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Original article

Modeling and simulation of fungi transport in waste dump site in Obioakpor, rivers Stater of Nigeria

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A B S T R A C T

Modeling and simulation of fungi transport in waste dump site has been evaluated. Mathematical model were developed considering all the variables in the system that influence transport process of fungi to ground water aquifers. Geologic history was found to influence the fast transport of fungi as presented in the figure. More so rapid increase of microbial growth were found to be influenced by porosity and permeability of the soil, geomorphology and geochemistry of the strategraphic were found insignificant on the transport process, these were experienced on high rate of microbial increase or growth as presented in the figure, the present of inhibitors (heavy metals) were also found to be insignificant, the study recommend that the derived model should be thoroughly apply to improve ground water quality in the study location.

1. Introduction

Modeling microbial processes in porous media is essential to improving our understanding of the biodegradation of contaminants and the movement of pathogens. Microbial processes incorporate physicochemical processes and biological processes. Microorganisms and their transport in the environment is a complex issue of growing concern. Most reactive transport models only consider physicochemical processes. The impact of biological processes in a flowing groundwater system can only be evaluated within this physicochemical framework (Murphy and Ginn, 2000). The physicochemical processes are primarily based on the physical structure and chemical properties of the subsurface flow system and porous media. Microbial mobility dominated by physicochemical interaction with the porous media is mainly described with the colloid infiltration model (Li, 2006).

The transport behavior of microorganisms in the subsurface environment is of great significance with respect to the fate of pathogens associated with wastewater recharge, riverbank filtration, septic systems, feedlots, and land application of biosolids. A common element to most of these applications is that the associated aqueous solutions typically have relatively high concentrations of dissolved organic carbon. Thus, the potential influence of DOC on pathogen transport is of interest. The factors affecting the transport and fate of viruses and bacteria in the subsurface have received significant attention (e.g., Yates and Yates, 1988; Schijven and Hassanizadeh, 2000; Ginn et al., 2002). Bacteriophages are often used as a surrogate to evaluate the transport and fate of pathogenic viruses. They serve as useful models because they are similar in size and structure to many enteric viruses in some condition, do not pose a human-health hazard, and are relatively inexpensive. MS-2 Bacteriophages was used in this study, and is considered a model virus for use in transport studies because it is relatively persistent during transport (e.g., Schijven, et al. 1999). MS-2 has been classified as a group I virus, which are those whose transport is considered to be influenced by soil characteristics such as pH, exchangeable iron, and organic matter content (Gerba and Keswick., 1981). Several prior studies have examined the transport of MS-2 in porous media (Hurst et al. 1980; Bales et al. 1993; 1997; Schijven, et al. 1999, 2002, 2003; Jin et al. 2000; Hijnen et al. 2005). The objective of this study was to investigate the influence of dissolved organic carbon on MS-2 Bacteriophages transport in a sandy soil. Miscible-displacement experiments were conducted to examine the retention and transport of MS-2, at two influent concentrations, in the absence and presence of DOC. The experiments were conducted by Alexandra Chetochine. The results of the experiments were analyzed with a mathematical model that incorporated inactivation and rate-limited attachment/detachment.

2. Theoretical background of the model

Mass balance on plug flow system in soil porosity and permeability can be expressed as

INPUT – OUTPUT – REACTION = ACCUMULATION

$$VoCAf = V \bullet \left[Vo\left(CAf + d\,CAf \right) \right] \bullet \left[\left(Vav \right) \partial Z \right] = \frac{\partial}{\partial t} \quad \text{..............................} \quad (1)$$

$$q \partial CAf \bullet \partial Z \quad \text{..} \quad (2)$$

Dividing the equation by *dz* and taking limit *adz* *0* .... ⟶ (3)

$$\varepsilon = \frac{\partial CAf}{\partial t} + Vo \frac{\partial CAf}{\partial z} + Vav = 0 \quad \text{..............................} \quad (4)$$

But for first order reaction fluid only

$$YAv \left[\frac{Mol}{M^3\, reactor} \right] - \frac{1}{V} \frac{\partial NA}{\partial z} + Kd(nk)CAf \quad \text{..............................} \quad (5)$$

Where,

n = Porosity and

K = permeability of the soil

$$\frac{\partial CAf}{\partial z} = 0$$

Therefore, $$Vo\frac{\partial C}{\partial z} + K(nk)CAf = 0 \qquad \text{..................................} \quad (6)$$

Considering the function of height integrating with *CAf = CAf* at *Z = 0*

$$X_A = \left[\frac{CAf}{CAf\ in} - \right] - \exp K_1^n\left((nk)Z\right) \qquad \text{..................................} \quad (7)$$

Balance on solid state

- ∂A (Fluid) + (Solid) → Product
- Input – Output reaction = Accumulation
- Over increment of ∂Z: Input = *0* Output = *0*.

$$-\left(YSv - \right)(nk)\frac{\partial C}{\partial t} - \Delta Z \qquad \text{..................................} \quad (8)$$

$$\frac{\text{Porosity and permeability}}{M^3\ of\ reactor\ volume} \qquad \frac{Mol}{M^3\ reactor}$$

$$(nk)\frac{\partial C}{\partial t} + YSv = 0 \qquad \text{..................................} \quad (9)$$

$$-(YSv) = \alpha(YSv) \qquad \text{..................................} \quad (10)$$

$$(nk)\frac{\partial C}{\partial t}Af + \frac{\partial CAf}{\partial Z}Af + Y\alpha v = 0 \qquad \text{..................................} \quad (11)$$

Substituting *YAf* equation (12) yields

$$\frac{\partial Cs}{\partial t} + \frac{Y\alpha v}{\alpha(nk)} = 0 \qquad \text{..................................} \quad (12)$$

$$\frac{\partial Cs}{\partial t} + \frac{Y\alpha v}{\alpha(nk)} - 0 \qquad \text{..................................} \quad (13)$$

$$\frac{\partial CAf}{\partial Z} - \frac{\partial Cs}{\partial t} = 0 \qquad \text{...} \qquad (14)$$

$$C^1 Af = f(Z,t) \qquad \text{...} \qquad (15)$$

$$C^1 s = f(Z,t) \qquad \text{...} \qquad (16)$$

E. coli transport is a continuous process as reflected in plug system application influenced by porosity and permeability.

Solve

$$\frac{\partial CAf}{\partial Z} - \alpha(nk)\frac{\partial C}{\partial t} = 0 \qquad \text{...} \qquad (17)$$

Considering when *CAf* = Cs, thus equation (17) can be written as

$$\frac{\partial C}{\partial Z} - \frac{(nk)}{Vo}\frac{\partial C}{\partial t} = 0 \qquad \text{...} \qquad (18)$$

Where *C = CAf = Cs* .... (19)

Applying separation of variables considering the coordinate of *Z* in terms of time dependent, thus equation (18) can be expressed as

C = TZ

Integrating boundary conditions are *t = 0, C = CoZ*

Therefore, $$\frac{\partial C}{\partial Z} = TZ^1 \qquad \text{...} \qquad (20)$$

$$\frac{\partial C}{\partial Z} = T^1 Z \qquad \text{...} \qquad (21)$$

Integrating equation (20) and (21) into equation (18) yield

$$TZ^1\left(\ell^{nk}\right)T^1 Z = 0 \qquad \text{...} \qquad (22)$$

Therefore

$$TZ^1 = \ell^{(nk)} T^1 Z = 0 \qquad \text{...} \quad (23)$$

$$\frac{Z}{Z} = \ell^{nk} \frac{T^1}{T^1 Z} = \lambda^2 \qquad \text{...} \quad (24)$$

$$Z^1 = \lambda^2 \qquad \text{...} \quad (25)$$

$$\frac{1}{Z} \frac{\partial Z}{\partial Z} = \lambda^2 \qquad \text{..} \quad (26)$$

$$\int \frac{\partial Z}{\partial Z} = \int^{-\lambda^2} \partial Z \qquad \text{...} \quad (27)$$

$$Ln\, Z = -\lambda^2 Z + C_1 \qquad \text{...} \quad (28)$$

$$Z\lambda^2 + C_1 = \ell^{-\lambda^2 Z} \qquad \text{...} \quad (29)$$

$$Z = A_0 - \ell^{\lambda^2 Z} \qquad \text{...} \quad (30)$$

$$\ell^{(nk)} \frac{T^1}{T} = \lambda^2 \qquad \text{...} \quad (31)$$

$$Ln\, T = \frac{\lambda nk}{\alpha} + C_2 \qquad \text{..} \quad (32)$$

$$\ell^{-\lambda^2 \frac{nkt}{\alpha}} \bullet \ell^{C_2} \qquad \text{...} \quad (33)$$

$$T = \beta \ell^{\frac{\lambda^2 nkt}{\alpha}} \qquad \text{..} \quad (34)$$

But $C = TZ$

$$\boxed{C = \beta^{\frac{\lambda^2 nkk}{\alpha}} \bullet A\ell^{-\lambda^2 Z}} \qquad \text{..} \quad (35)$$

$$i.e.\ C = A\beta^{\frac{\lambda^2 nk}{\alpha}t \; -Z} \qquad (36)$$

At $0\ Zo = C_{(o)} = Co$

$$C = C_o \ell^{\frac{\lambda^2 (nktZ)}{\alpha}} \qquad (37)$$

Therefore, Transfer in the above equation into sinusoidal curve, so that we have

$$C = C_o \, Sin\left(\frac{nk}{\alpha}t + Z\right) \qquad (38)$$

$$\boxed{C = C_o \, Sin\left(\frac{nk}{\alpha}t + Z\right)V} \qquad (39)$$

3. Result and discussion

Results and disunion for modeling and simulation in waste dump site in obioAkpor Niger delta are presented in tables and figure

Table 1
theoretical and experimental values at various depths.

Depth m	Theoretical values	Experimental values
3	4.66	4.34
6	9.33	9.44
9	14.01	14.11
12	18.67	18.51
15	23.33	21.98
18	28.01	29.11
21	32.68	34.22
24	37.35	37.23
27	42.01	42.56
30	46.66	45.98

Table2
theoretical and experimental values at various depths.

Time	Theoretical values	Experimental values
10	4.66	4.34
20	9.33	9.44
30	14.01	14.11
40	18.67	18.51
50	23.33	21.98
60	28.01	29.11
70	32.68	34.22
80	37.35	37.23
90	42.01	42.56
100	46.66	45.98

Table 3
theoretical and experimental values at various depths.

Depth m	Theoretical values	Experimental values
1.5	1.1	0.9
3	2.29	2.55
4.5	3.48	3.51
6	4.68	4.55
7.5	5.87	5.66
9	7.1	6.89
10.5	8.26	8.56
12	9.46	9.55
13.5	10.65	10.44
15	11.84	11.78

Table 4
theoretical and experimental values at various depths.

Time	Theoretical values	Experimental values
3	1.1	0.9
7	2.29	2.55
14	3.48	3.51
21	4.68	4.55
28	5.87	5.66
35	7.1	6.89
42	8.26	8.56
49	9.46	9.55
56	10.65	10.44
63	11.84	11.78

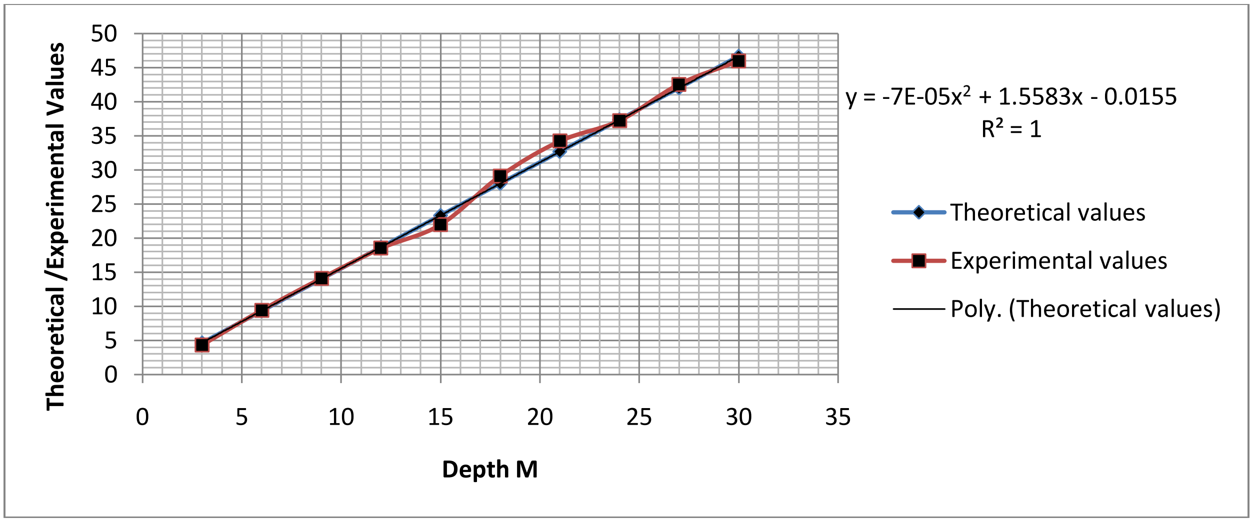

Fig. 1. theoretical and experimental values at various depth.

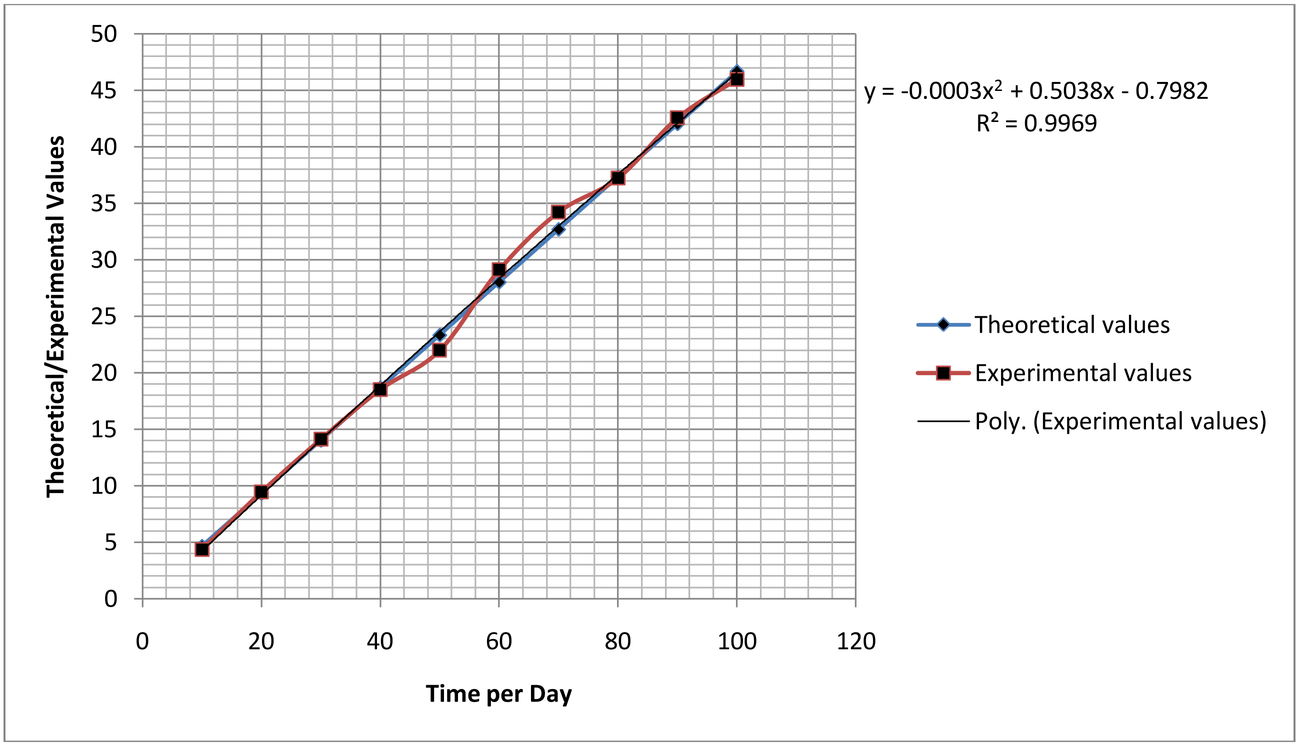

Fig. 2. theoretical and experimental values at various depth.

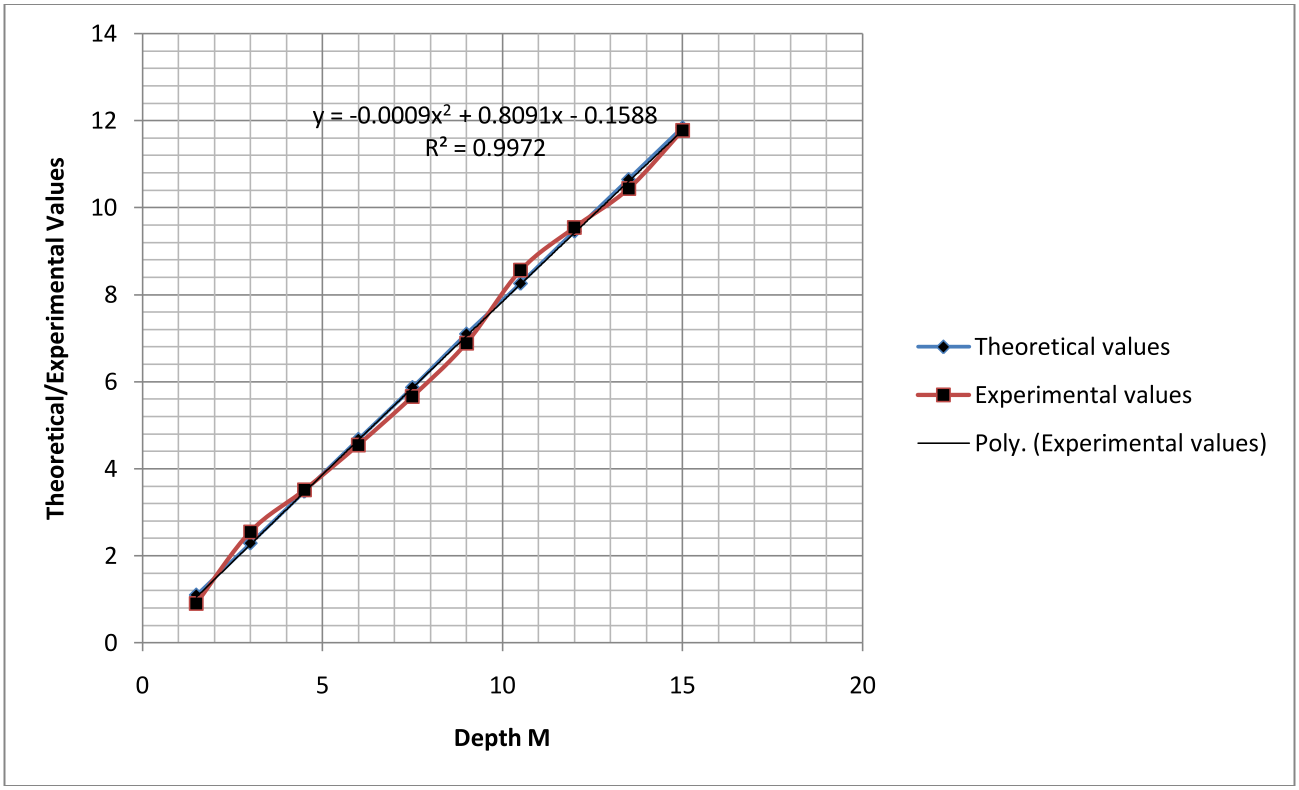

Fig. 3. theoretical and experimental values at various depth.

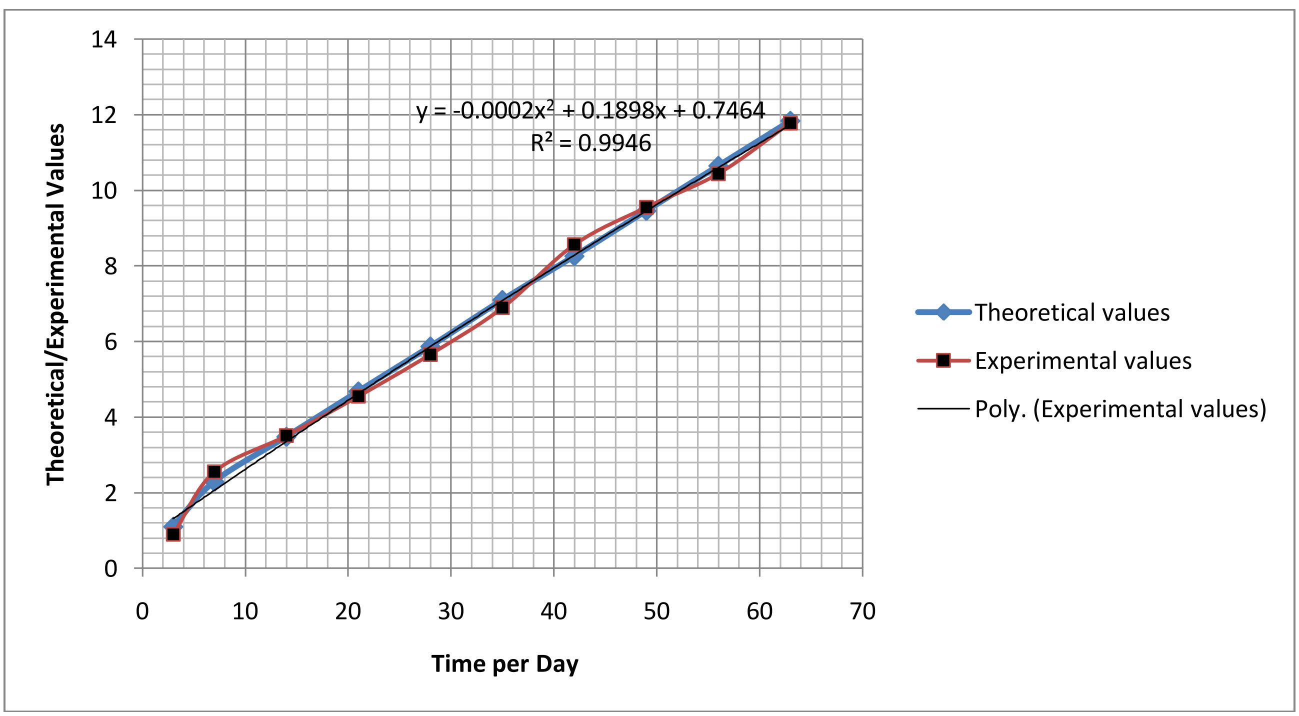

Fig. 4. theoretical and experimental values at various depths.

Figure one shows that the microbes gradually increase to a point were the optimum values were recorded at thirty meters similar, condition can be attributed to the experimental value this condition implies that the transport process experience rapid growth under the influence of substrate utilization that deposit in the formation both parameters compared favorably well. Figure two have a similar trend to figure one, formation characteristics where found to influence the transport process at different formation. The microbes were influenced by the soil structural stratigarphy influence by geomorphology and geochemistries of the formation were insignificant on the transport process. as it could not influence the microbial growth. The increase at various depths explained the high rate of fungi pollution as presented in the figure, optimum value were recorded at hundred days. Similar condition were experienced in figure three as the microbial growth were increasing at various depth under the influence of porosity and permeability of the soil, as an alluvia deposit that develop homogenous formation, the influence of permeability and porosity where predominant in the study location. Fast migration of fungi can also be attributed to environmental factors.

Figure four experienced linear transport of the microbes, were by both parameters linearly increase to the optimum value as sixty-three days the microbes were monitored at intervals or seven days and resulted to increase in microbial population, predominant influence from high rate hydraulic conductivity in the soil plays a major role on the transport process. These conditions were found to generate a lot of water pollution emanating from fungi transport in the study location as deltaic in nature shallow aquifers are predominant in the study location, and that allowed for fast contamination of ground water in the study area.

4. Conclusion

Modeling and simulation of fungi transport in waste dump site has been thoroughly examined. Mathematical model were developed to monitor the transport process in waste dump site. The models were simulated in other to examine the transport process in phreatic aquifers. the result shows that microbial transport increase rapidly in a linear condition between ten to hundred days and three to thirty meters. This condition can be attributed to high degree of substrate utilization including high rate of porosity and the deposition of the soil structure such observation implies that high rate of water related diseases are caused by these source of water pollution. The model is imperative because its serve as a base line in monitoring fungi transport in the study location. It also serve as a benchmark for practicing engineers and scientist to understand the behavior of this type of microbial transport in shallow aquifers, it is recommended that the model developed should be apply in design and construction of ground water in other to produce quality ground water for human consumption.

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