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Research article

PREDICTIVE MODEL TO MONITOR THE RATE OF BACILLI TRANSPORT THROUGH FLUID PRESSURE IN UNCONFINED FORMATION IN ELEME RIVERS STATE OF NIGERIA

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Abstract

Bacilli is one of the microbial specie that are found in water, these microbes are generated from biological waste, constant regeneration of biological waste produce accumulation of this type of microbial specie, it transport between the fluid passing through the flow part of the soil formation to aquiferous zone, the formation are found to be homogenous between the porous media, high concentration of these contaminant are influence by the porous medium, this condition can be attributed to high rate of hydraulic conductivity in the formation. Mathematical model was develop to monitor the rate of bacilli at different formation, It is recommended that ground water design should be thoroughly design to prevent bacilli contaminant in the study area. The study is imperative because the trace of bacilli has been a threat to human settlement in the study location.

Keywords: water, biological waste, Mathematical model,

1. Introduction

In order to develop a model that simulates bacterial die-off and transport processes, it is necessary to understand what bacterial models currently exist and how bacteria survive under different conditions, such as in storage, in fecal deposits, and in soils. Literature sources provided information regarding the aforementioned subjects; relevant information is presented in the following sections. Pathogens are organisms, such as viruses and some bacteria, which are able to inflict damage on hosts that they infect [Mostaghim et al 1989]. Enumeration of pathogens is often time-consuming technically intensive, and costly; therefore, pathogen presence is often estimated through the utilization of indicator organisms. The presence of indicator organisms means that pathogenic organisms may be present. Water quality standards, which vary from state to state, are typically based upon the presence/absence or concentration of indicator organisms such as Enterococcus bacteria, fecal coliform (FC), and *Escherichia coli* (EC) [USEPA,2002]. Because FC and EC are found in the intestines of warm-blooded animals, their presence is indicative of fecal contamination. Potential sources of fecal contamination in water bodies include land-applied manure and sludge, manure from grazing animals, wildlife feces, combined sewer overflows, and failing septic systems. [Youngblood, 2001] Investigated a potential alternative to testing waters for indicator organisms. The objective of her study was to determine if nutrient concentrations in runoff could be correlated with the presence and concentration of indicator organisms. Because nutrient testing is generally less time-consuming and expensive than bacterial testing, a correlation between nutrients and pathogens or indicator organisms could potentially provide a more cost-effective water body assessment tool. [Youngblood, 2001], land-applied different types of animal manure, including dog, horse, beef, swine, turkey, and sheep, to pasture plots and measured the runoff water quality. She found that nutrients were correlated with FC for all manure types, although the correlation was not quantified. The [Coyne and Bleyins,1995] study was the only work found that investigated the link between nutrients and indicator organisms. Further research in this area may provide a viable alternative for estimating pathogen presence in Water bodies. Processes that are important to bacterial survival should be included in a bacterial nonpoint source model, including bacterial growth/die-off; sorption of bacteria to the soil matrix; partitioning of bacteria between water and sediment; and effects of management practices [Huysmans and Verstraete, 1993, Walker et al1990 Reddy et al, 1981, Mancini, 1978, and Crane and Moore, 1995]. In addition, if in-stream bacterial concentrations are of concern, then in stream processes must be modeled because bacterial populations are dynamic and are affected by growth/die-off and settling, as well as re-suspension of bottom materials [Polprate et al, 1988] described three commonly observed patterns of coliform die-off: first-order decay; bacterial growth followed by first-order die-off; and die-off rate that changes with time. The first-order decay equation often used to describe bacterial die-off is expressed as Chick's Law [Crane and Moore, 1985] Modifications of Chick's Law by [Mancini,1978,Crane and Moore, 1985, 9] adjust the die-off rate constant for environmental impacts of temperature, solar radiation, pH, and/or soil moisture content. [Crane and Moore, 1985] Researcher express the ability of waste stabilization ponds to reduce total and fecal coliform concentrations in wastewater, which was approximately the equivalent bacterial concentration of domestic waste, under both controlled (laboratory) and field conditions. They noted that algal concentration, organic loading, and temperature influenced bacterial reductions in the waste stabilization ponds: increasing temperature (up to 30^oC) increased the die-off rate constant; increasing algal concentration increased the die-off rate constant, and an increase in organic loading decreased the die-off rate constant. [Kimberly,2002] Also stated that algal concentrations are directly related to solar radiation and, therefore, solar radiation is also indirectly represented in their die-off rate calculations.

2. Materials and Method

Column experiments were also performed using soil samples from several borehole locations, the soil samples were collected at intervals of three metres each (3m). bacilli solute was introduced at the top of the column and effluents from the lower end of the column were collected and analyzed for bacilli, and the effluent at the down of the column were collected at different days, analysis, velocity of the transport were monitored at different days. Finally, the results were collected to be compared with the theoretical values.

3. Theoretical Background

$$Sop\frac{\partial^2 p}{\partial t^2} + \left[\varepsilon w\frac{\partial p}{\partial t}\right] w\frac{\partial p}{\partial t} - \frac{\partial p}{\partial x_1}\left[\frac{K_1 p}{\mu}\right]\left[\frac{\partial p}{\partial x_j} + pg\frac{\partial p}{\partial x_i}\right] = QP_z \qquad \ldots\ldots\ldots\ldots \qquad (1)$$

Taking Laplace transformation of (1)

$$\frac{\partial^2 p}{\partial t^2} = S^2 P_{(t)} - SP - P_{(0)} \qquad \ldots\ldots\ldots \qquad (2)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \qquad \ldots\ldots\ldots \qquad (3)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \qquad \ldots\ldots\ldots \qquad (4)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \qquad \ldots\ldots\ldots \qquad (5)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \qquad \ldots\ldots\ldots \qquad (6)$$

$$P = P_{(0)} \qquad \ldots\ldots\ldots \qquad (7)$$

Submitting equation (2), (3), (4), (5), (6) and (7) into equation (1), yields

$$Sop\left[S^2P_{(t)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w\left[SP_{(t)} - P_{(0)}\right]w\left[SP_{(t)} - P_{(0)}\right] - \left[SP_{(x)} - P_{(0)}\right]\frac{Kp}{\mu}$$

$$\left\|SP_{(t)} - P_{(0)} + Pg\,(SP_{(t)} - P_{(0)})\right\| = QPz \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$-\,2SP_{(x)}P_{(0)} - (P_{(0)})^2 + Pg\left(SP_{(t)}\right)^2 - 2SP_{(x)}P_{(0)} - (P_{(0)}{}^2) = QP_z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Equating (9) with respect to time, *t*, we have

$$Sop\left[S^2P_{(0)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w^w\left[(SP_{(t)})^2 - 2SP_{(0)} + P_{(0)})^2\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Equating (9), with respect to Time direction of flow gives

$$-\frac{Kp}{\mu}\left(Sp_{(x)}\right)^2 - 2SP_{(t)}P_{(0)} + \left(P_{(0)}\right)^2 + Pg\left(Sp_{(x)}\right)^2 - 2SP_{(t)}P_{(0)} + \left(P_{(0)}\right)^2 = QP_Z \quad \ldots\ldots\ldots\ldots \quad (11)$$

Rearranging (11), yields

$$a^2 - 2ap + P(a-p)^2$$

$$(1+Pg)\left(Sp_{(x)}\right)^2 - (1+Pg)2SP_{(t)}P_{(0)} + (1+Pg)\left(P_{(0)}\right)^2 = \frac{QP_Z\,\mu}{K,P} \quad \ldots\ldots\ldots\ldots\ldots \quad (12)$$

$$\left[\left(Sp_{(x)}\right)^2 - 2SP_{(t)}P_{(0)} + \left(P_{(0)}\right)^2\right](1+Pg) = -\frac{QP_Z\,\mu}{K,P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\left(Sp_{(x)}\right)^2 - 2Sp_{(x)}P_{(0)} + \left(P_{(0)}\right)^2 = -\frac{QP_Z\,\mu}{K,P(1+Pg)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

$$\left[Sp_{(x)} - P_{(0)}\right]^2 = -\frac{QP_Z\,\mu}{K,P(1+Pg)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$\left[Sp_{(x)} - P_{(0)}\right]^2 Sp_{(x)} - P_{(0)} = -\sqrt{\frac{-QP_Z\,\mu}{K,P(1+Pg)}} = \pm i\sqrt{\frac{QP_Z\,\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$P_{(x)} = P_{(0)} \pm i\sqrt{\frac{QP_Z\,\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (17)$$

$$Sp_{(x)} = P_{(0)} \pm i\sqrt{\frac{QP_Z\,\mu}{K,P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots \quad (18)$$

When $x > 0,\ P_{(0)} = P_0$

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$$P_{(x)} = \frac{P_0}{S} \pm i \sqrt{\frac{QP_Z \mu}{K, P(1+Pg)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Hence in any direction *x*, we have

$$P_{(x)} = \ell^{P_0/S} \left[A\, Cos \sqrt{\frac{\frac{QP_Z \mu}{K, P(1+Pg)}}{S}} \; + \; B\, Sin \sqrt{\frac{\frac{QP_Z \mu}{K, P(1+Pg)}}{S}} \right] x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

$$\Rightarrow \quad P_{(x)} = \ell^{P_{0_t}} \left[A\, Cos \sqrt{\frac{\frac{QP_Z \mu}{K, P(1+Pg)} t}{S}} \; + \; B\, Sin \sqrt{\frac{\frac{QP_Z \mu}{K, P(1+Pg)} t}{S}} \right] x \quad \ldots\ldots\ldots\ldots \quad (21)$$

Again, we consider (10) so that we have

$$Sop\left[S^2 P_{(t)} - SP_{(t)} - P_{(0)}\right] + \varepsilon w^w \left[(SP_{(t)})^2 - 2SP_{(t)} P_{(0)} + P_{(0)})^2\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

$$Sop\left[S^2 P_{(t)} - SP_{(t)} - P_{(0)}\right] = -\, \varepsilon w^w\, (SP_{(t)} - P_{(0)})^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

$$\frac{S^2 P_{(t)} - SP_{(t)} - P_{(0)}}{\left(SP_{(t)} - P_{(0)}\right)^2} = \frac{-\varepsilon w^w}{Sop} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

$$SP_{(t)} - P_{(0)} \neq 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

Considering the left hand side of the number of (23) gives

$$P_{(t)} = \frac{S \pm \sqrt{S^2 + 4S^2 P_{(o)}}}{2S^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (26)$$

$$P_{(t)} = \frac{\frac{1}{2S} \pm \sqrt{1 + 4P_{(o)}}}{2S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

When $t > 0,\ P_{(o)} = P_o$

So that $P_{(t)} = \frac{1}{2S} \pm \frac{\sqrt{1 + P_o}}{2S}$

Hence $P_{(t)} = A\ell^{\frac{1}{2}\left(1 + \sqrt{1 + P_o}\right)^t} + B\ell^{\frac{1}{2}\left(1 - \sqrt{1 + P_o}\right)^t}$ ………………………….. (28)

Since the Denominator of the left hand side of (23) has equal roots;

$$P_{(t)} = \frac{-\varepsilon w^w}{Sop} \left(C + Dt\right) \ell^{(t - P_o)^t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

Combining equation (28), we have

$$P_{(t)} = \frac{-\varepsilon w^{w}}{Sop}\left(C+Dt\right)\ell^{(t-P_o)^t} + A\ell^{\frac{1}{2}\left(1+\sqrt{1+P_o}\right)^t} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+P_o}\right)^t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

But if $t = \frac{x}{v}$

$$\boxed{P_{(x,v)} = A\ell^{\frac{1}{2}\left(1+\sqrt{1+P_o}\right)^t} + B\ell^{\frac{1}{2}\left(1-\sqrt{1+P_o}\right)^{\frac{x}{v}}} - \frac{\varepsilon w^{w}}{Sop}\left(C+Dt\right)\ell^{(1-P_o)^{\frac{x}{v}}}} \quad \ldots\ldots\ldots\ldots\ldots \quad (31)$$

4. Results and Discussion

Predictive model to monitor the rate of bacilli transport through fluid pressure in unconfined formation are presented in tables and figures.

Table 1: Comparison of theoretical and Experimental values of bacilli at various Depths

Depth	Theoretical values	Experimental values
3	0.25	0.21
6	3.72	3.45
9	8.41	8.34
12	14.98	15.11
15	23.43	23.78
18	37.77	37.67
21	39.42	41.11
24	60.11	61.11
27	73.85	72.78
30	93.97	92.87

Table 2: Comparison of theoretical and Experimental values of bacilli at various Depths

Depth	Theoretical values	Experimental values
3	1.43	1.34
6	5.79	5.45
9	3.66	4.1
12	6.71	6.44
15	9.68	9.22

18	15.87	15.56
21	22.11	22.23
24	29.52	31.2
27	38.17	37.34
30	48.11	48.23

Table 3: Comparison of theoretical and Experimental values of bacilli at various Depths

Depth	Theoretical values	Experimental values
3	-4.47E-04	-4.34E-04
6	8.59E-04	8.45E-04
9	3.92E-03	3.45E-04
12	8.77E-03	6,54E-04
15	1.50E-02	1.47E-02
18	2.30E-02	2.14E-02
21	3.30E-02	3.24E-02
24	4.50E-02	4.77E-02
27	5.90E-02	5.78E-02
30	7.50E-02	7.45E-02

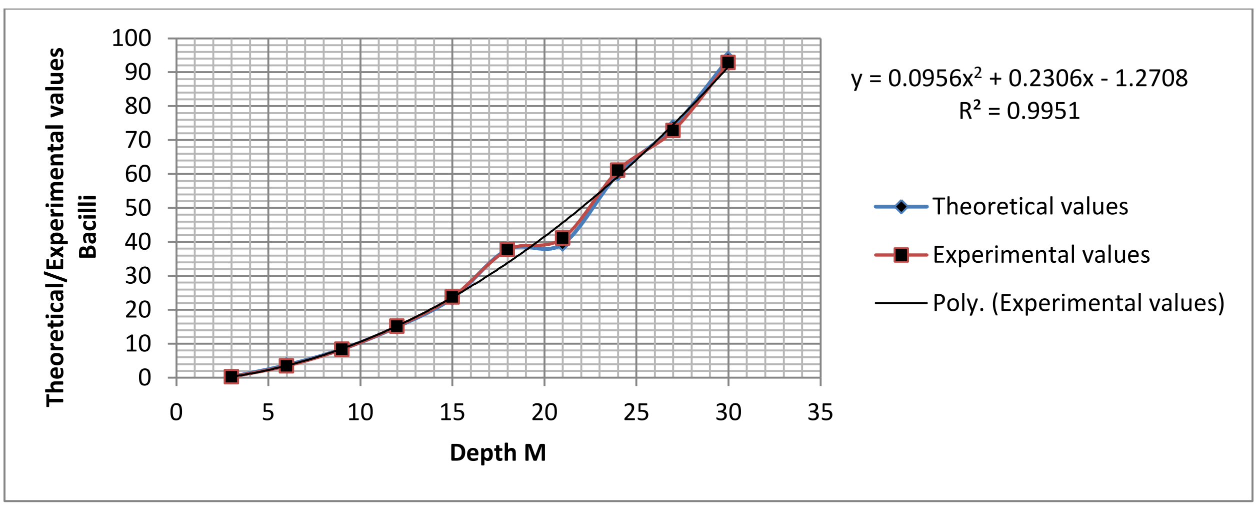

Figure 1: Comparison of theoretical and Experimental values of bacilli at various Depths

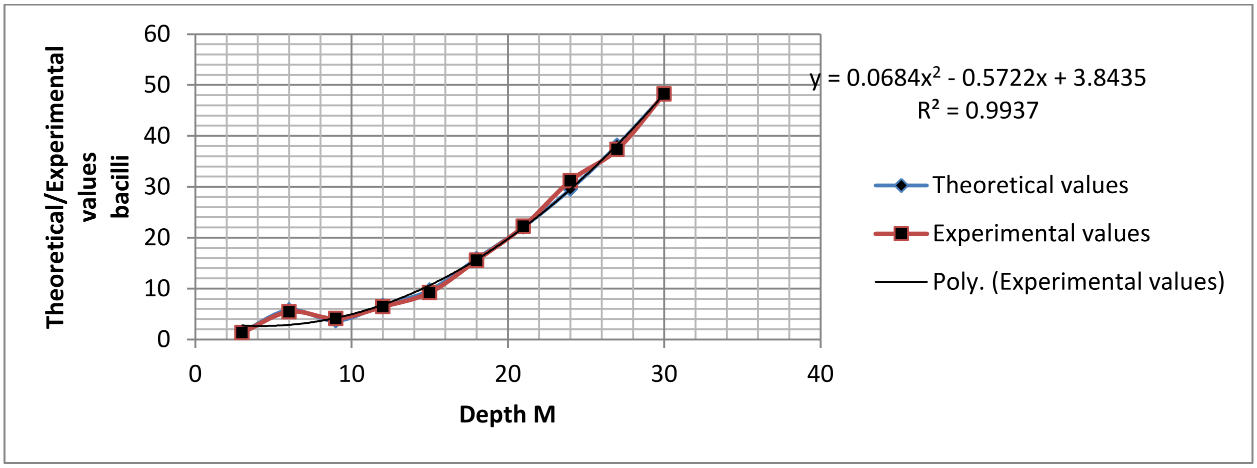

Figure 2: Comparison of theoretical and Experimental values of bacilli at various Depths

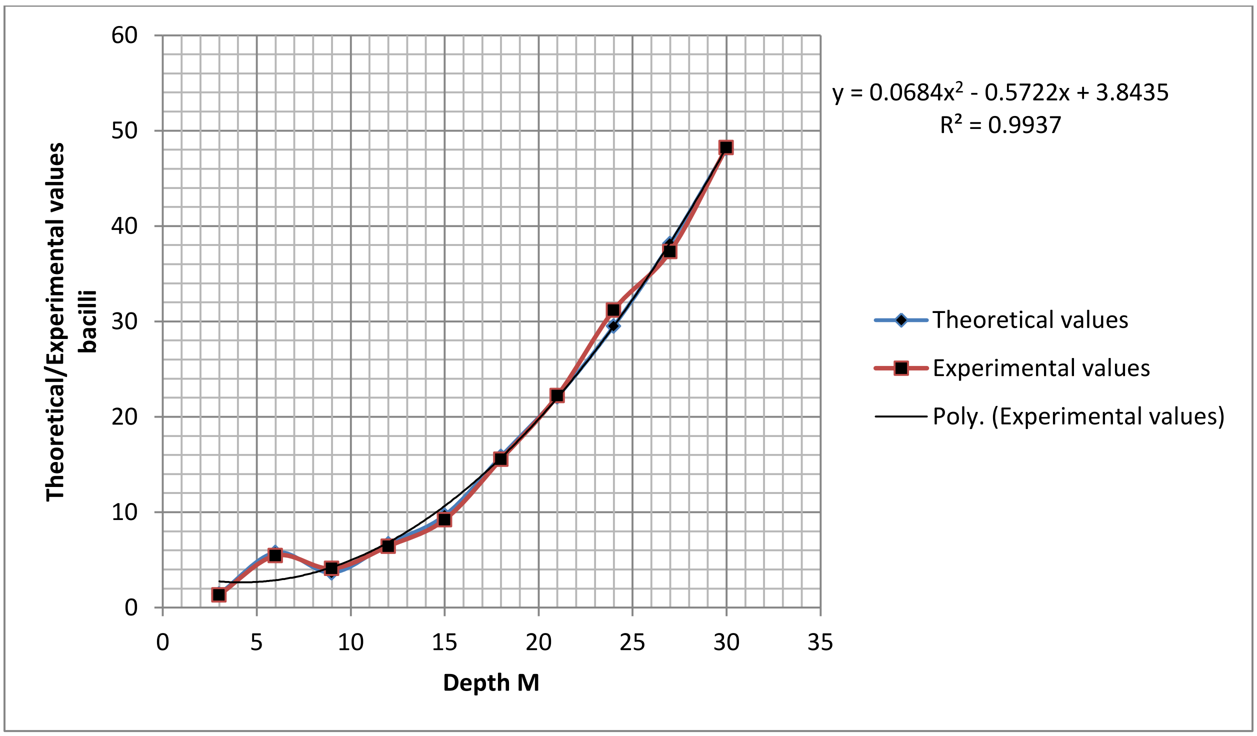

Figure 3: Comparison of theoretical and Experimental values of bacilli at various Depths

The result presented in figure 1 show that the microbes' bacilli gradually increase to the optimum values recorded at thirty meters. Slight fluctuation were observed between eighteen and twenty-one meters, while the experimental values expressed similar condition as the lowest were recorded at three meters and the highest contaminant were observed at thirty meters. Figure 2 experience a slight fluctuation between three and nine meters and finally increase in a gradual process to where the optimum level where observed at thirty meters, while the experimental values maintained similar condition, fluctuation where observed between three and nine meters, in the same vein it gradually increase to where the optimum value were recorded at thirty meters Figure 3 observed the lowest degree of concentration at three meters and gradually increase to where the maximum degree of concentration where observed at thirty meters. Similarly the experimental values expressed a similar condition at three meters with slight fluctuation; it increases with change in distance to where the optimum values were obtained. The figures express rapid growth of the microbes,' bacilli as it is observed, inhibition where found to be insignificant in those formation. The stratification of the soil was confirmed to play a major role, because high degree of microbus may have influence on the transport as it is expressed in the figures. High degrees of saturation also express its influence on the migration of the microbes,' bacilli were on the fast trace of ground water aquifers.

5. Conclusion

Mathematical modeling of bacilli transport to ground water aquifer has been thoroughly examined, the model were established to monitor the trace of microbial species at different soil formation to ground water aquifers. Theoretical values where generated from the model, and where compared with Colum experimental result, both parameters compared favorably well. The microbes were observed to develop fast migration at different formation, where by high deposition of the microbes were recorded at thirty meters, this condition are express from the figures as it shows high deposition of substrates, these influence fast migration of microbes and it produce high deposition of the contaminant in all the porous media, in this condition microbes generate energy and increase in their microbial population, thus develop increase in concentration in the auriferous zone, the model develop considered this conceptual frame work,. Consequently it implies that there is high deposition of bacilli in auriferous zone.

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