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Evolving Novelty in Oil Spill Evaluation

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Abstract — This study brings to limelight the fact that the contemporary spill assessment routines need to be improved upon, a procedure that will enable virtual visualization of spatial distribution of spilled oil (petroleum) in the subsurface (isosurface) should be included. There are added values to that such as the subsurface distribution of spilled oil at a site, precise knowledge of GPS locations of emplaced patches and accummulated oils in the isosurface and the potential ease of remediation/clean up. The possible application of risk based corrective action (RBCA) is a critical advantage

Index Terms— innovation; isosurface (subsurface); oil spill; petroleum geochemistry; RBCA; remediation.

1 Introduction

THERE has been some contentions on spill and remediation as an aspect of petroleum geochemistry, however the course content of MSc petroelum geochemistry in Newcastle University in United Kingdom has spill and remediation as part of a module which is Petroleum and the Environment.

The frequency of oil spill particularly in Nigeria, calls for innovative techniques of spill assessment. Nigeria is a beehive of exploration and production of petroleum (crude oil), hence oil at one time or another has to be transported via rail, trucks and ship and these modes of transport have one inherent risk or another, thus accidents occur [1]. These accidents lead to spillages, in contemporary times restiveness as a result of local or regional politics, activism also lead to pipeline vandalism. Hence spillages also occur. However the efforts to remediate spilled environments are evolving either with respect to remediation methods, remediation tools and in assessment method that allow the degree of spillage and extent to be delineated [1], [2].

Oil spill can occur advertently and inadvertently, adventitious spills which is operational includes cargo washings, produce water from offshore rigs and recreational vessels and the inadventitious spills include tanker/barge vessel, pipeline spills, coastal facility spills, non-tanker spills and production platforms spills. In some countries, in these modern days pipleines are laid on the surface of the Earth, however, exceptions are made in other places where pipelines of 6 inches diameter are trenched 4–6ft into the subsurface [1]. These procedures provide for protective measures aganist incidences and vandalism.

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In this study an innovative assessment method will be examined and its contribution to improving the understanding of the distribution of crude oil in the subsurface due to spill incidents, the distribution in the subsurface is key to effective and efficient remediation.

The present-day oil spill evaluation method includes some routine analysis that are performed alongside the TPH analysis for impacted soil. These analysis includes assessments of soil contamination, groundwater contamination, natural occuring radioactive materials, surface water and sediments, fish contamination, impact on vegetations, mangroves and atmospheric air and public health [11].

2 Sampling and Analysis

These aspects are very crucial, they need a lot of expertise, sample collection cut across all media but specific techniques are applied for sensitive media like surface water where techniques such as used of polyethylene cornet, use of aluminum pan and the use of Teflon net with clothespin are adopted. Soil sampling also requires some special skill with the use of hand auger.

The analysis of the samples is another bridge to cross, the advent of GC–FID (Gas Chromatogram–Flame Ionization Detector) and GC-MS (Gas Chromatogram–Mass Spectormetry) [8], [9], [10] has phased out the gravimetric method where samples will be dissolved, evaporated in a fume cupboard and weighed. Samples are diluted to appropriate concentrations and injected to the GC-FID for a TIC and a percnt report printout and further into the spectrometer for the respective m/z scans [8], [9], [10]. The reports used quantification and qualitative analysis for genetic purposed where there are conflicts on potential source [3].

Environmental awareness and the concept of 'polluter pays' has brought so much conciousness on restitution, fines and cost of rehabilitation programs [3], this has led to partial expolitation of these new methods to their advantage. Fig. 1. shows the higlights of the guidelines for various assessments stepwise from pre sampling and planning to shipmet for analysis.

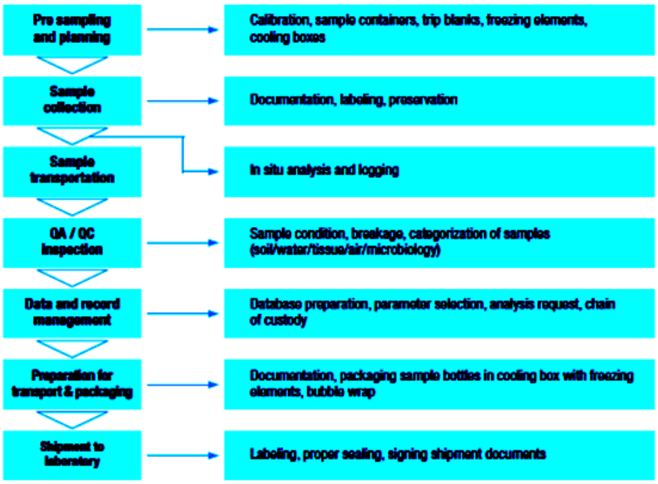

Fig. 1. Assessment Guide [11]

rerun as headspace gas using GC–FID.

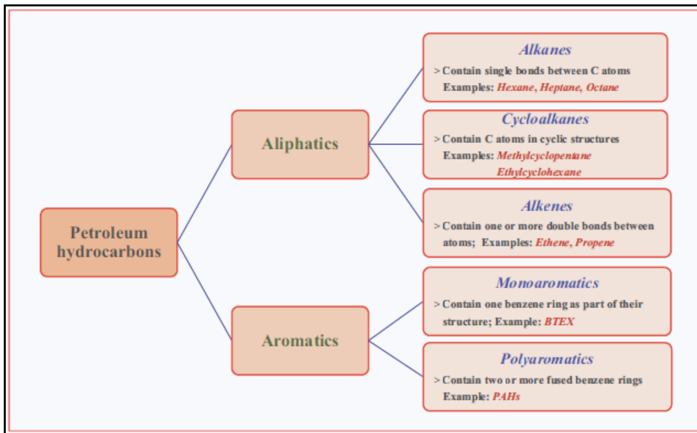

Fig. 2. TPHs distributions in classes [11]

3 RESULT PRESENTATION.

The results have always been presented as 1D plots, 2D contour plots and tables. 3D model images have not been adopted popularly. The environmental guideline and standard for petroleum Industries in Nigeria (EGASPIN) has stated permissible limits of oil in soil, and water. A summary is presented in Table 1.

Table 1. EGASPIN intervention and target values for water and soil [11]

Substance	Soil/sediment #		Groundwater	
	Target value	Intervention value	Target value	Intervention value
A. Aromatic compounds	(mg/kg dry material)		(µg/l)	
Benzene	0.05	1	0.2	30
Ethyl benzene	0.05	50	0.2	150
Phenol	0.05	40	0.2	2,000
Toluene	0.05	130	0.2	1,000
Xylene	0.05	25	0.2	70
B. Metals				
Barium	200	625	50	625
E. Other pollutants				
Mineral oil	50	5,000	50	600

The values given for soil are for 20 % soil organic matter with a forumula given for calibrating for other soil organic matter concentrations

The intervention values are threshold above which remediation must be performed, while target values are threshold to be achieved by remediation at which the flora and fauna are safe. The parameter of interest has always been the TPHs (total petroleum hydrocarbon) which consists the VPHs (Volatile petroleum hydrocarbons) and EPHs (extractable petroleum hydrocarbons)[4], this can be listed as gasoline, kerosine, diesel jet fuel, stoddard solvent, mineral based motor oils and fuel oils. The most important reason for considering clean up and remediation and possible rehabilitation of crude oil/petroleum spills is that petroleum is neurotoxic to humans, animals and plants, this drives the need for correct measurement TPHs in the environment [4]. The analysis can be done for the TPHs to obtain the TICs (total ion chromatograms) separately for saturates and aromatics, as in Fig. 2. Thus TPHs consist saturates (aliphatics), BETEX and PAHs (poly aromatic hydrocarbons)[4]. Where the BETEX seems lost, resampling can be performed and analysis

Table. 2. Typical summary of assessment result. [11]

UNEP site code	qc_001-001
Site name	Ejama-Ebubu
LGA	Eleme
Site description	SPDC pipeline right of way
Total Investigated Area (m^2)	169,712
Number of soil samples	92
Number of groundwater samples	15
Number of drinking water samples	2
Number of surface water samples	1
Deepest investigation (m)	6.00
Maximum soil TPH (mg/kg)	49,800
Number of soil measurements greater than EGASPIN intervention value	36
Deepest sample greater than EGASPIN intervention value (m)	6.00
Number of wells where free-phase hydrocarbon was observed	1
Maximum water TPH (µg/l)	485,000
Number of water measurements greater than EGASPIN intervention value	8
Presence of hydrocarbons in drinking water	No
Number of soil measurements below 1 metre	62
Number of soil measurements below 1 metre greater than EGASPIN intervention value	23
Total volume of soil above intervention value (m^3)	105,302
Total volume of soil above target value (m^3)	236,077

The presentation of results is critical to the understanding of the distribution of the spilled petroleum on the surface and subsurface, in this case the use of GPS (Global Positioning System) data will suffice that purpose espcially in the subsurface, since locations will remain constant [5].

Fig. 3 is a contamination contour of Korokoro Well 8 in Tai–Eleme, Rivers State, Nigeria. Contour diagrams are 2Ds [11]. Variograms are used to express variability between data points as a function of distance and the contour maps are extension of variograms, expressing them as surface 2D or 3D, thus expressed as contours of variograms, which show changes due to distance or data points [11].

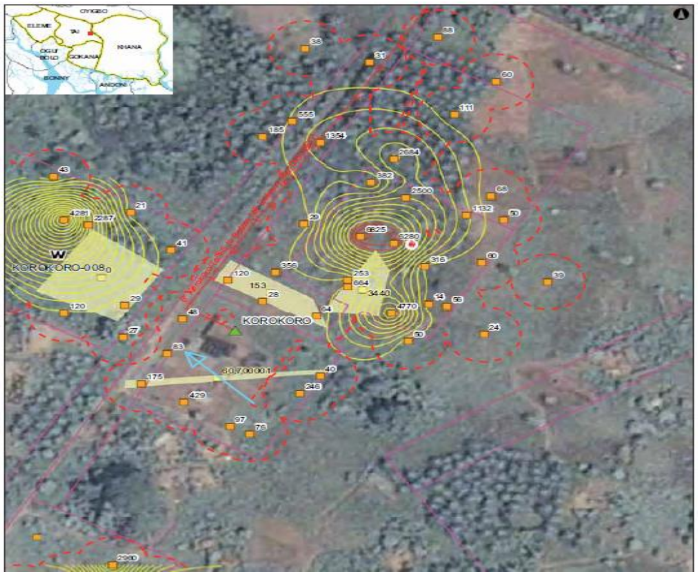

Fig. 3. Contamination contour at Korokoro Well, Nigeria. [11]

4. FILLING THE GAP

Filling the gap entails bringing to limelight what was not considered in the current spill assessment method adopted by most environmental agencies.

Surface and the subsurface are not uniform, they have variable porosity and permeability, thus when a spill occurs oil flows on the surface take the least resistant pathway, however it also percolates through the connecting pore network in the matrix of the sediment, but there may be a dead-end where permeability will be negligible and the oil will accumulate and possibly spreads out at a particular depth. This has been the case in some areas where the Exxon Valdez Oil spill impacted, it was discovered that after 20 years of the spill, oil was still present in patches in the subsurface as in Fig. 4. [6],[12]

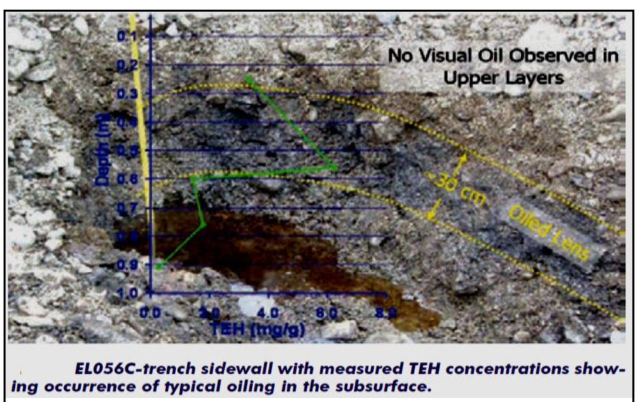

Fig. 4. Spilled oil in subsurface 20 yrs after spill event [12]

Most of the results are being expressed in 2D, which does not provide a proper picture of the subsurface. The isosurface concept is a better approach, it is an innovation on the existing spill assessment method.

5. INNOVATION

The innovation in this context implies additional idea that will improve the understanding, presentation and interpretation of the data generated from various assessments. On a wider horizon it entails converting ideas, thoughts into solutions to problems. The innovation also involves moving from 2D to 3D. The 3D isosurface interpolated view will give a detail of the hydrocarbon distribution in the subsurface, this includes where there are patches and accumulations and their concentrations. The will provide the basis for appropriate decisions on remediation method and depth to consider. The most important aspect is that of easy access to appropriate position/location of the patches and accumulations in the subsurface, since the GPS data for each sample location/position is an essiential data required in this innovation.

Data required in addition to the usual are sample coordinates, sample I–data (interval data or P–data (point data) and modelling instructions.

6. VIABLE RESULTS AND INTERPRETATION.

The potential results that could be obtained in addition to the regular results include flow direction of ground water, sample location map, hydrocarbon distribution map, the interpolated I–data cross section and i–data index profile map and then i–data subsurface (isosurface models) these data are generated using RockWare's Rockwork software [5]. Example of data are in Tables 1 and 2.

Table 1. Example of Location Data

Bore	Easting	Northing	Elevation	TotalDepth
P-01	257754.56	548012.29	17.3	75
P-02	257751.45	548015.37	17	75
P-03	257745.26	548009.24	17.65	75
P-04	257748.35	548012.31	17.32	75
P-05	257748.37	548018.48	17.57	75
P-06	257742.21	548018.47	17.42	75
P-07	257745.29	548018.46	17.9	75
P-08	257745.3	548018.45	17.22	75
P-09	257745.31	548018.46	17.65	75

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Table 2. Example of I–data (Interval Data)

Bore	Type	Depth1	Depth2	Value
P-01	Petroleum Soil	0	25	40,870
P-01	Petroleum Soil	25	50	2204
P-01	Petroleum Soil	50	75	1598
P-02	Petroleum Soil	0	25	10892
P-02	Petroleum Soil	25	50	366.02
P-02	Petroleum Soil	50	75	1270
P-03	Petroleum Soil	0	25	2977
P-03	Petroleum Soil	25	50	4361
P-03	Petroleum Soil	50	75	1574

These data are some of other data types that are needed for this innovative addendum [5]. These data will foster the generation of models that will add value to the regular results that are used.

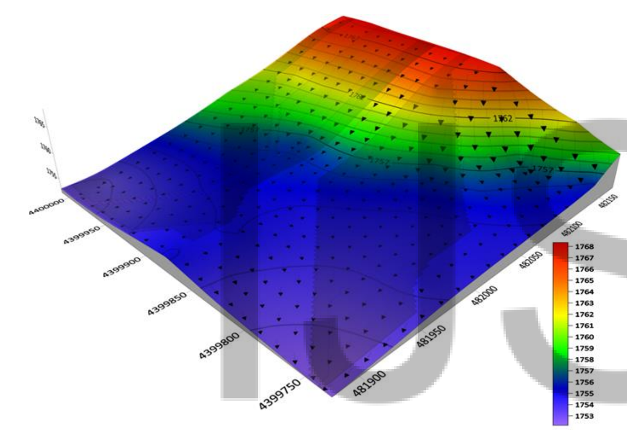

Fig. 4. Water flow direction

Flow direction is important beause most spills that impacted the ground water will likely flow in that direction, thus flow rate will determine distance cover within certain radius from the location [5].

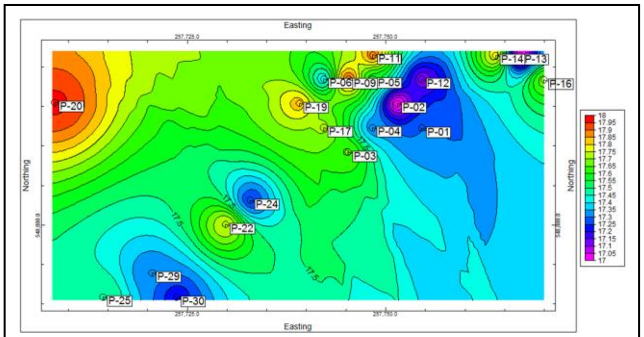

Fig. 5. Sample Location Map

Fig. 5. represents the sample/borehole location, corroborating the two diagrams will show the wells on the lower elevations.

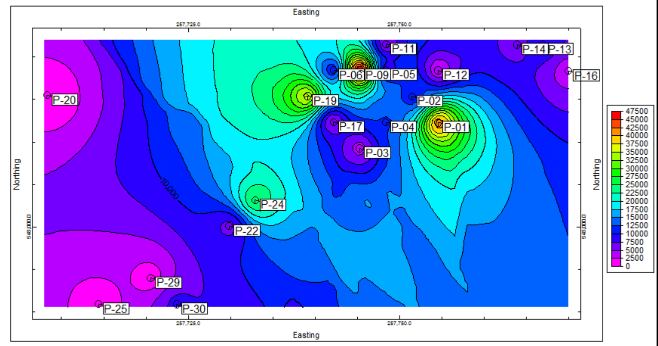

Fig. 6. The TPH distribution

The TPH distribution can be obtained at every depth level, the locations bearing high TPH can be identified [5]. These locations can be spotted at the spill site for effective remediation.

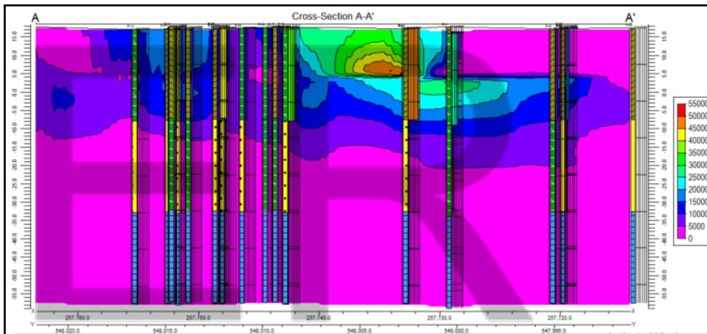

Fig. 7. Cross Section profile

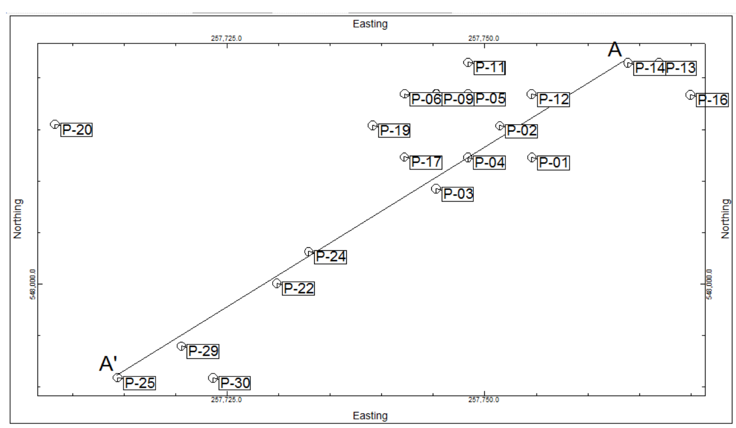

Fig. 8. Cross section profile index map

Fig. 7 is the cross-section profile, showing the TPH distribution on a vertical cross-section, the A–A′ transverse on Fig. 8 represents the depthwise vertical cross-section in Fig. 7 [5],[7]. The sample location bearing the highest and lowest TPH values can be delineated, the depth hosting the patches and accumulation of percolated spilled oil can be deduced. These are additional tools that foster a better understanding of the distribution of spilled oil in the subsurface, it provides the basis for better decisions on best practice methods of remediating oil spill impacted enironments.

This new idea can also provide the basis for effective implementation of RBCA (Risk based corrective action), RBCA is a new philosophy for managing spill imapcted sites, it categorizes sites according to risk, with this regulators can make sound, quick, consistent management decisions for a variety of sites. The information derivable from these tools can assist the use of RBCA strategies for remediation and future use of impacted sites.

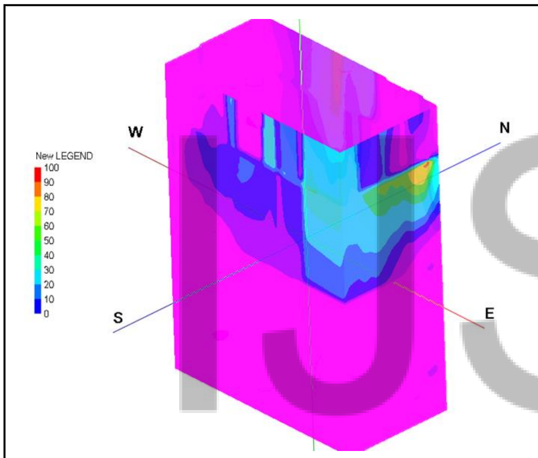

Fig. 9. Soild subsurface model.

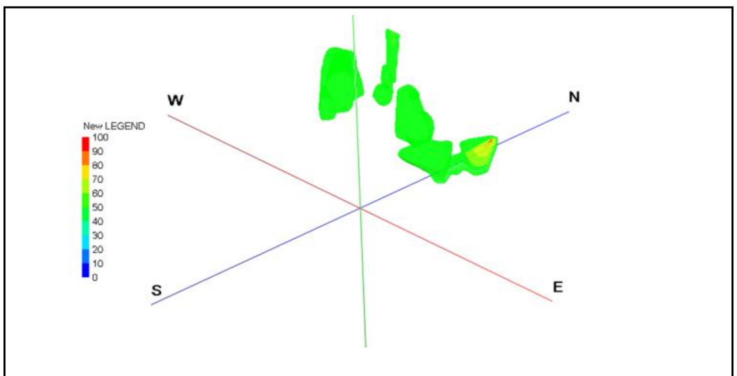

Fig. 10. Soild subsurface model, depicting areas with TPH greater than 60% of the maximum value.

Figs. 9 and 10 are solid models depicting the overall distribution of TPH in the subsurface (isosurface). The models can be viewed in slides depthwise and across laterally, thus revealing the areas of spill impact.

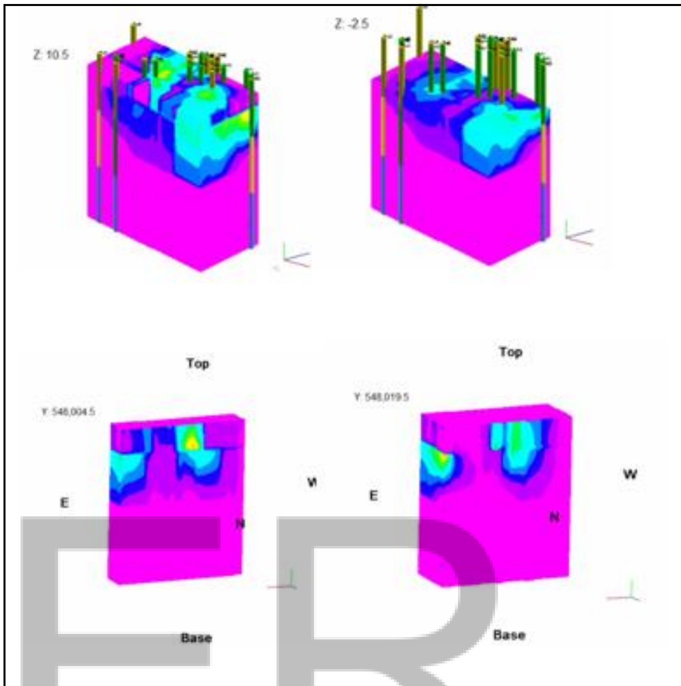

Fig. 11. Showing depthwise slides and vertical cross section

Fig. 11. Shows the slides as it could be obtained, varieties of view provides wide provision of choice for efficient and effective decision making with respect to remediation/clean-up of oil spill sites.

7. CONCLUSION

The contemporary spill assessment as indicated in the United Nation Environment Program on the Environmental Assessment of Ogoniland can be improved upon by innovative ideas presented in this paper. Thus the difference between the contemporary and innovation is clear. There is some added value i.e. the subsurface distribution of spilled oil at a site, precise knowledge of GPS locations of emplaced patches and accummulated oils in the isosurface and the potenial ease of remediation/clean-up. The possible application of risk based corrective action (RBCA) is critical advantage.

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