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Most Probable Numer) MPN

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pH

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Trace Elements	mg/L
EDTA-Sodium Salt	500
ZnSO ₄ .7H ₂ O	10
FeSO ₃ .7H ₂ O	200
MnCl ₂ .4H ₂ O	3
H ₃ BO ₃	30
CoCl ₂ .6H ₂ O	20
CuSO ₄ .2H ₂ O	10
NiCl ₂ .6H ₂ O	6
Na ₂ MoO ₄ .2H ₂ O	3

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ماده مغذی	محلول ماده مغذی (mg/L)	محلول ماده مغذی (max)	محلول ماده مغذی (min)
Macro & Micro	K ₂ HPO ₄	800	0/132
	KH ₂ PO ₄	200	0/103
	KNO ₃	1000	1/7
	MgSO ₄ .7H ₂ O	200	200
	CaCl ₂ .2H ₂ O	100	100
Trace	NaCl	100	100
	FeCl ₃ .6H ₂ O	10	10
	Trace elements	1mL	1mL

Excel
fANOVA

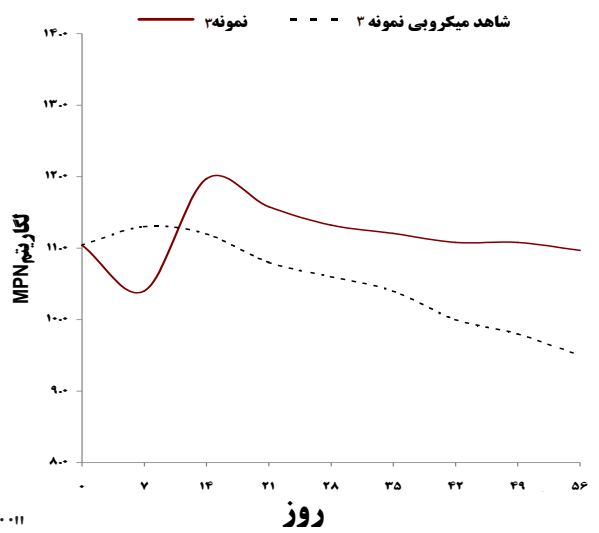
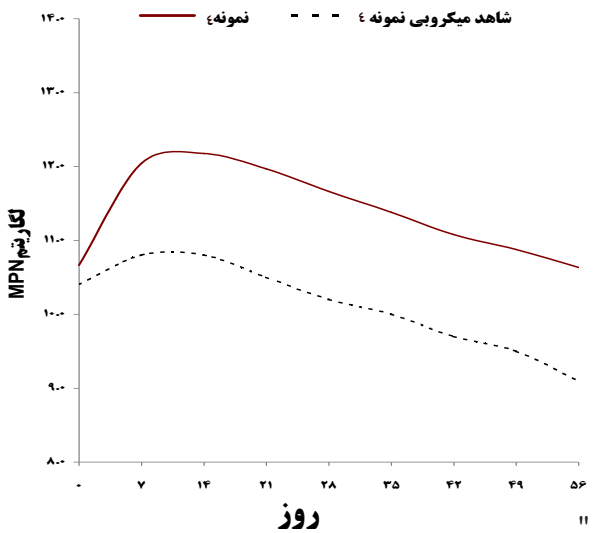
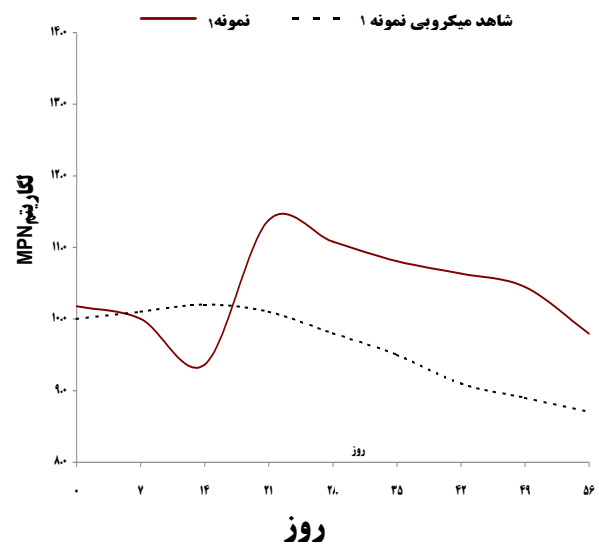
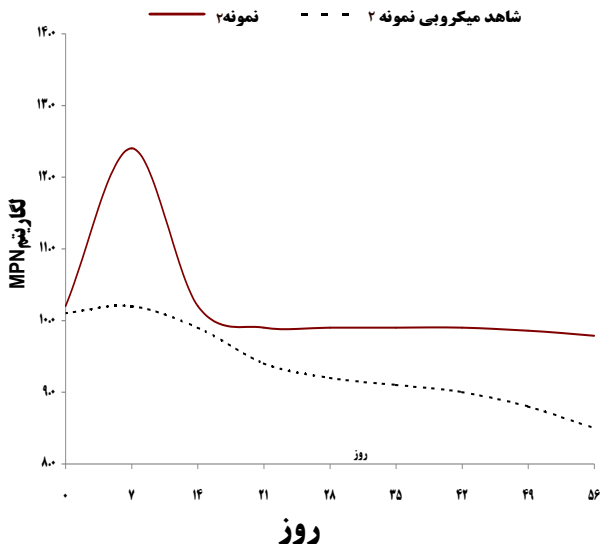
Design-Expert V.7

آزمایش	مواد مغذی (Nu.)	شوری (Sal.)	مخلوط میکروبی	فناثرین
نمونه ۱	+۱	+۱	+	+
نمونه ۲	+۱	-۱	+	+
نمونه ۳	-۱	+۱	+	+
نمونه ۴	-۱	-۱	+	+
شاهد شیمیایی نمونه ۱	+۱	+۱	-	+
شاهد شیمیایی نمونه ۲	+۱	-۱	-	+
شاهد شیمیایی نمونه ۳	-۱	+۱	-	+
شاهد شیمیایی نمونه ۴	-۱	-۱	-	+
شاهد میکروبی نمونه ۱	+۱	+۱	+	-
شاهد میکروبی نمونه ۲	+۱	-۱	+	-
شاهد میکروبی نمونه ۳	-۱	+۱	+	-
شاهد میکروبی نمونه ۴	-۱	-۱	+	-

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GC
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B 3550 BANDELIN SONOPLUS
 fl) (EPA
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 " HP5 CHROMPACK CP9001



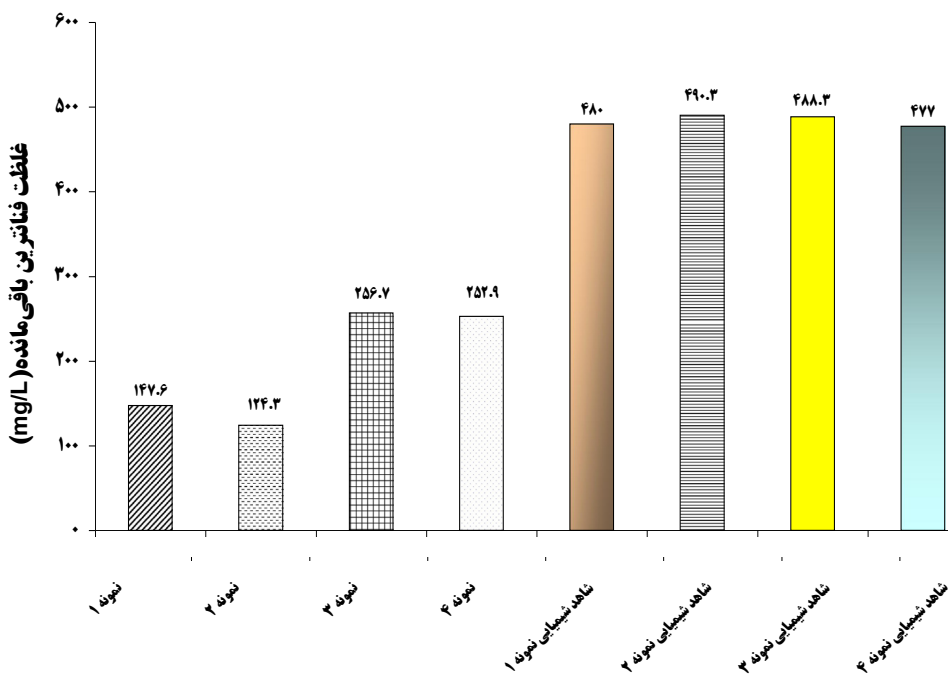
ANOVA

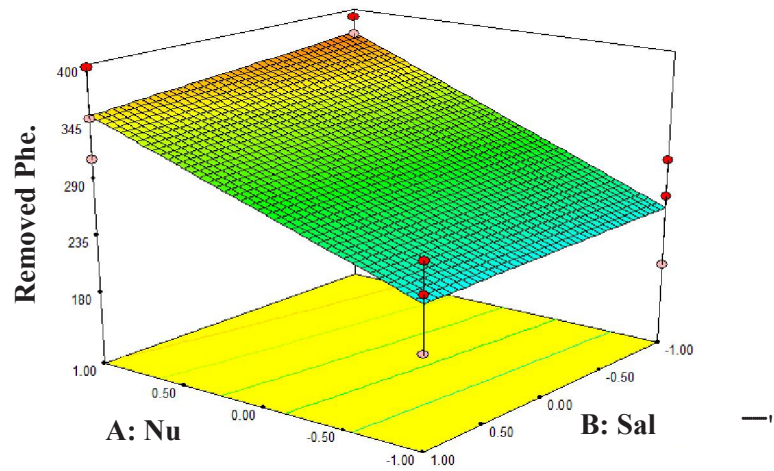
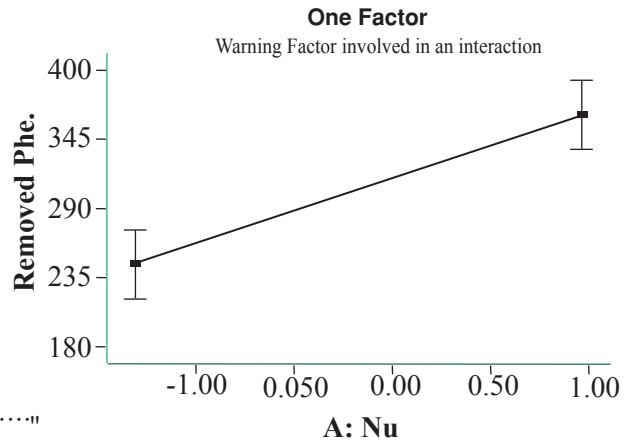
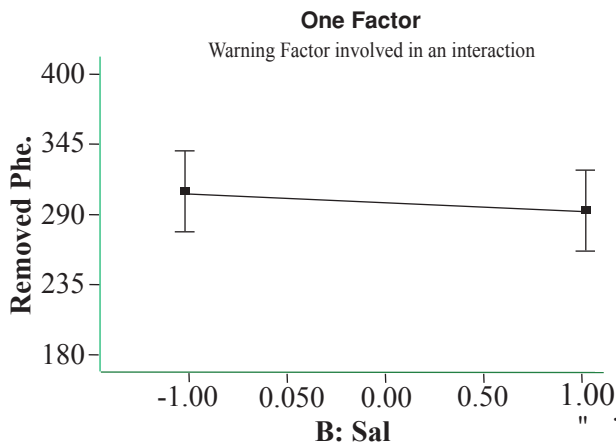
Source	Effects	Sum of Square	df	Mean Square	F-Value	P Value Prob > F	
Model		43228/1	3	14409/4	8/464	0/0073	significant
A-Nu	118/87	42387/9	1	42387/9	24/900	0/0011	
B-Sal	-13/57	552/2	1	552/2	0/324	0/5846	
AB	-9/80	288/1	1	288/1	0/169	0/6916	
Pure Error		13618/8	8	1702/3			
Cor Total		56846/9	11				

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PAHs

Linear ANOVA

(Significant $P < 0.05$)

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1. Doble M, Kumar A. Biotreatment of Industrial Effluents. Burlington: Elsevier Butterworth-Heinemann Publication; 2005.
2. Piskonen R, Itävaara M. Evaluation of chemical pretreatment of contaminated soil for improved PAH bioremediation. *Applied Microbiology and Biotechnology*. 2004;65(5):627-34.
3. Chen J, Wong MH, Wong YS, Tam NFY. Multi-factors on biodegradation kinetics of polycyclic aromatic hydrocarbons (PAHs) by *Sphingomonas* sp. a bacterial strain isolated from mangrove sediment. *Marine Pollution Bulletin*. 2008;57(6-12):695-702.
4. Samanta SK, Singh OV, Jain RK. Polycyclic aromatic hydrocarbons: Environmental pollution and bioremediation. *Trends in Biotechnology*. 2002;20(6):243-8.
5. Kolomytseva MP, Randazzo D, Baskunov BP, Scozzafava A, Briganti F, Golovleva LA. Role of surfactants in optimizing fluorene assimilation and intermediate formation by *Rhodococcus rhodochrous* VKM B-2469. *Bioresource Technology*. 2009;100(2):839-44.
6. Pothuluri JV, Cerniglia CE. Microbial metabolism of polycyclic aromatic hydrocarbons. In: Chaudhry GR, editors. *Biological Degradation and Bioremediation of Toxic Chemicals*. Portland: Dioscorides Press; 1995.
7. Srogi K. Monitoring of environmental exposure to polycyclic aromatic hydrocarbons: A review. *Environmental Chemistry Letters*. 2007;5(4):169-95.
8. Scullion J. Remediating polluted soils. *Naturwissenschaften*. 2006;93(2):51-65.
9. Keane A, Lau PC, Ghoshal S. Use of a whole-cell biosensor to assess the bioavailability enhancement of aromatic hydrocarbon compounds by nonionic surfactants. *Biotechnology and Bioengineering*. 2008;99(1):86-98.
10. Powell SN, Singleton DR, Aitken MD. Effects of enrichment with salicylate on bacterial selection and PAH mineralization in a microbial community from a bioreactor treating contaminated soil. *Environmental Science and Technology*. 2008;42(11):4099-105.
11. Avramova T, Sotirova A, Galabova D, Karpenko E. Effect of Triton X-100 and rhamnolipid PS-17 on the mineralization of phenanthrene by *Pseudomonas* sp. cells. *International Biodeterioration & Biodegradation*. 2008;62(4):415-20.
12. Ahn CK, Woo SH, Park JM. Enhanced sorption of phenanthrene on activated carbon in surfactant solution. *Carbon*. 2008;46(11):1401-10.
13. Liang Y, Sorensen DL, McLean JE, Sims RC. Pyrene fate affected by humic acid amendment in soil slurry systems. *Journal of Biological Engineering*. 2008;2(1):1-7.
14. Haderlein A, Legros R, Ramsay B. Enhancing pyrene mineralization in contaminated soil by the addition of humic acids or composted contaminated soil. *Applied Microbiology and Biotechnology*. 2001;56(3-4):555-9.
15. Mohan SV, Kisa T, Ohkuma T, Kanaly RA, Shimizu Y. Bioremediation technologies for treatment of PAH-contaminated soil and strategies to enhance process efficiency. *Reviews in Environmental Science and Biotechnology*. 2006;5(4):347-74.
16. Yaghmaei S. Bioremediation of polluted soils with Phenanthrene and Anthracene. *Proceedings of the 6th National Congress on Chemistry Engineering*; 2001; Tehran, Iran (in Persian).
17. Robles-González IV, Fava F, Poggi-Varaldo HM. A review on slurry bioreactors for bioremediation of soils and sediments. *Microbial Cell Factories*. 2008;7(1):5.
18. Niqui-Arroyo JL, Bueno-Montes M, Posada-Baquero R, Ortega-Calvo JJ. Electrokinetic enhancement of phenanthrene biodegradation in creosote-polluted clay soil. *Environmental Pollution*. 2006;142(2):326-32.
19. Alvarez PJ, Illman WA. *Bioremediation and Natural Attenuation: Process Fundamentals and Mathematical Models*. Hoboken: John Wiley & Sons; 2006.
20. Shin WS, Pardue JH, Jackson WA, Choi SJ. Nutrient enhanced biodegradation of crude oil in tropical salt marshes. *Water, Air, and Soil Pollution*. 2001;131(1-4):135-52.
21. King RB, Sheldon JK, Long GM. *Practical Environmental Bioremediation: The Field Guide*. 2nd ed. The Boca Raton: CRC Press LLC; 1997.
22. Kwok CK, Loh KC. Effects of Singapore soil type on bioavailability of nutrients in soil bioremediation. *Advances in Environmental Research*. 2003;7(4):889-900.

23. Eweis JB. Bioremediation Principles. Boston : WCB McGraw-Hill; 1998.
24. Chauhan A, Fazlurrahman, Oakeshott JG, Jain RK. Bacterial metabolism of polycyclic aromatic hydrocarbons: strategies for bioremediation. *Indian Journal of Microbiology*. 2008;48(1):95-113.
25. Andreoni V, Gianfreda L. Bioremediation and monitoring of aromatic-polluted habitats. *Applied Microbiology and Biotechnology*. 2007;76(2):287-308.
26. Liebeg EW, Cutright TJ. The investigation of enhanced bioremediation through the addition of macro and micro nutrients in a PAH contaminated soil. *International Biodeterioration & Biodegradation*. 1999;44(1):55-64.
27. Shi GT, Chen ZL, Xu S-Y, Yao C-X, Bi C-J, Wang L. Salinity and persistent toxic substances in soils from Shanghai, China. *Pedosphere*. 2009;19(6):779-89.
28. Mukherji S, Jagadevan S, Mohapatra G, Vijay A. Biodegradation of diesel oil by an Arabian Sea sediment culture isolated from the vicinity of an oil field. *Bioresource Technology*. 2004;95(3):281-6.
29. Chandrasekar S, Sorial GA, Weaver JW. Dispersant effectiveness on oil spills - impact of salinity. *ICES Journal of Marine Science*. 2006;63(8):1418-30.
30. Carlstrom CJ, Tuovinen OH. Mineralization of phenanthrene and fluoranthene in yardwaste compost. *Environmental Pollution*. 2003;124(1):81-91.
31. RashidAshmagh F, Rezaei Kalantary R, Farzadkia M, Joneidi Jafari A, Nabizadeh R. Survey of phenanthrene biodegradation's model in contaminated soils by *Acinetobacter* SP. *Iranian Journal of Environmental Health Science & Engineering*. 2009;3(2):196-203.
32. Ressler BP, Kneifel H, Winter J. Bioavailability of polycyclic aromatic hydrocarbons and formation of humic acid-like residues during bacterial PAH degradation. *Applied Microbiology and Biotechnology*. 1999;53(1):85-91.
33. Nasser S, Rezaei Kalantary R, Nourieh N, Naddafi K, Mahvi AH, Baradaran N. Influence of bioaugmentation in biodegradation of PAHs contaminated soil in bio-slurry phase reactor. *Iranian Journal of Environmental Health Science & Engineering*. 2010;7(3):191-200.
34. Maier RM, Pepper IL, P.Gerba PC. *Environmental Microbiology*. 2nd ed. Salt Lake City: Academic Press; 2009.
35. Minai-Tehrani D, Minoui S, Herfatmanesh A. Effect of salinity on biodegradation of polycyclic aromatic hydrocarbons (PAHs) of heavy crude oil in soil. *Bulletin of Environmental Contamination and Toxicology*. 2009;82(2):179-84.
36. Ruberto L, Vazquez SC, Mac Cormack WP. Effectiveness of the natural bacterial flora, biostimulation and bioaugmentation on the bioremediation of a hydrocarbon contaminated Antarctic soil. *International Biodeterioration & Biodegradation*. 2003;52(2):115-25.
37. Gao Y, Yu XZ, Wu SC, Cheung KC, Tam NF, Qian PY, et al. Interactions of rice (*Oryza sativa* L.) and PAH-degrading bacteria (*Acinetobacter* Sp.) on enhanced dissipation of spiked phenanthrene and pyrene in waterlogged soil. *Science of the Total Environment*. 2006;372(1):1-11.
38. Betancur-Galvis LA, Alvarez-Bernal D, Ramos-Valdivia AC, Dendooven L. Bioremediation of polycyclic aromatic hydrocarbon-contaminated saline-alkaline soils of the former Lake Texcoco. *Chemosphere*. 2006;62(11):1749-60.
39. Børresen MH, Rike AG. Effects of nutrient content, moisture content and salinity on mineralization of hexadecane in an Arctic soil. *Cold Regions Science and Technology*. 2007;48(2):129-38.
40. Hughes JB, Beckles DM, Chandra SD, Ward CH. Utilization of bioremediation processes for the treatment of PAH-contaminated sediments. *Journal of Industrial Microbiology and Biotechnology*. 1997;18(2-3):152-60.
41. Lee GT, Ro HM, Lee SM. Effects of triethyl phosphate and nitrate on electrokinetically enhanced biodegradation of diesel in low permeability soils. *Environmental Technology*. 2007;28(8):853-60.
42. Olivera FJS, De Franca FP. Increase in removal of polycyclic aromatic hydrocarbons during bioremediation of crude oil-contaminated sandy soil. *Applied Biochemistry and Biotechnology*. 2005;121-124:593-603.
43. De Silva AC, de Oliveira FJ, Bernardes DS, de França FP. Bioremediation of marine sediments impacted by petroleum. *Applied Biochemistry and Biotechnology*. 2009;153(1-3):58-66.

Comparison of Nutrients and Salinity on Phenanthrene Removal from Polluted Soil

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ABSTRACT

Background and Objectives: The poor accessibility of microorganisms to PAHs in soil has limited success in the process of bioremediation as an effective method for removing pollutants from soils. Different physicochemical factors are effective on the rate of biodegradation. The main objective of this study is to assess effects of nutrient and salinity on phenanthrene removal from polluted soils.

Materials and Methods: The soil having no organic and microbial pollution was first artificially polluted with phenanthrene then nutrients and salinity solution in two concentrations were added to it in order to have the proportion of 10% w:v (soil: water). After that a microbial mixture enable to degrade phenanthrene was added to the slurry and was aerated. Finally, the residual concentration of Phenanthrene in the soil was extracted by ultrasonic and was analyzed using GC. We measured the microbial population using MPN test. This study was conducted based on the two level full factorial design of experiment.

Results: MPN test showed that the trend of microbial growth has experienced a lag growth. The full factorial design indicated that nutrient had the maximum effect on bioremediation; the rate of phenanthrene removal in the maximum nutrients – minimum salinity solution was 75.14%.

Conclusion: This study revealed that the more nutrient concentration increases, the more degradation will be happened by microorganisms in the soils. However, salinity in the concentration used had no effect on inhabitation or promoting on the Phenanthrene removal.

Keywords: PAHs, Experimental Design, Soil Bioremediation, Nutrient, Salinity

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