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Sensitivity of Ogoni Groundwater to Salinization Risk and Susceptibility to Bioremediation

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Abstract

The aim of this study is to conduct a systematic sensitivity analysis of Ogoni groundwater to salinization risk and susceptibility to bioremediationin order to control the extent of uncertainty of the duration of the groundwater salinization risk. A numerical simulation approach has been implemented to tackle this challenging environmental problem. The full details of the novel contribution of this present analysis have not been seen elsewhere; they are presented and discussed in this study.

1.0 Introduction

The solution to the mathematical problem of interface upconing in a coastal aquifer by the method of a small perturbation has been well posed by [1-4]. This formidable mathematical problem has attracted lots of modifications from a few scientists [1-4]. However, there is a dearth of the numerical simulation approach in the tackling of this problem. In this study, we are interested to consider the Ogoni environment due to its uncontrolled environmental exploitation. We strongly believe that any achievable policy based on the outcome of this numerical simulation analysis has the rich potential of alleviating the Ogoni environmental issue and other Niger Delta communities that have suffered similar devastations.

2.0 Mathematical Formulation

The model equation of the upconing that is measured from the initial level of the interface at time t in the unit of months in terms of the distance between the point sink (in this case located in the middle of the well) and the interface [1] is defined by the following differential equation of first order with the initial condition $\xi(s_0) = \xi_0$

$$\frac{d\xi}{ds} = -\frac{\delta Q}{2\pi K_f s^2} - \frac{\delta Q(2n + n\delta)^2}{(2ns + ns\delta + tK_f)^2} \qquad (1)$$

with the initial condition

$$\xi(s_0) = \xi_0 \qquad (2)$$

For the purpose of this study, the meaning of each model parameter is defined as follows:

δ stands for the unit weights of fresh water and sea water respectively, Q is the pumping rate, K_f stands for the hydraulic conductivity of the homogeneous isotropic porous medium, s stands for the distance between the point sink and the interface and n is called the medium porosity. Here, we have assumed the following deterministic parameter values after some consultations with a few experts in this field: δ =0.65, Q=0.75, π =3.1429, $K_f = 0.24$, s = 4, n = 0.78. For this simulation analysis, we have considered when the unit of time ranges from one (1) month to about eighty (80) months.

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The above equation is also called the sensitivity of the groundwater salinization risk. The sensitivity of the duration of the groundwater salinization risk needs to be quantified as a short-term strategy to mitigate against the Ogoni environmental problem.

3.0 Method of Solution

The duration of the groundwater salinization risk is assumed to be changing while other model parameter values are fixed. On the basis of this simplifying assumption, the sensitivity of the duration of the groundwater salinization risk was quantified using a Matlab simulation method. The results of this method of solution are presented and discussed next.

4.0 Results and Discussion

A detailed set of results based on the above mentioned method of solution is presented for some distinct durations of the groundwater salinization risk as follows:

Table 1: Accessing the sensitivity of the duration of the groundwater salinization risk

Example	Sensitivity values for the range of the duration of the groundwater salinization risk			
	1-20 months	**21-40 months**	**41-60 months**	**61-80 months**
1	-0.048971	-0.031958	-0.026549	-0.024166
2	-0.047414	-0.031545	-0.026384	-0.024084
3	-0.045980	-0.031153	-0.026225	-0.024005
4	-0.044656	-0.030781	-0.026073	-0.023928
5	-0.043432	-0.030428	-0.025926	-0.023853
6	-0.042297	-0.030093	-0.025784	-0.023781
7	-0.041244	-0.029773	-0.025648	-0.023710
8	-0.040264	-0.029469	-0.025516	-0.023642
9	-0.039351	-0.029179	-0.025390	-0.023576
10	-0.038499	-0.028902	-0.025267	-0.023512
11	-0.037702	-0.028638	-0.025149	-0.023449
12	-0.036957	-0.028386	-0.025036	-0.023388
13	-0.036258	-0.028145	-0.024925	-0.023329
14	-0.035602	-0.027915	-0.024819	-0.023272
15	-0.034985	-0.027694	-0.024716	-0.023216
16	-0.034404	-0.027483	-0.024617	-0.023161
17	-0.033857	-0.027280	-0.024521	-0.023108
18	-0.033342	-0.027086	-0.024428	-0.023057
19	-0.032854	-0.026900	-0.024338	-0.023007
20	-0.032394	-0.026721	-0.024251	-0.022958

For the first twenty (20) months, simulation predicts that the sensitivity of the duration of the groundwater salinization risk ranges between -0.048971 and -0.032394 whereas when the duration of the groundwater salinization risk covers between 21 months and 40 months, simulation predicts that the sensitivity of the duration of the groundwater salinization risk ranges between -0.031958 and -0.026721. Between 41 months and 60 months, the sensitivity of the duration of the groundwater salinization risk ranges between-0.026549 and -0.024251whereas when the duration of the groundwater salinization risk covers between 61 months and 80 months, simulation predicts that the sensitivity of the duration of the groundwater salinization risk ranges between -0.024166 and -0.022958.

According to the statistical theory, the smaller the standard deviation of the sensitivity estimate, the more precise it is. Without loss of generality, the standard deviation for the 1-20 months sensitivity data is 0.0051; the standard deviation for the 21-40 months sensitivity data is 0.0016; the standard deviation for the 41-60 months sensitivity data is 0.00071255; the standard deviation for the 61-80 months sensitivity data is 0.00037509. Despite the precision of the 61-80 months sensitivity data over other durations of sensitivity data, the 1-20 months sensitivity data are associated with smaller sensitivity values and lower uncertainty.

Since data sets are not totally free of error because the defining model formulation can be an approximation to a real life phenomenon except in some experimentally derived data and model parameter values are estimated, it is imperative to report this present analysis in terms of the p-norms error values using 1-norm, 2-norm and infinity-norm: for the 1-20 months sensitivity data, the estimated 1-norm error is 0.7805, the estimated 2-norm error is 0.1759, the estimated infinity-norm is 0.049; for the 21-40 months sensitivity data, the estimated 1-norm error is 0.5795, the estimated 2-norm error is 0.1298, the estimated infinity-norm is 0.032; for the 41-60 months sensitivity data, the estimated 1-norm error is 0.5056, the estimated 2-norm error is 0.1131, the estimated infinity-norm is 0.0265; for the 61-80 months sensitivity data, the estimated 1-norm error is 0.4702, the estimated 2-norm error is 0.1052, the estimated infinity-norm is 0.0242.

Lower sensitivity values due to the variation of the duration of the groundwater salinization risk have occurred for the first twenty months in contrast to the relatively higher sensitivity values that have occurred between 61 months and 80 months. Due to the randomness of the geometry of the network of fractures and conduits, higher sensitivity values tend to be associated with bigger uncertainty whereas lower sensitivity values tend to be associated with smaller uncertainty. In terms of some sort of scientific bioremediation, the first twenty months scenario is recommended as the best-fit duration of remediation that is more likely to yield useful results for the affected Niger Delta communities that have suffered severe environmental degradations of which the issue of Ogoni environmental devastation is a particular concern.

Despite the historical research contributions [1-4], our present cutting-edge contribution in which a sound database system has been constructed for the effective monitoring of the sensitivity of the duration of the groundwater salinization risk is a novel contribution in terms of early mitigation of the almost endemic Ogoni environmental problem over previous contributions that focused only on theoretical analyses with rare statistical and limited mathematical analyses as we have done in this present work.

5.0 Conclusion

For this single model equation of groundwater salinization risk, the method of a numerical simulation has successfully been used to quantify the sensitivity of the duration of the groundwater salinization risk. In particular, the scenario of 1-20 months is associated with a smaller sensitivity value which is capable of minimizing the uncertainty of the duration of the groundwater salinization risk. A longer duration of the groundwater salinization is more vulnerable to bigger sensitivity values with some intensity of uncertainty due to the randomness in the geological system that describes the problem being analysed in this work. Therefore, a shorter duration of the groundwater salinization risk is preferred for the purpose of a scientific bio-remediation of the Ogoni devastated environment. The 1-20 months sensitivity data that we have obtained in the present analysis mimic the consideration of a single polluted site. In reality, there are several such polluted sites within the Ogoni environment in which the sensitivity for a shorter duration of the groundwater salinization risk may vary as the pumping rate and the hydraulic conductivity of the homogeneous isotropic porous medium undergo some changes. The details of the sensitivity impact of the pumping rate and the hydraulic conductivity of the homogeneous isotropic porous mediumfor the 1-20 months duration of the groundwater salinization risk will be the subject of a future publication.

6.0 References

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