Journal of
Chemical Engineering & Process Technology

El-Shamy et al., J Chem Eng Process Technol 2017, 8:1
DOI: 10.4172/2157-7048.1000325

Research Article Open Access

Modelling the Methodology for Crude Oil Bioremediation Decision Tree for an Integrated Environmental Management System

Ukpaka CP*

Department of Chemical/Petrochemical Engineering, Rivers State University of Science and Technology, Nkpolu Port Harcourt, Nigeria

Abstract

The application of Matrix Laboratory (MATLAB) computer programme language was used in the simulation approach to determine the best methodology for crude oil bioremediation using the concepts of decision tree mechanism with an integrated environmental management system to achieve high efficiency at end of the cleanup. Bioremediation is a process in which microorganisms metabolize contaminants either through oxidative or reductive processes. Under favorable conditions, microorganisms can oxidatively degrade organic contaminants completely into non-toxic by-products such as carbon dioxide and water or organic acids and methane. The area, volume, concentration of the soil, concentration of the liquid (crude oil) and the film mass transfer coefficients influence the effectiveness of bioremediation process. To obtain the parameters, $\mu_{max,}$ K_S, K_1 and y_x numerical solutions of these equations were performed using MATLAB. The method for the numerical modelling involves integration using fourth-order Runge Kutta numerical scheme to determine the trend and efficiency of the system.

Keywords: Modelling; Methodology; Crude oil; Bioremediation decision tree; Integrated environmental management system

Introduction

Nature has the ability to recycle and purify itself, but in recent years, the demand placed on the environment by huge amounts of anthropogenic pollution exceeds its capacity to recover, hence the need to save (remediate) the environment is necessary. Conventional techniques have been employed in environmental remediation [1-4]. Most recently, there is a need for bioremediation as this technique has proved to be more eco-friendly. Oil due to exploration and exploitation activities is a threat to the environment, particularly the mangrove ecosystem and agricultural land. World reserves of arable agricultural land are constantly diminishing and 25% of cultivated lands are affected by soil degradation due to man's activities. For example, a good percentage of oil spills that occurred on dry land between 1978 and 1979 in Nigeria affected farms in which crops such as rice, maize, yams, cassava, and plantain were cultivated. The primary concern of petroleum contamination of soil has been its effects on ground water, but its effect on the germination and growth of some plants have been reported [4-8].

Bioremediation technologies simply attempt to optimize microorganisms' natural capacity to degrade/recycle by supplying essential inorganic limiting reactants and minimizing abiotic stress. Recommendations have been advocated or the microbial seeding of oil spills, because bacteria and fungi are the only biological species which have the metabolic capacity of utilizing petroleum carbon for cell synthesis [1-3]. Bioremediation is the use of biological treatment systems to destroy or reduce the concentrations of hazardous wastes from a contaminated site. Such systems include the use of higher plants, which are efficient in removing or destroying the hazardous wastes [9-12]. These microbes and higher plants can also be variously modified through genetic engineering to become efficient and suitable for bioremediation. Bioremediation is an engineered technology that modifies environmental conditions (physical, chemical, biochemical, or microbiological) to encourage microorganisms to destroy or detoxify organic and inorganic contaminants in the environment [5]. The process can be applied above ground in land farms, tanks, biopiles, or other treatment systems (referred to as *ex situ*) or below ground in the soil or groundwater, referred to as in situ. In situ bioremediation of groundwater has become one of the most widely used technologies for contaminated site treatment because of its relatively low cost, adaptability to site-specific conditions, and efficacy when properly implemented [11].

Bioremediation techniques are versatile and can be utilized at various stages of treatment [7]. Applications include removal of contaminants from raw materials prior to processing, treatment of wastes before discharge, treatment of effluent streams, and decontamination of soils, sediments surface water and ground water. In environmental management, bioremediation techniques (including phytoremediation) have a variety of applications including the clean-up of ground water, soils, lagoons, sludge, and process water streams. One of the most important examples of large scale bioremediation is the shore-line clean-up efforts in Alaska, where in 1989; an environmental hazard resulted from a large oil-spill [10]. This led to clean-up operation covering 70 miles of shore-line. There are numerous other successful applications of bioremediation including clean-up of pollution due to chemical spills [2].

A decision tree can be used as a model for sequential decision problems under uncertainty [2]. A decision tree describes graphically the decisions to be made, the events that may occur, and the outcomes associated with combinations of decisions and events. Probabilities are assigned to the events, and values are determined for each outcome. A major goal of the analysis is to determine the best decisions. The bioremediation decision tree in this work was developed to aid interested parties (regulators, site owners and stakeholders) in evaluating sites as candidates for a particular type of bioremediation [6]. The background

***Corresponding author:** Ukpaka CP, Department of Chemical/Petrochemical Engineering, Rivers State University of Science and Technology, Nkpolu PMB 5080, Port Harcourt, Nigeria, Tel: 2349038858167; E-mail: chukwuemeka24@yahoo.com

Received January 02, 2017; **Accepted** February 16, 2017; **Published** February 21, 2017

Citation: Ukpaka CP (2017) Modelling the Methodology for Crude Oil Bioremediation Decision Tree for an Integrated Environmental Management System. J Chem Eng Process Technol 8: 325. doi: 10.4172/2157-7048.1000325

information required in the decision process should be available from the site characterization data. Using the decision tree and the reference documents will assist regulators, site owners, technology vendors, the public and stakeholders in determining if a particular bioremediation type is applicable to a contaminated site [2-7]. This study is aimed at developing a bioremediation decision tree model for an integrated environmental management system.

Materials and Methods

In this research the materials and methods are based on the bioremediation decision tree concepts as well as the developed mathematical models in relation to functional parameters that influence bioremediation processes. These functional parameters are well classified and examined in terms of the integrated environmental management system for effective remediation of the polluted environment.

Model Development

The mathematical model was developed by considering the contamination of soil with polycyclic aromatic hydrocarbons (PAHs) which is a serious environmental issue because some polycyclic aromatic is toxic, carcinogenic and mutagenic.

The flux of substance from the particle interface to the bulk liquid phase can be described based on a mass balance over a certain thickness film.

$$N = \frac{D}{\delta}(C_S - C_L) \quad (1)$$

Where, N is the flux ($gm^{-2}h^{-1}$), δ is the film thickness (m), C_s is the saturation on the saturation in liquid phase (gm^{-s}), C_L is the dissolved concentration in liquid phase ($gm.^{-s}$). By definition the ratio of the diffusion coefficient to the film thickness can be expressed a

$$\frac{D}{\delta} = K_L \quad (2)$$

Where, K_L is the film mass transfer coefficient (mh^{-1})

The flux causes the change in substrate concentration with time that is observed in the bulk liquid phase giving

$$\frac{dC_t}{dt} = K_t \frac{A}{V}(C_s - C_t) \quad (3)$$

In which v is the liquid phase volume (m^{-3}) and A is a surface area of the particle (m^2).

Equation (1), (2) and (3) are combined and it will give

$$\frac{dC_t}{dt} = K_t \frac{A}{V}(C_s - C_t) \quad (4)$$

Since it is difficult to determine the surface area of particles, another form of mass transfer coefficient is often used:

$$\mu = \mu_{\max} \frac{S}{Ks + S} \quad (5)$$

Where $(K_t a)_{SL}$ is the solid-liquid volumetric mass transfer coefficient (L^{-1}). The appropriate boundary conditions (C_L=0 at t=0) gives:

$$C_L = C_S\,[1 - \text{esp}\{-(K_L a)_{SL} \times t\}] \quad (6)$$

In this work, the metric mass transfer coefficient and saturation concentration. $(K_L a)_{SL}$ and C_S least square minimization in equation (6) to the experimental data using MATLAB.

Bioremediation Kinetics

Although the growth of microorganism is a complex phenomenon, it is a common practice to represent this growth by a relatively simple expression. One of the most widely employed expressions for the specific growth rate, μ, is the Monod equation which states that μ with the concentration of a single essential substrate. The Monod equation is

$$\mu = \mu_{\max} \frac{S}{Ks + S} \quad (7)$$

Where, μ_{max} is the maximum specific growth rate (h^{-1}), K_S is known as the saturation constant ($mg\ L^{-1}$). Under such circumstances, the Haldane inhibition model has been proposed to express the specific growth rate.

$$\mu = \frac{\mu\,\text{maxs}}{Ks + S + ^{s^2}/k_I}(K_1 >> K_s) \quad (8)$$

Microorganism is usually inhibited by these products whose effect can be added to the Monod equation as

$$\mu = \mu_{\max}[\frac{s}{Ks + S}]\left(1 - \frac{p}{P_w}\right)y \quad (9)$$

Concentration increase and stoichiometric relationship between substrate utilization and biomass production. The bioremediation can be shown below

$$\frac{dX}{dt} = \mu \times X \quad (10)$$
$$\frac{dX}{dt} = -Y_{XS}\frac{ds}{dt}$$

To obtain the parameters, μ_{max}, K_S, K_1 and $y_{x/s}$ numerical solutions of these equations were performed using MATLAB. The method for the numerical modelling involves integration using fourth-order Runge Kutta numerical scheme.

Experimental

Sample collection

Crude oil obtained from an oil terminal in Niger Delta area of Nigeria was collected and transported to the department of Chemical/Petrochemical engineering laboratory in Rives State University of Science and Technology Port Harcourt for onward analysis. The soil used in this investigation was collected within the campus of Rivers State University of Science and Technology Nkpolu, Port Harcourt and then transported to the Department of Chemical/Petrochemical Engineering laboratory.

Experimental procedure

The crude oil and soil sample was measured using measuring cylinder with soil sample of 3.2 gm^2 mixed in a batch rector and 2.5 gm^{-2} of the crude oil, then both samples was mixed in a batch reactor A and 2.2 gm^{-2} of soil and 1.05 gm^{-2} crude oil in reactor B and finally 2.1 gm^{-2} of soil sample and 1.5 gm^{-2} of crude oil for reactor C. The volume and area of various sampled for this investigation is defined in terms of zone A, we have 7 m^3 in volume and 0.15 m^2 in area and for zone C we have 5 m^3 in volume and 0.12 m^2 in area. The experimental set up was examined to enable use determine the film mass transfer coefficient for each reactor (Figure 1). This was examined by considering the rate of diffusion of the crude oil in the solid medium subjected in the batch reactor. The process was monitored with variation in time. The samples were collected from the batch reactor and subjected into further examination to ascertain the penetration of the crude oil as well as the GC (Gas chromatography) was used to determine the concentration of the solid and liquid (soil and crude oil) and AS (Absorption spectrograph) used in examining the film thickness concentration. The result obtained from this investigation is

Citation: Ukpaka CP (2017) Modelling the Methodology for Crude Oil Bioremediation Decision Tree for an Integrated Environmental Management System. J Chem Eng Process Technol 8: 325. doi: 10.4172/2157-7048.1000325

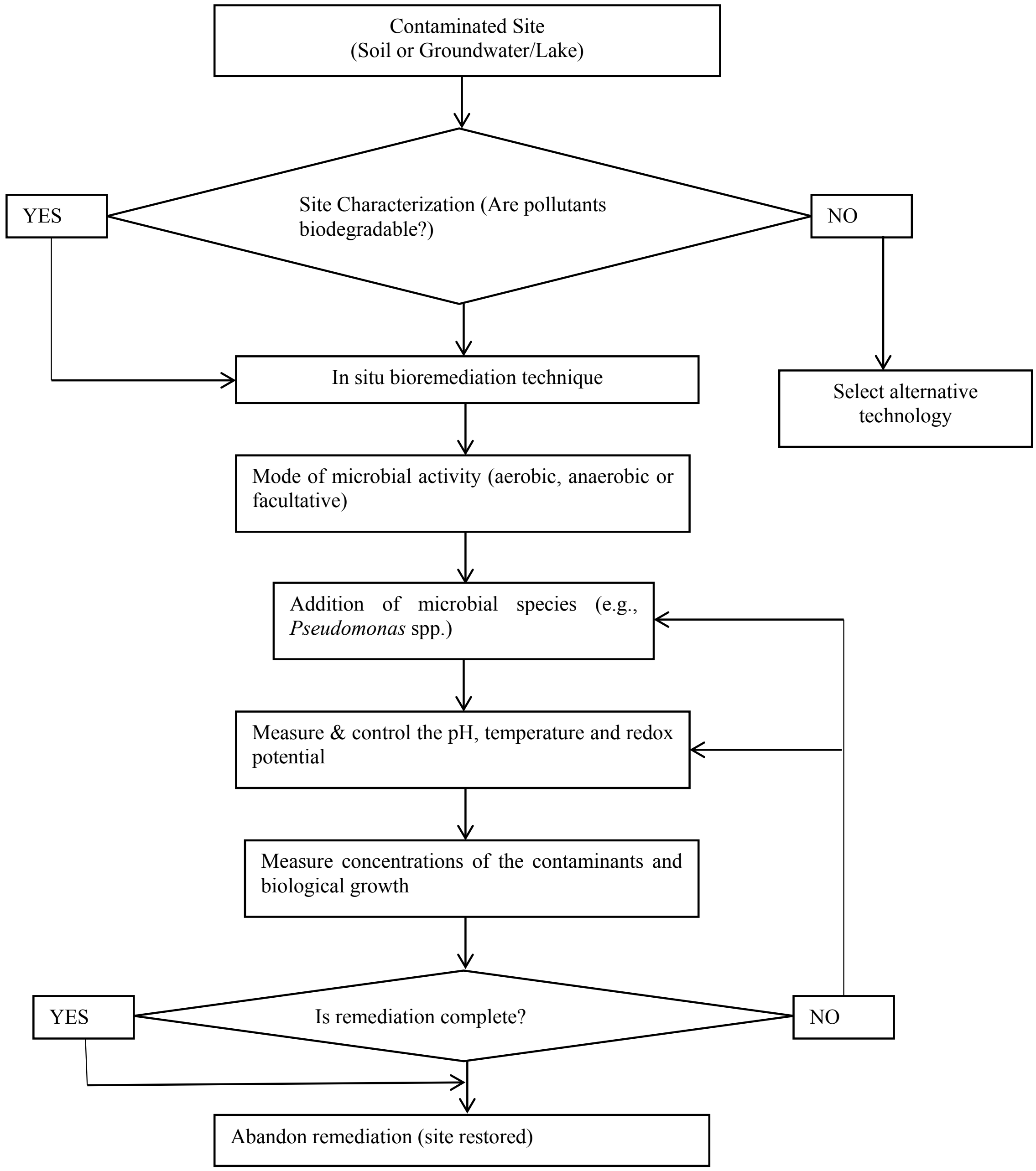

Figure 1: Decision Tree showing general approach to bioremediation.

simulated using matrix laboratory computer language programme. This application was useful to enable us determine the film mass transfer coefficient at interval as well as the degree on concentration of the pollutants upon the influence of diffusion in a batch reactor.

Results and Discussion

The results are presented in Tables 1-3, as defined in the computational procedures as well as in Figures as presented in the research work.

Figure 2 demonstrates the decrease in the chlorine concentration upon the influence of the microorganism in degradating the crude oil contaminated soil environment as a function of time. As the concentration of the microorganisms increases the substrate concentration decreases with respect time. In the case, the chlorine becomes the substrate and as shown in Figure 2 the chlorine concentration decreases with increase in time. The variation in the concentration of the substrate can be attributed to the variation in microbial concentration, integrated environmental management system put in place for high efficiency in the process as well as time effective monitoring of the process to check made other inhibiting factors. To obtain the parameters, μ_{max}, K_s, K_1 and $y_{x/s}$

S. No	Parameters	Values	SI Unit
1	Area (A)	0.15	M^2
2	Volume (V)	7	M^3
3	Concentration of solid (C_S)	2.2	Gm^{-2}
4	Concentration of liquid (C_L)	1.05	Gm^{-2}
5	Film mass transfer coefficient (k_L)	2	Mh^{-1}

Table 1: Computational Parameters at various functional values.

S. No	Parameters	Values	SI Unit
1	Area (A)	0.14	M^2
2	Volume (V)	7	M^3
3	Concentration of solid (C_S)	3.2	Gm^{-2}
4	Concentration of liquid (C_L)	2.5	Gm^{-2}
5	Film mass transfer coefficient (k_L)	4	Mh^{-1}

Table 2: Computational Parameters at various functional values.

S. No	Parameters	Values	SI Unit
1	Area (A)	0.12	M^2
2	Volume (V)	5	M^3
3	Concentration of solid (C_S)	2.1	Gm^{-2}
4	Concentration of liquid (C_L)	1.5	Gm^{-2}
5	Film mass transfer coefficient (k_L)	2	Mh^{-1}

Table 3: Computational Parameters at various functional values.

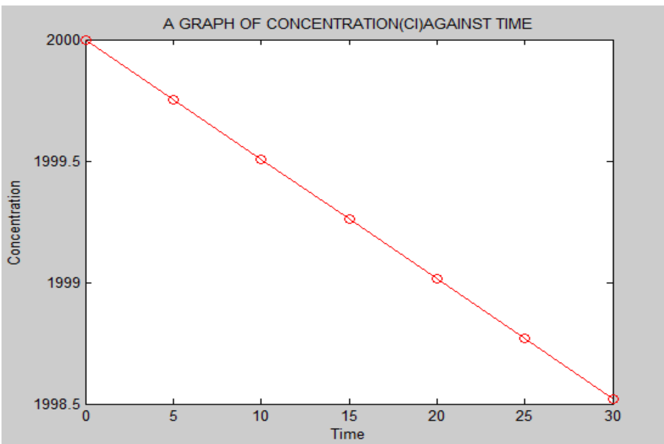

Figure 2: Matlab graphical solution showing decrease in concentration of pollutants in the contaminated site upon the influence of time for range of parameters.

numerical solutions of these equations were performed using MATLAB. The method for the numerical modelling involves integration using fourth-order RungeKutta numerical scheme. In this case, the functional parameters of the maximum specific rate of substrate degradation and the equilibrium constants are contributing factors to the process. The graph above shows a pilot of concentration against time putting into consideration the *in-situ* bioremediation of a soil contaminated site, it is observed that as the time increases the concentration of substrate decrease which shows a favourable sign for that methodology (*in-situ* bioremediation) chosen.

Figure 3 demonstrates the decrease in the chlorine concentration upon the influence of the microorganism in degrading the crude oil contaminated soil environment as a function of time. As the concentration of the microorganisms increases the substrate concentration decreases with respect time. In the case, the chlorine becomes the substrate and as shown in Figure 3 the chlorine concentration decreases with increase in time. The variation in the concentration of the substrate can be attributed to the variation in microbial concentration, integrated environmental management system put in place for high efficiency in the process as well as time effective monitoring of the process to check made other inhibiting factors. The graph above shows a pilot of concentration against time putting into consideration the *in-situ* bioremediation of a soil contaminated site, it is observed that as the time increases the concentration of substrate decrease which shows a favourable sign for that methodology (*in-situ* bioremediation) chosen. To obtain the parameters, μ_{max}, K_S, K_I. And $y_{x/s}$ numerical solutions of these equations were performed using MATLAB. The method for the numerical modelling involves integration using fourth-order Runge Kutta numerical scheme. In this case, the functional parameters of the maximum specific rate of substrate degradation and the equilibrium constants are contributing factors to the process.

The graph below shows a pilot of concentration against time putting into consideration the *in-situ* bioremediation of a soil contaminated site, it is observed that as the time increases the concentration of substrate decrease which shows a favourable sign for that methodology (*in-situ* bioremediation) chosen.

Figure 4 demonstrates the decrease in the chlorine concentration upon the influence of the microorganism in degrading the crude oil contaminated soil environment as a function of time. As the concentration of the microorganisms increases the substrate concentration decreases with respect time. In the case, the chlorine becomes the substrate and as shown in Figure 4 the chlorine concentration decreases with increase in time. The variation in the concentration of the substrate can be attributed to the variation in microbial concentration, integrated environmental management system put in place for high efficiency in the process as well as time effective monitoring of the process to check made other inhibiting factors. To obtain the parameters, μ_{max}, K_S, K_I. And $y_{x/s}$ numerical solutions of these equations were performed using MATLAB. The method for the numerical modelling involves integration using fourth-order Runge Kutta numerical scheme. In this case, the functional

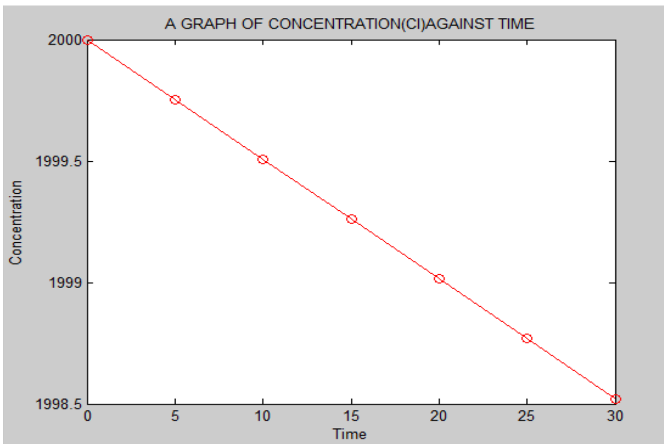

Figure 3: Matlab graphical solution showing decrease in concentration of pollutants in the contaminated site upon the influence of time for range of parameters.

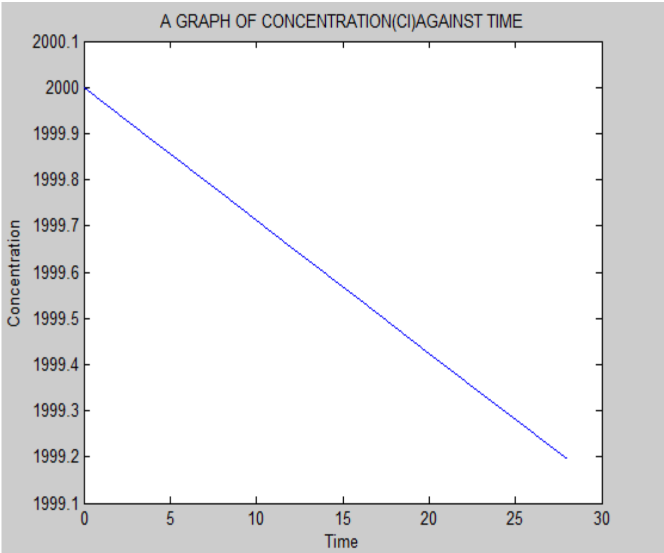

Figure 4: Matlab graphical solution showing decrease in concentration of pollutants in the contaminated site upon the influence of time for range of parameters.

parameters of the maximum specific rate of substrate degradation and the equilibrium constants are contributing factors to the process.

Conclusion

The following conclusion was drawn from the investigation such as:

1. Good integrated environmental management system will improve the bioremediation process.
2. Optimum remediation performance with low cost of project execution.
3. Low rate of inhibiting factors.
4. Less period required to accomplish the programme.
5. Reduction in constrain factors.

References

1. Cookson JT (1995) Bioremediation Engineering Design and Application. McGraw-Hill, New York, USA.
2. Environmental Protection Agency (2013) Introduction to in-situ bioremediation of groundwater. EPA 86.
3. Gupter PK (2006) Biotechnology and Genomics. Meerut, India.
4. Kogbara RB (2008) Ranking Agro-technical Methods and Environmental Parameters in the Biodegradation of Petroleum-Contaminated Soils in Nigeria. Electronic Journal of Environmental Biotechnology 11: 4.
5. Lee JY, Roh JR, Kum HS (1994). Metabolic Engineering of Pseudomonas Pulida for the Simultaneous Biodegradation of Benzene, Toluene and P-xylene Mixture. Biotech Bioeng 43: 1146-1152.
6. Sandro JB, Magali CC, Denize DCF (2005) Production off CO2, in Crude Oil Bioremediatin in Clay Soil. Brazilian Archives of Biology and Technology, p: 48.
7. US Environmental Protection Agency (1990) Interim Report, Oil Spill Bioremediation Project. US Environmental Protection Agency, Office of Research and Development, Washington, USA.
8. Amadi SA, Ukpaka CP (2015) Evaluation of the metals corrosion in soil environment of Niger Delta Area of Nigerian. Nigerian Journal of Oil and Gas Technology 1: 104-117.
9. Ikenyiri PN, Ukpaka CP (2016) Application of moringa dry stem for effective remediation of crude oil processing induced water environment using packed bed reactor. Nigerian Journal of Oil and Gas Technology 1: 58-73.
10. Igwe FU, Dokubo A, Ukpaka CP (2016) Overview of crude oil toxicity: a potential health and environmental hazard in the Niger Delta. Nigerian Journal of Oil and Gas Technology 2: 94-104.
11. Ukpaka CP, Farrow TS (2016). Simulation of Pneumatic Pressure Transducer Reliability on the Transfer Function of Bellow. Nigerian Journal of Oil and Gas Technology 2: 216-228.
12. Ukpaka C (2016). Evaluation of Olu-Obasanjo Groundwater Parameters: Application of Finite Element Concepts. Nigerian Journal of Oil and Gas Technology 2: 117-127.

Citation: Ukpaka CP (2017) Modelling the Methodology for Crude Oil Bioremediation Decision Tree for an Integrated Environmental Management System. J Chem Eng Process Technol 8: 325. doi: 10.4172/2157-7048.1000325