and B were found to increase with the increase in the initial sludge depth in the drying beds, except in two cases that are not explainable. In the case of the total coliform, the constants A and B were found to increase in the initial stage of increasing the sludge depth, but after that the values were almost constant. In order to come up with one approximated values of constants A and B, average values were found to be 8.05 and 1.79, respectively.Based on these results, the general mathematical representation of the process is the following form:

$$\ln(y) = 8.05 - 1.79 \times \ln(time)$$

The graphical representation of the approximated mathematical representation is shown in Fig. 9 which is represented by a solid line. The dashed line in Fig. 9. is the best fit of the data pertinent to all species. The figure clearly shows that the differences between the two attempts are insignificant. However, it is clear, from the figure, that the mathematical representation of the data was not satisfactory in both attempts. In order to improve the mathematical representation, average values of constants A and B for individual species were determine and presented in Table 3.

Table 1. Effect of Initial Depth on the Fate of Pathogens

Organism	Depth (m)	Empirical Model	R^2
Entamoeba histolytica	10	ln (y) = -1.43 × ln (time) + 2.87	0.98
	15	ln (y) = -1.90 × ln (time) + 2.45	0.90
	20	ln (y) = -1.95 × ln (time) + 2.49	0.93
	25	ln (y) = -1.71 × ln (time) + 2.60	0.95
	30	ln (y) = -1.30 × ln (time) + 2.91	0.97
	35	ln (y) = -1.34 × ln (time) + 2.98	0.95
Trichurus trichura	10	ln (y) = -1.17 × ln (time) + 1.92	0.91
	15	ln (y) = -1.61 × ln (time) + 2.30	0.98
	20	ln (y) = -1.79 × ln (time) + 2.03	0.90
	25	ln (y) = -1.62 × ln (time) + 2.48	0.98
	30	ln (y) = -1.29 × ln (time) + 2.47	0.997
	35	ln (y) = -1.36 × ln (time) + 2.71	0.996
Ascaris lumbricoides	10	ln (y) = -1.66 × ln (time) + 2.62	0.997
	15	ln (y) = -1.04 × ln (time) + 2.20	0.99
	20	ln (y) = -1.23 × ln (time) + 2.85	0.99
	25	ln (y) = -1.52 × ln (time) + 3.16	0.97
	30	ln (y) = -1.65 × ln (time) + 3.31	0.99
	35	ln (y) = -1.95 × ln (time) + 3.56	0.93
Clostridium	10	ln (y) = -2.26 × ln (time) + 10.3	0.99
	15	ln (y) = -2.07 × ln (time) + 10.2	0.99
	20	ln (y) = -1.95 × ln (time) + 10.15	0.99
	25	ln (y) = -1.88 × ln (time) + 10.14	0.98
	30	ln (y) = -1.82 × ln (time) + 10.14	0.98
	35	ln (y) = -1.77 × ln (time) + 10.13	0.98
Streptococcus	10	ln (y) = -2.72 × ln (time) + 12.18	0.98
	15	ln (y) = -2.67 × ln (time) + 12.19	0.98
	20	ln (y) = -2.63 × ln (time) + 12.19	0.98
	25	ln (y) = -2.58 × ln (time) + 12.46	0.98
	30	ln (y) = -2.53 × ln (time) + 12.46	0.99
	35	ln (y) = -2.54 × ln (time) + 12.29	0.98
Shigella	10	ln (y) = -1.28 × ln (time) + 7.28	0.98
	15	ln (y) = -1.18 × ln (time) + 7.31	0.97
	20	ln (y) = -1.17 × ln (time) + 7.38	0.98
	25	ln (y) = -1.10 × ln (time) + 7.44	0.98
	30	ln (y) = -1.06 × ln (time) + 7.43	0.97
	35	ln (y) = -1.03 × ln (time) + 7.47	0.98
Salmonella	10	ln (y) = -1.43 × ln (time) + 8.34	0.99
	15	ln (y) = -1.37 × ln (time) + 8.37	0.99
	20	ln (y) = -1.33 × ln (time) + 8.42	0.98
	25	ln (y) = -1.27 × ln (time) + 8.42	0.98
	30	ln (y) = -1.21 × ln (time) + 8.44	0.98
	35	ln (y) = -1.14 × ln (time) + 8.50	0.98
Total Coliform	10	ln (y) = -2.56 × ln (time) + 18.00	0.91
	15	ln (y) = -2.46 × ln (time) + 17.79	0.98
	20	ln (y) = -2.50 × ln (time) + 18.21	0.90
	25	ln (y) = -2.49 × ln (time) + 18.21	0.98
	30	ln (y) = -2.48 × ln (time) + 18.21	0.997
	35	ln (y) = -2.48 × ln (time) + 18.23	0.996

Table 2. Range Values and Trends of Constants A and B for Various Pathogens

Microorganisms	Constant A		Constant B	
	Value	Trend	Value	Trend
Entamoeba histolytica	2.45 – 2.98	Increasing	1.3 – 1.95	Increasing
Trichurus trichura	1.92 – 2.71	Increasing	1.17 – 1.79	Increasing
Ascaris lumbricoides	2.20 – 3.56	Decreasing	1.23 – 2.04	Increasing
Clostridium	10.13 – 10.3	Increasing	1.77 – 2.26	Decreasing
Streptococcus	12.18 – 12.46	Increasing	2.53 – 2.72	Increasing
Shigella	7.28 – 7.47	Increasing	1.03 – 1.28	Increasing
Salmonella	8.34 – 8.50	Increasing	1.14 – 1.43	Increasing
Total Coliform	17.97 – 18.23	Increasing	2.46 – 2.56	Increasing

Table 3. Average Values of Constants A and B for Various Microorganisms

Microorganisms	Constant A		Constant B	
	Range	Average	Range	Average
Entamoeba histolytica	2.45 – 2.98	2.72	1.3 – 1.95	1.61
Trichurus trichura	1.92 – 2.71	2.32	1.17 – 1.79	1.47
Ascaris lumbricoides	2.20 – 3.56	2.95	1.23 – 2.04	1.68
Clostridium	10.13 – 10.3	10.18	1.77 – 2.26	1.96
Streptococcus	12.18 – 12.46	12.30	2.53 – 2.72	2.61
Shigella	7.28 – 7.47	7.39	1.03 – 1.28	1.14
Salmonella	8.34 – 8.50	8.42	1.14 – 1.43	1.34
Total Coliform	17.97 – 18.23	18.14	2.46 – 2.56	2.50
Overall Average	**8.05**		**1.79**	

Mathematical representations using average values of constants A and B for individual species are shown in Figs (10 to 17). Generally, the figures clearly show that mathematical representations of the drying beds for individual species were dramatically improved when average values of constants A and B for individual species were used. Summary of mathematical representations of individual species are shown in Table 4.

CONCLUSION

The effect of sludge initial depth on the fate of pathogens namely, total *coliform, streptococci, shigella, salmonella,* and *clostridium* and helminthic and protozoan pathogens, namely, *Ascaris lumbricoides, Enterobious vermicularis, Ancylostoma doudenale, Trichuris trichura, Hymenolepis nana,* and *Entamoeba histolytica* of dried sludge samples was investigated for one full year. The investigation revealed that initial sludge depth was influencing the

Table 4. Average Values of Constants A and B for Various Microorganisms

Microorganisms	Average Constant A	Average Constant B	Empirical Model
Entamoeba histolytica	2.72	1.61	$\ln(y) = 2.72 - 1.61 \times \ln(\text{time})$
Trichurus trichura	2.32	1.47	$\ln(y) = 2.32 - 1.47 \times \ln(\text{time})$
Ascaris lumbricoides	2.95	1.68	$\ln(y) = 2.95 - 1.68 \times \ln(\text{time})$
Clostridium	10.18	1.96	$\ln(y) = 10.18 - 1.96 \times \ln(\text{time})$
Streptococcus	12.30	2.61	$\ln(y) = 13.30 - 2.61 \times \ln(\text{time})$
Shigella	7.39	1.14	$\ln(y) = 7.39 - 1.14 \times \ln(\text{time})$
Salmonella	8.42	1.34	$\ln(y) = 8.42 - 1.34 \times \ln(\text{time})$
Total Coliform	18.14	2.50	$\ln(y) = 18.14 - 2.50 \times \ln(\text{time})$

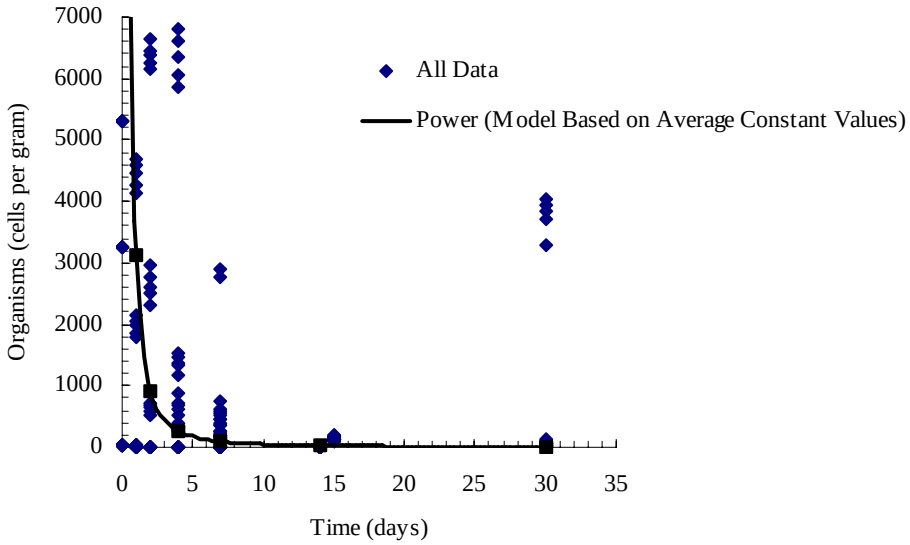

Fig. 9. Effect of Using Average Values of Constants A and B on the Empirical Model

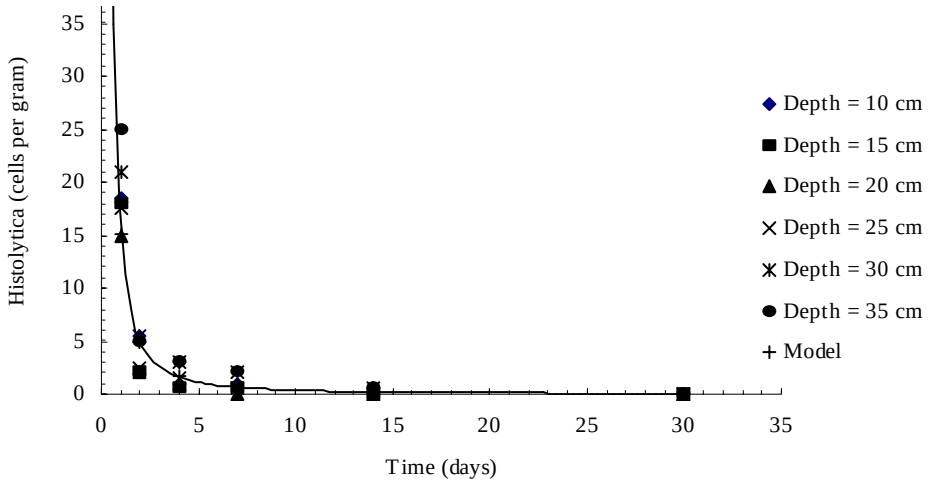

Fig. 10. Modeling of Histolytica Die-off Using Average Constant Values

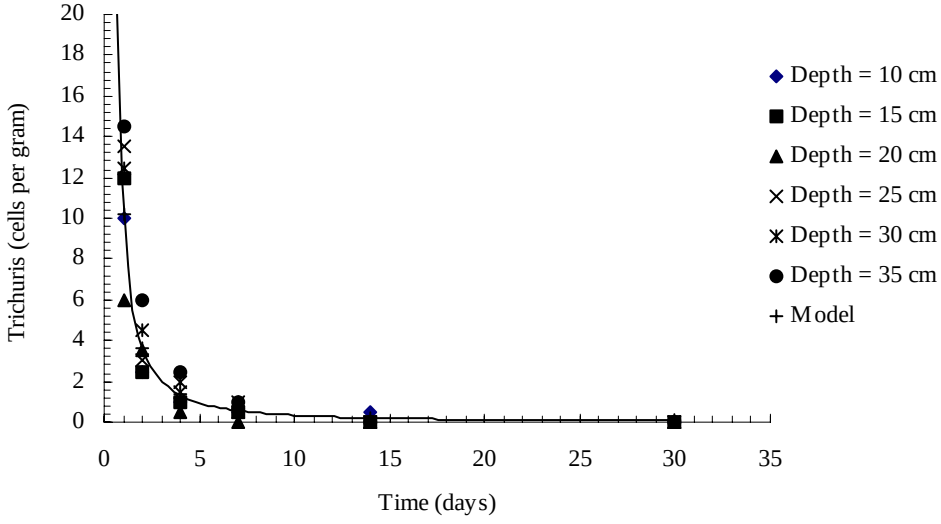

Fig. 11. Modeling of Trichuris Die-off Using Average Constant Values

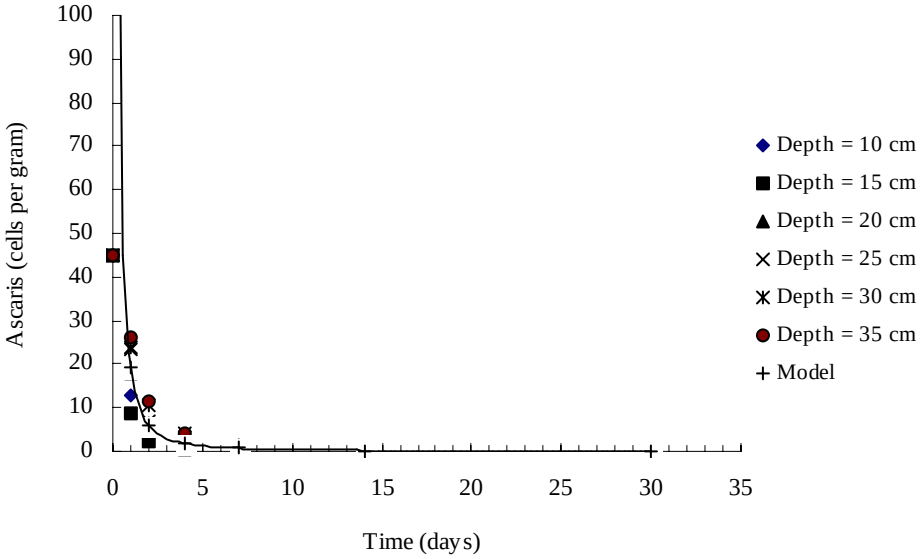

Fig. 12. Modeling of Ascaris Die-off Using Average Constant Values

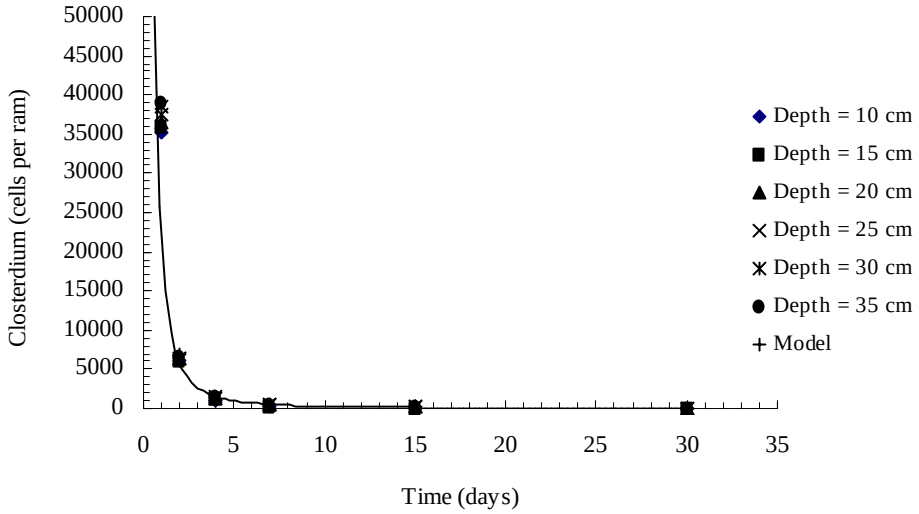

Fig. 13. Modeling of Closterdium Die-off Using Average Constant Values

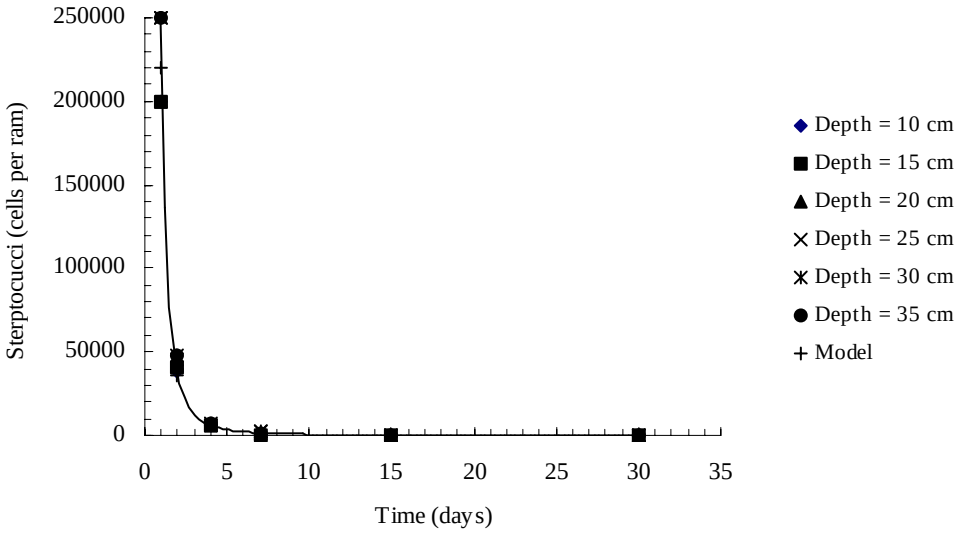

Fig. 14. Modeling of Streptocucci Die-off Using Average Constant Values

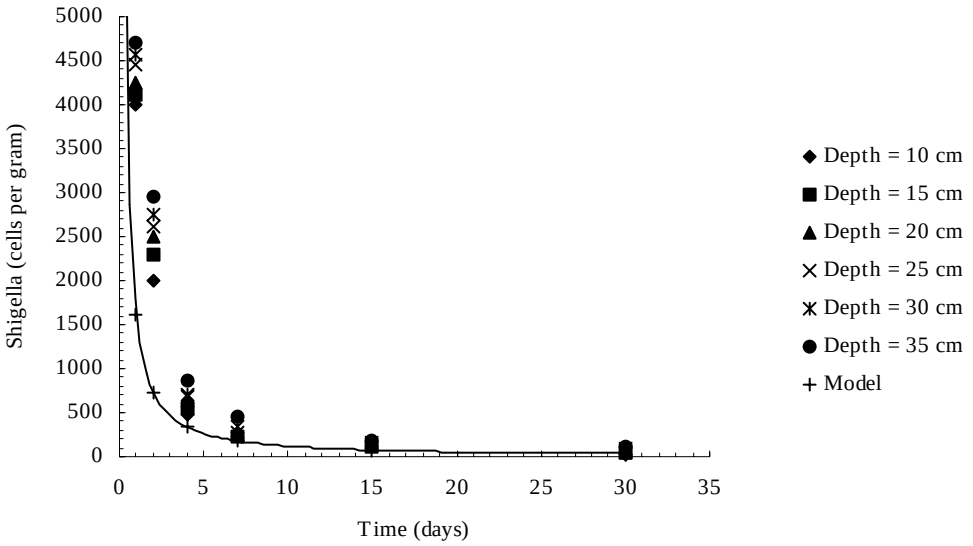

Fig. 15. Modeling of Shigella Die-off Using Average Constant Values

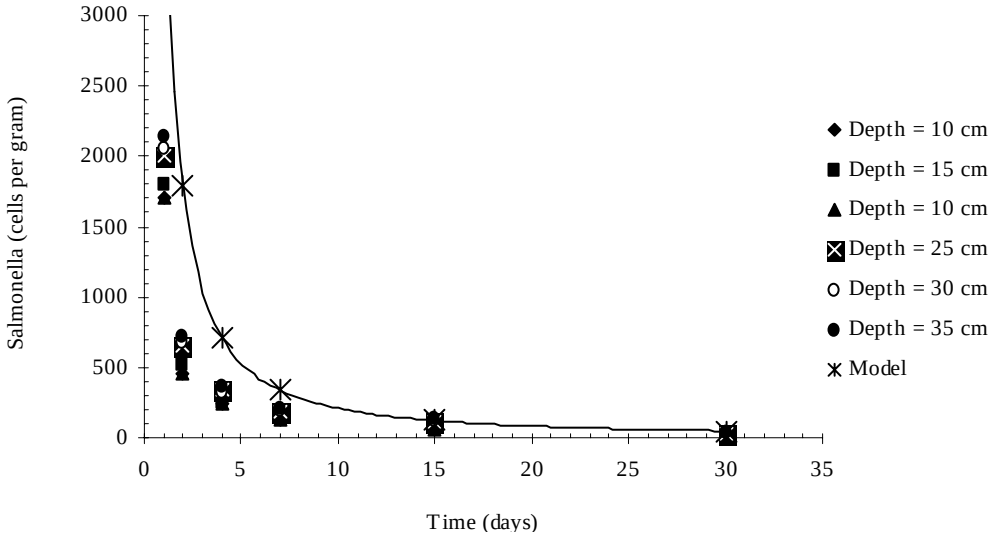

Fig. 16. Modeling of Salmonella Die-off Using Average Constant Values

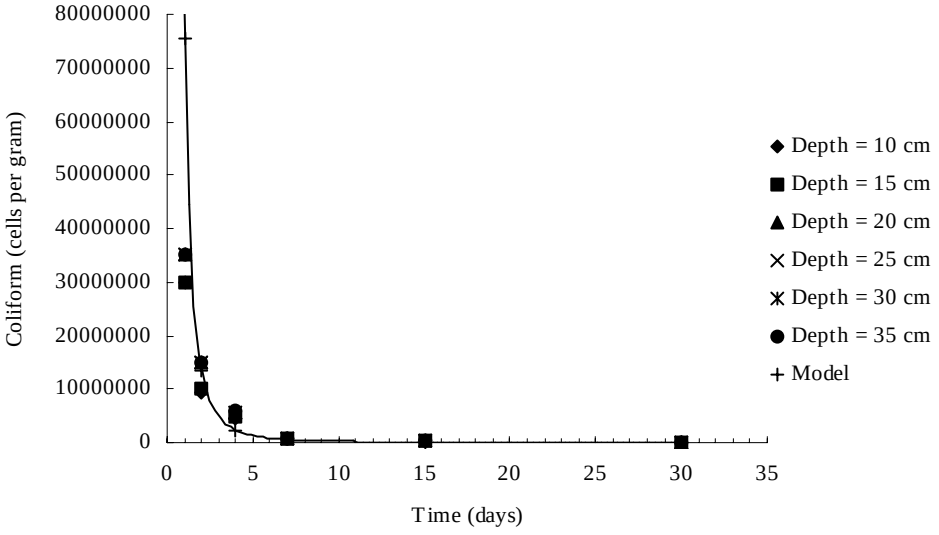

Fig. 17. Modeling of Coliform Die-off Using Average Constant Values

fate of pathogens under investigation. Mathematical representation of the drying beds revealed that the fate of pathogens, under investigation, with respect to drying time obeyed the following model:

$$\ln(y) = A - B \times \ln(time)$$

Moreover, the investigation showed that the use of constants (A and B) that are pertinent to individual species, in the model, produced better results than the use of overall average values of the constants.

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