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Research article

PREDICTIVE MODEL TO MONITOR THE TRANSPORT OF NICKEL AND SALMONELLAE ON VELOCITY AND DISPERSION INFLUENCING UNCONFINED BED, MGBUOBA DISTRICT OF PORT HARCOURT, NIGER DELTA OF NIGERIA

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Abstract

Velocity and dispersion were found to influences the deposition and migration process of phosphorous and nickel in the study area. The study location were found to deposit nickel and phosphorous through few industrial and biological waste generation, the investigation carried out express the rate of these deposition in the strata to unconfined bed, such expression implies that the unconfined bed will definitely be at pollution risk, this investigation from risk assessment of soil and water in the study area also shows the formation characteristics, these influences developed fast migration of nickel and phosphorous in the study area. Several challenging influences has be evaluated in the study of these deposition, these were considered in the governing equation, the derived solution applied different mathematical method considering several expressed variables, these condition were integrated in different phase , thus produced the final model that will monitor the deposition and migration of phosphorous in the study area.

Keywords: predictive model nickel, salmonella's velocity and dispersion

1. Introduction

European river catchments are often densely populated and industrialized (Leuven and Poudevigne, 2002; Van der Velde et al., 2004). Due to a lack of water pollution control and wastewater treatment facilities, many river floodplains have become polluted in the past (Admiraal et al., 1993; Middelkoop, 1997; Albering et al., 1999; Vink et al., 1999b; Mertens et al., 2001). The effects of these pollutants on ecosystems are largely unknown, but local extinctions or population declines due to deteriorated river water, sediment and floodplain soil quality have been suggested in several studies (Balk et al., 1993; Kerkhofs et al., 1993; Hendriks et al., 1995; Kooistra et al., 2001 Eluozo,2013). Deposited pollutants are subject to hydromorphodynamics (e.g. flooding, erosion and sedimentation processes) and turbation by animals. However, knowledge on the fate of heavy metals, especially in relation to turbation and inundation, is scarce of Floodplain soils often abundantly harbour burrowing animals, so-called bioturbators, including various mammals (e.g. voles, mice and moles) and soil macro-invertebrates, like earthworms and insects and their larvae (Mitchell, 1988; Mu¨ller-Lemans, 1996; Tyler et al., 2001,Eluozo2013). Bioturbation processes include digging, casting, and construction of nests and burrows. Bioturbation occurs especially in the upper 20 cm of soils, where the most recently deposited pollutants are present (Middelkoop, 1997). Some species like epigeic earthworms (e.g. Lumbricus rubellus) are especially active in the upper 3 cm of topsoil (Zorn, 2004), and all species burrowing deeper but frequently surfacing (e.g. endogeic and anecic earthworm species and underground dwelling small mammal species) or species burrowing from the surface to deeper layers (e.g. rabbits and voles searching for food) turbate the topsoil as well. Zinc is a widespread heavy metal in river systems, occurring in elevated and potentially toxic quantities all over Europe (Balk et al., 1993; Kalbitz and Wennrich, 1998). Zinc is essential for life in all organisms but is toxic in excess, which requires homeostatic mechanisms to control intracellular zinc levels. E\ux of zinc in Escherichia coli is accomplished by the P-type ATPase ZntA and the cation di!usion facilitator (CDF) ZitB The CDF family Grass et 2001,Njes and Silven, 1996 stated that of proteins has common structural characteristics, with (in most cases) six transmembrane helices and N- and C-terminal histidine-rich motifs predicted to extend into the cytosol. These membrane transporters are usually involved in zinc transport across cytoplasmic or organelle membranes [3^6]. Some prokaryotic CDF proteins also transport cobalt and cadmium [7^10]. Recently, Gu!anti et al 2002. Rosen el at 1978, Padan and Schaldener, 1994 showed that CzcD from Bacillus subtilis utilizes an antiport mechanism. Antiporters are secondary transporters that couple electrochemical gradients of ions or organic solutes to drive transport reactions Rosen el at 1978, Padan and Schaldener, 1994. CzcD catalyzes active e\ux of Zn2þ in exchange for Kþ and Hþ [10]. However, the amino acid residues that participate in catalysis are unknown. Secondary active transport proteins convert free energy stored in electrochemical ion gradients into work in the form of a concentration gradient. Comprehensively studied examples include the proton/substrate symporter lactose permease (LacY) and the Naþ/Hþ Antiporters NhaA and NhaB kaback and Rashet 1978. Surprisingly, extensive use of site-directed mutagenesis demonstrated that only six amino acid residues in LacY are irreplaceable with respect to active lactose transport. Charge pairs have been identi ¢ ed that mediate substrate binding and Hþ translocation.

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2. Theoretical Background

Mgbuoba district of pot Harcourt were found to increase in population size, lots of new developed area has increase the migration human settlement in the study area , this generated lots of positive and negative impact in the Mgbuoba district, the generation of biological and industrial waste were confirmed through the few individual industries and other big restaurant generating large tons of biological waste , other individual biological waste are found to increase due to fast migration of human settlements, subject to this negative impact, further challenges were found to develop more pollution in the study area, the pollution sources is from few industrial and biological waste produced in Mgbuoba district of port Harcourt, both parameters nickel and salmonellae were found to be predominantly deposited in the formation of the soil, subject to these challenging factors, the need of preventing migration nickel and salmonellae in unconfined bed becomes imperative in the study location development of a system to produce a governing equation were appropriate, the system generated the governing equation to produce a model the governing equation are state above.

3. Governing Equation

$$V\frac{\partial q}{\partial t} = D(x)\frac{\partial^2 q}{\partial x^2} - V\frac{\partial q}{\partial x} - \frac{\partial q\mu(x)}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Nomenclature

q = salmonellae concentration [MLT^{-1}]

D = Dispersion coefficient in longitudinal location (MT^{-1})

μ(x) = Nickel concentration [MLT-1

V = Velocity [LT-^{1}]

T = Time [T]

X = Distance [M]

V = Void ratio [-]

The deposition of nickel of nickel and salmonellae were found to deposit through high influences from velocity and dispersion in the formation, there is the need to monitor various concentration rate at different depths in the study area, such migration to unconfined bed implies there lots of influences that allow for fast migration and deposition of nickel and salmonellae in the study area, these condign developed the system that produces the governing equation stated above.

$$V\frac{\partial^2 q_1}{\partial t} = D(x)\frac{\partial^2 q_1}{\partial x^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\left.\begin{array}{l} t = 0 \\ x = 0 \\ C_{(o)} = 0 \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\left.\frac{\partial C}{\partial t}\right|_{t = 0, B} = 0$$

$$\left.\begin{array}{l} V\dfrac{\partial q_2}{\partial t} = V(x)\dfrac{\partial q^2}{\partial x} \\ t = 0 \\ x = 0 \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$q_{(o)} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$\left.\frac{\partial q}{\partial t}\right|_{t = 0, B}$$

$$V\frac{\partial q_3}{\partial t} = -\frac{\partial q_3 \mu(x)}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$\left.\begin{array}{l} t = 0 \\ C_{(o)} = 0 \\ \left.\dfrac{\partial q_3}{\partial t}\right|_{t = 0, B} = 0 \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$V\frac{\partial q_4}{\partial x} - \frac{\partial q_4 \mu c}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

$x = 0$

$t = 0$

$$C_{(o)} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

$$\left.\frac{\partial C_4}{\partial x}\right|_{x = 0, B} = 0$$

$$D(x)\frac{\partial^2 q_5}{\partial x^2} - V\frac{\partial q_5}{\partial x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

$x = 0$

$$q_{(o)} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$\left.\frac{\partial q_5}{\partial x}\right|_{x = 0, B}$$

Applying direct integration on (2)

$$V\frac{\partial q_1}{\partial t} = D(x)q + K_1 \qquad \text{..........} \qquad (12)$$

Again, integrate equation (12) directly yield

$$VC = D(x)qt + Kt + K_2 \qquad \text{..........} \qquad (13)$$

Subject to equation (3), we have

$$Vq_o = K_2 \qquad \text{..........} \qquad (14)$$

And subjecting equation (12) to (3) we have

$$\text{At } \left.\frac{\partial q_1}{\partial t}\right|_{t=0} = 0 \quad q(o) = qo$$

Yield

$$0 = D(x)q_o + K_2$$

$$\Rightarrow V_1 = D(x)q_o = K_2 \qquad \text{..........} \qquad (15)$$

So that we put (13) and (14) into (13), we have

$$Vq_1 = D(x)q_{1t} - D(x)qox\,Vqo \qquad \text{..........} \qquad (16)$$

$$RC_1 - D(x)q_{1x} = Vq_o - D(x)qox \qquad \text{..........} \qquad (17)$$

$$q_1 = q_o \qquad \text{..........} \qquad (18)$$

Hence equation (18) entails that at any given distance x, we have constant concentration of the contaminant in the system.

Constant concentration were found in some region of the strata as expressed in equation[18] above , the situation will definitely been influenced by constant velocity of floe through homogenous setting of the strata, developing constant concentration of nickel and salmonellae in the study area. The expressions in [18] consider this situation as stated above.

$$V\frac{\partial q_2}{\partial t} = -V\frac{\partial q^2}{\partial x} \qquad \text{..........} \qquad (4)$$

We approach the system, by using the Bernoulli's method of separation of variables

$$q_2 = XT \qquad \text{..........} \qquad (19)$$

i.e. $$V\frac{\partial q_2}{\partial t} = XT^1 \qquad \text{..........} \qquad (20)$$

$$V\frac{\partial q_2}{\partial x} = X^1T \qquad \ldots\ldots\ldots \qquad (21)$$

Put (20) and (21) into (19), so that we have

$$VXT^1 = -VX^1T \qquad \ldots\ldots\ldots \qquad (22)$$

i.e. $$V\frac{T^1}{T} = V\frac{X^1}{X} = -\lambda^2 \qquad \ldots\ldots\ldots \qquad (23)$$

Hence $$V\frac{T^1}{T} + \lambda^2 = 0 \qquad \ldots\ldots\ldots \qquad (24)$$

i.e. $$X^1 + \frac{\lambda}{R}x = 0 \qquad \ldots\ldots\ldots \qquad (25)$$

$$VX^1 + \lambda^2 X = 0 \qquad \ldots\ldots\ldots \qquad (26)$$

From (25), $$X = ACos\frac{\lambda}{R}X + BSin\frac{\lambda}{\sqrt{R}}X \qquad \ldots\ldots\ldots \qquad (27)$$

And (20) gives

$$T = C\ell^{\frac{-\lambda^2}{V}t} \qquad \ldots\ldots\ldots \qquad (28)$$

And (20) gives

$$\boxed{C_2 = \left(ACos\frac{\lambda}{V}t + BSin\frac{\lambda}{\sqrt{V}}t\right)C\ell^{\frac{-\lambda^2}{V}x}} \qquad \ldots\ldots\ldots \qquad (29)$$

Subject to equation (29) to conditions in (5), so that we have

$$q_o = AC \qquad \ldots\ldots\ldots \qquad (30)$$

Equation (30) becomes

$$q_2 = q_o\ell^{\frac{-\lambda^2}{V}x}\ Cos\frac{\lambda}{\sqrt{V}}{}^{t} \qquad \ldots\ldots\ldots \qquad (31)$$

Again, at

$$\left.\frac{\partial q_2}{\partial t}\right|_{t = 0,\ B} = 0,\ x = 0$$

Equation (31) becomes

$$\frac{\partial q_2}{\partial t} = \frac{\lambda}{\sqrt{V}} q_o \ell^{\frac{-\lambda}{V}x} \; Sin \frac{\lambda}{\sqrt{V}} t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (32)$$

i.e. $0 = -\frac{qo\lambda}{\sqrt{V}} \; Sin \frac{\lambda}{V} 0$

$Co\frac{\lambda}{V} \neq 0$ Considering NKP

Which is the substrate utilization for microbial growth (population) so that

$$0 = qo \frac{\lambda}{\sqrt{V}} \; Sin \frac{\lambda}{\sqrt{V}} B \quad \ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots \quad (33)$$

$$\Rightarrow \frac{\lambda}{R} = \frac{n\pi}{2} n, 1, 2, 3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (34)$$

$$\Rightarrow \lambda = \frac{\lambda}{V} = \frac{n\pi\sqrt{R}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (35)$$

So that equation (31) becomes

$$\Rightarrow q_2 = qo\,\ell^{\frac{-n^2\pi^2 R}{2}t} \; Cos \frac{n\pi\sqrt{R}}{2\sqrt{R}} x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (36)$$

$$\Rightarrow q_2 = qo\,\ell^{\frac{-n^2\pi^2 R}{2}t} \; Cos \frac{n\pi}{2} x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (37)$$

Now, we consider equation (7), we have the same similar condition with respect to the behaviour

$$v\frac{\partial q_3}{\partial t} = -\frac{\partial q_3 \mu(x) q}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$q_3 = XT^1$ ………………………….. (38)

$\frac{\partial q_3}{\partial t} = XT^1$ ………………………….. (39)

i.e. $V\frac{\partial q_3}{\partial t} = XT^1$ ………………………….. (40)

Put (20) and (21) into (19), so that we have

$VXT^1 = -XT^1\mu(x)q$ ………………………….. (41)

i.e. $V\frac{T^1}{T} = -\frac{T^1}{T}\mu(x)q - \lambda^2$ ………………………….. (42)

$V\frac{T^1}{T} + \lambda^2 = 0$ ………………………….. (43)

$X^1 + -\frac{\lambda}{V}t = 0$ ………………………….. (44)

And $VT^1 + \lambda^2 t = 0$ ………………………….. (45)

From (44), $t = ACos\frac{\lambda}{V}t + BSin\frac{\lambda}{\sqrt{V}}t$ ………………….. (46)

and (39) give

$$T = C\ell\frac{-\lambda^2}{\mu(x)q}t$$ ………………………….. (47)

By substituting (46) and (47) into (38), we get

$$C_3 = \left(A Cos \frac{\lambda}{V} t + B Sin \frac{\lambda}{\sqrt{V}} t \right) C \ell^{\frac{-\lambda^2}{\mu(x)q} t} \qquad \text{.................} \qquad (48)$$

Subject equation (48) to conditions in (7), so that we have

$$qo = AC \qquad \text{..............................} \qquad (49)$$

Equation (49) becomes

$$q_3 = qo \, \ell^{\frac{-\lambda^2}{\mu(x)q} t} \; Cos \frac{\lambda}{q} t \qquad \text{..............................} \qquad (49)$$

Again, at $\left. \frac{\partial q_3}{\partial t} \right|_{t = 0, B} = 0 \quad t = 0$

Equation (50) becomes

$$\frac{\partial q_3}{\partial t} = \frac{\lambda}{V} Co \ell \frac{-\lambda}{\mu(x)q} t \; Sin \frac{\lambda}{V} t \qquad \text{.......................} \qquad (51)$$

i.e. $0 = qo \frac{\lambda}{V} \; Sin \frac{\lambda}{V} 0$

$qo \frac{\lambda}{V} \neq 0$ Considering NKP again

Due to the rate of growth, which is known to be the substrate utilization of the microbes we have

$$0 = -qo \frac{\lambda}{\sqrt{V}} \; Sin \frac{\lambda}{\sqrt{V}} B \qquad \text{..............................} \qquad (52)$$

$$\Rightarrow \frac{\lambda}{V} = \frac{n\pi}{2} n,1,2,3 \quad \text{.............................} \quad (53)$$

$$\Rightarrow \lambda = \frac{n\pi\sqrt{R}}{2} \quad \text{.............................} \quad (54)$$

So that equation (50) becomes

$$q_3 = qo\,\ell^{\frac{-n^2\pi^2 R}{2\mu(x)q}t}\,Cos\frac{n\pi}{2}t \quad \text{.............................} \quad (55)$$

Salmonellae and nickel depositing in unconfined bed implies that there should be some process it pleasing through before getting to unconfined bed, the deposition of substrate were paid attention by integrating it phase in the derived solution as it is expressed in equation [52] these expression are considered in different stage because the deposition of substrate are not in homogeneous setting, therefore the expression were considered according the depositions of substrate in the formation As it is expressed on the derived solution above.

Now, we consider equation (8), we have

$$V\frac{\partial q_4}{\partial x} - \frac{\partial q_4 \mu(x) q}{\partial x} \quad \text{......................} \quad (8)$$

Using Bernoulli's method, we have

$$C_4 = XT \quad \text{.............................} \quad (56)$$

$$\frac{\partial q_4}{\partial x} = X^1 T \quad \text{.............................} \quad (57)$$

$$\frac{\partial C_4}{\partial t} = X^1 T \quad \text{.............................} \quad (58)$$

Put (57) and (58) into (56), so that we have

$$VX^1 T = -X^1 T \;\mu(x) X^1 T \quad \text{......................} \quad (59)$$

i.e. $V\frac{X^1}{X} = -\frac{X^1}{X}\mu(x)$ …………………… (60)

$$V\frac{X^1}{X} = \varphi \quad \text{…………………………..} \quad (61)$$

$$\frac{X^1}{X}\mu(x)q = \varphi \quad \text{…………………………..} \quad (62)$$

$$X = A\,\ell^{\frac{\varphi}{V}x} \quad \text{…………………………..} \quad (63)$$

Put (62) and (63) into (56), gives

$$C_4 = A\,\ell^{\frac{\varphi}{\mu(x)}} \bullet B\,\ell^{\frac{-\varphi}{\mu(x)}x} \quad \text{…………………………..} \quad (64)$$

$$C_4 = AB\,\ell^{(t-x)}\frac{\varphi}{\mu(x)} \quad \text{…………………………..} \quad (65)$$

Subject equation (66) to (8)

$$q_4\ (o) = qo \quad \text{…………………………..} \quad (66)$$

So that equation (67) becomes

$$q_4 = qo\,\ell^{(t-x)}\frac{\varphi}{\mu(x)q} \quad \text{…………………………..} \quad (67)$$

Considering equation (10), we have

$$D(x)\frac{\partial^2 q_5}{\partial x^2} - V\frac{\partial q_5}{\partial x} \quad \text{…………………} \quad (10)$$

$$q_5 = X^{11}T \quad \text{…………………………..} \quad (68)$$

$$\frac{\partial^2 C_5}{\partial x^2} + X^{11}T \quad \text{..............................} \quad (69)$$

$$\frac{\partial q_5}{\partial x} + X^{1}T \quad \text{..............................} \quad (70)$$

Put (69) and (70), so that we have

$$D(x)X^{11}T - VX^{1}T \quad \text{..............................} \quad (71)$$

$$D(x)\frac{X^{11}}{X}T - V\frac{X^{1}}{X} \quad \text{..............................} \quad (72)$$

$$D(x)\frac{X^{11}}{X} = \varphi \quad \text{..............................} \quad (73)$$

$$V\frac{X^{1}}{X} = \varphi \quad \text{..............................} \quad (74)$$

$$X^{1} = A\ell\frac{\varphi}{D(x)}x \quad \text{..............................} \quad (75)$$

Put (74) and (75) into (68), gives

$$q_5 = A\ell\frac{\varphi}{V} \bullet B\ell\frac{-\varphi}{V}x \quad \text{..............................} \quad (76)$$

$$q_5 = AB\ell^{(x-x)}\frac{\varphi}{V} \quad \text{..............................} \quad (77)$$

Subject (76) to (10)

$$q_5\ (o) = Co \quad \text{..............................} \quad (78)$$

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So that equation (78) becomes

$$q_5 = qo\,\ell^{(x-x)}\frac{\varphi}{V} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (79)$$

Now, assuming that at the steady flow, there is no NKP for substrate utilization, our concentration here is zero, so that equation (79) becomes

$$q_5 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (80)$$

Most time there are the tendencies where substrate are no longer substrate deposition in the formation, it implies that the deposition of phosphorous may not be found in some region of the formation .either not deposited and been inhibited by nickel , the condition were considered in the derived solutions as it is expressed above

Therefore, $C_1 + C_2 + C_3 + C_4 + C_5$ ………………….. (81)

We now substitute (18), (37), (55), (67) into (81) so that we have the model of the form

$$q = qo + qo\,\ell\,\frac{-n^2\pi^2 R}{2V}x\,Cos\frac{n\pi}{2}t \bullet Co\,\ell\,\frac{-n^2\pi^2 R}{2\mu(x)}t\,Cos\frac{n\pi}{2}t +$$

$$qo\,\ell^{(t-x)}\frac{\varphi}{\mu C} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (82)$$

$$\Rightarrow q = qo + 1 + \ell\,\frac{n^2\pi^2 V}{2V}x\,Cos\frac{n\pi}{2} \bullet Co\,\ell\,\frac{-n^2\pi^2 V}{2\mu(x)}t\,Cos\frac{n\pi}{2}t +$$

$$Co\,\ell^{(t-x)}\frac{\varphi}{\mu(x)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (83)$$

The expression in [83] is the final model equations that monitor the migration and deposition of nickel and phosphorous in the study location, the model was derived from the system formulated that generated the governing equation, the derived solution established the model through different mathematical approach, the derived solution mathematically consider several phase in the soil that explain different behaviour of nickel and phosphorous transport process to unconfined bed ,these expression shows how every influential parameters were integrated base on several behaviour on transport process of the two parameters, the developed model will definitely monitor the system at every considered phase in the transport system influenced by velocity and dispersion in the sturdy area.

4. Conclusion

Nickel and phosphorous deposition has found to predominant in Mgbuoba district of Port Harcourt, this condition were found to be predominant in Mgbuoba districts of port Harcourt through few industrial and biological waste generation in the study area, the study area developed some geological setting that were investigated to deposit high degree of void ratio developing high rate of dispersions rate in the formation, the deposition also develop high degree of velocity in the strata, these influences the deposition of nickel and phosphorous in the study area, several conditions were expressed that also influences the transport system in the study area, this to ensure that every stage of the transport system that develop different stage are integrated to produced the derived final model, the study is imperative because several process that influences the migration and deposition of nickel and phosphorous has been thoroughly expressed in the system , the developed model will definitely monitor the deposition and transport of nickel and phosphorous in the study area.

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