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Research Article

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Some Innovations in Oil Spill Evaluation

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Abstract: Evolving novelty in oil spill evaluation is a study that examines and advocates to the glare of our professional bodies and colleagues, 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 as an indispensable aspect. 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 accumulated 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.

Keywords innovation; isosurface (subsurface); oil spill; petroleum geochemistry; RBCA; remediation.

1. Introduction

The transitory from the former conceptual geochemistry to a more application based geochemistry, reconstituted petroleum geochemistry into exploration geochemistry, production geochemistry, development geochemistry, and environmental oil geochemistry. Environmental oil geochemistry is that aspect that deals with Oil spill and remediation and provides for the use of biomarkers (molecular markers), in delineating source of oil spill, its trajectory and their spatial distribution in the subsurface. This implies that petroleum geochemists should be involved in resolving oil spill issues. This, to an extend also settles the uncertainty, if an environmental geologist is best suited for oil spill evaluations.

The awareness with which oil spill issues are resolve, calls for an innovation from current conventional techniques of spill assessment.

Spillages, in contemporary times can result from accidents, restiveness as a result of local or regional politics, activism, also pipeline vandalism, in bid to steal oil or petroleum products. In some countries, in these modern days pipelines are laid on the surface of the Earth, however, exceptions are made in other places where pipelines more than 6 inches in diameter are trenched 4–6ft into the subsurface (Abrakasa & Douglas, 2022). These procedures provide for protective measures against incidences and vandalism.

However, the efforts to remediate spilled environments are evolving either with respect to remediation methods, remediation tools and in assessment methods that allow the degree of spillage and extent to be delineated (Allison & Mandler, 2018)

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, knowledge of the spitial distribution in the subsurface is key to effective and efficient remediation.

2. Conventional spill evaluation

The present-day oil spill evaluation method includes some routine analysis that are performed alongside the Total Petroleum Hydrocarbon (TPH) analysis for impacted soil. This 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 (UNEP, 2011).

Sampling and analysis

Sampling and analysis are very crucial aspects of spill evaluation, sample collection cuts 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 Chromatography–Flame Ionization Detector) and GC-MS (Gas Chromatography–Mass Spectormetry) (Stout et al., 2001; 2002; 2005.) 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 percent report printout and further into the spectrometer for the respective m/z scans (Stout et al., 2001; 2002; 2005.) The reports used quantification and qualitative analysis for genetic analysis, where there are conflicts on potential source, rerun of the analysis can be performed (Daling et al., 2002).

Environmental awareness and the concept of 'polluter pays' has brought so much consciousness on restitution, fines and cost of rehabilitation programs (Daling et al., 2002), this has led to partial exploitation of these new methods to individuals advantage. Fig. 1. shows the highlights of the guidelines for various assessments stepwise from presampling and planning to shippment for analysis.

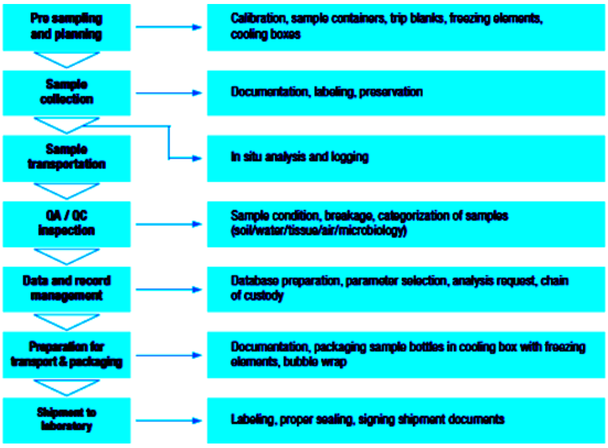


Figure 1: The highlights of the guidelines for various assessments (Unep, 2011)

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 guidelines and standards for petroleum Industries in Nigeria (EGASPIN) has stated permissible limits of oil in soil, and water. A summary is presented in Table 1.

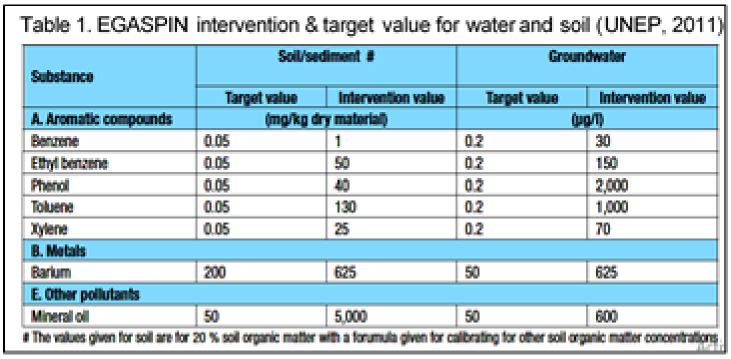


Table 1. EGASPIN intervention & target value for water and soil (UNEP, 2011)

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 thresholds 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), 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 cleanup and remediation and possible rehabilitation of crude oil/petroleum spills impacted areas is that petroleum is neurotoxic to humans, animals and plants, this drives the need for correct measurement of TPHs in the environment

(Kuppusamy et al., 2020). The analysis can be done for the TPHs to obtain the TICs (total ion chromatograms) separately for saturates and aromatics, as in Fig. 2.

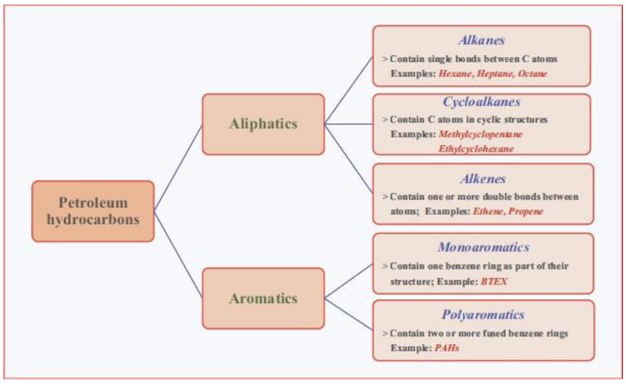


Figure 2: TPHs distributions in classes (UNEP, 2011)

Table 2: Typical summary of assessment result. (UNEP, 2011)

UNEP site code	**qc_001-001**
Site name	**Ejama-Ebubu**
LGA	Eleme
Site description	SPDC pipeline right of way
Total Investigated Area (m²)	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 (m³)	105,302
Total volume of soil above target value (m³)	236,077

Thus TPHs consist saturates (aliphatics), BETEX and PAHs (poly aromatic hydrocarbons), When a rerun as headspace gas using GC–FID seems needed, resampling can be performed for analysis. The presentation of results is critical to the understanding of the distribution of the spilled crude oil on the surface and subsurface, in this case the use of GPS (Global Positioning System) data will suffice that purpose especially in the subsurface, since locations will remain constant (RockWares, 2020).

Fig. 3 is a contamination contour at Korokoro Well 8 in Tai–Eleme, Rivers State, Nigeria. Contour diagrams are 2Ds (UNEP, 2011). 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 (UNEP, 2011).

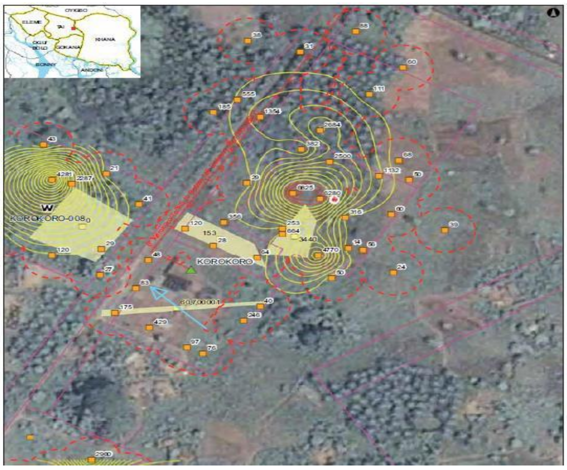
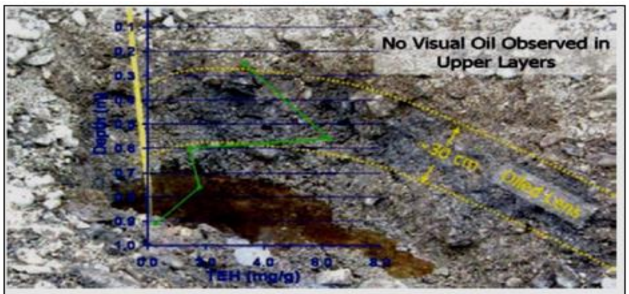


Figure 3: Contamination contour at Korokoro Well 8 in Tai–Eleme, Rivers State, Nigeria

3. Filling the gap

Filling the gap entails bringing to awareness ideas that had not been considered/adopted in the current spill assessment method by most environmental agencies.

The surface and the subsurface are not uniform, they have variable porosity and permeability, thus when an oil spill occurs, oil flows on the surface taking 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 that where impacted by the Exxon Valdez Oil spill, it was discovered that after 20 years of the spill, oil was still present in patches in the subsurface as in Fig. 4. (Shekwolo, 2020; Grey, 2011)



EL056C-trench sidewall with measured TEH concentrations showing occurrence of typical oiling in the subsurface.

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. This implies that in some situations, the realms of our imaginations are our limitations.

4. 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 of 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. This will provide the basis for appropriate decisions on remediation method. The most important aspect is that of easy of access to appropriate position/location of the patches and accumulations in the subsurface, since the GPS data for each sample location/position is an essential 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.

5. 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 (RockWares, 2020). Example of data are in Tables 3 and 4.

Table 3: Sample Coordinates

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

Table 4: 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

Tables 3 and 4 are some of the data types that are needed for this innovative addendum (RockWares, 2020). These data will foster the generation of models that will add value to the regular results that are used.

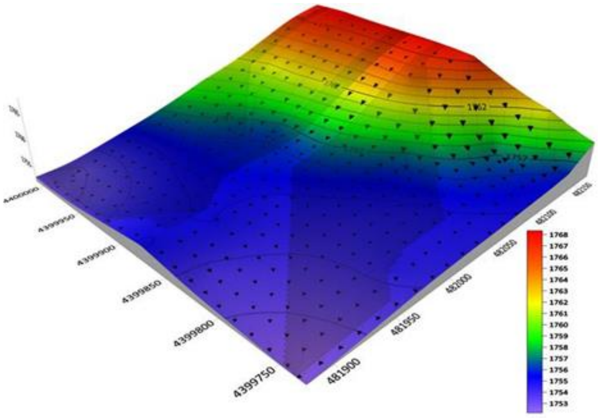


Figure 5a: Flow direction

Flow direction (fig 5a) is important because 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 (RockWares, 2020).

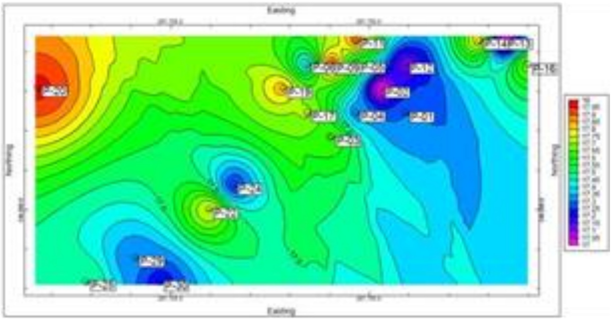


Figure 5b:. Sample Location Map

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

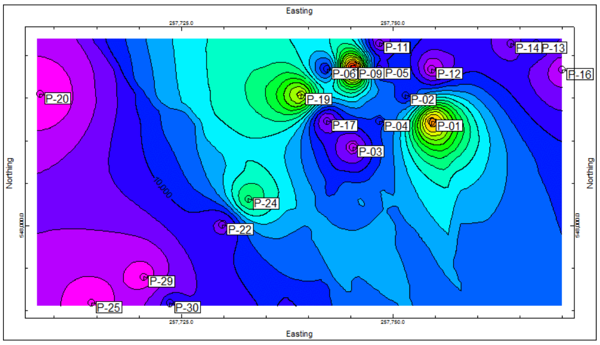


Figure 6: The TPH Distribution

The TPH distribution can be obtained at every depth level, the locations bearing high TPH can be identified (RockWares, 2020). These locations can be spotted at the spill site for effective remediation.

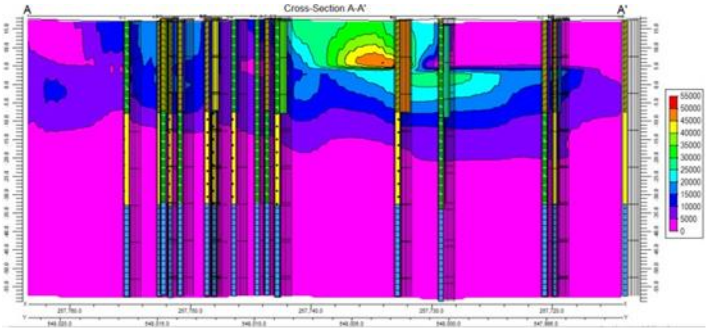


Figure 7: Cross Section Profile

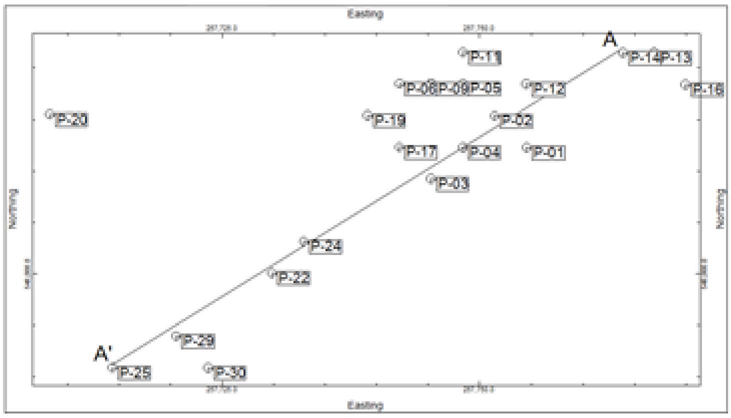


Figure 8: Cross Section Profile Map

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 generated in Fig. 7 (RockWares, 2020; Stout & Wang, 2016). The sample locations bearing the highest and lowest TPH values can be delineated, the depth hosting the patches and accumulations 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 environments.

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 impacted 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 in the use of RBCA strategies for remediation and future use of impacted sites.

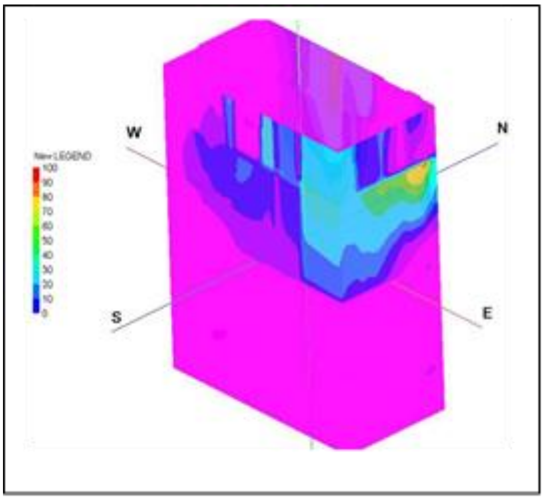


Figure 9: Solid subsurface model

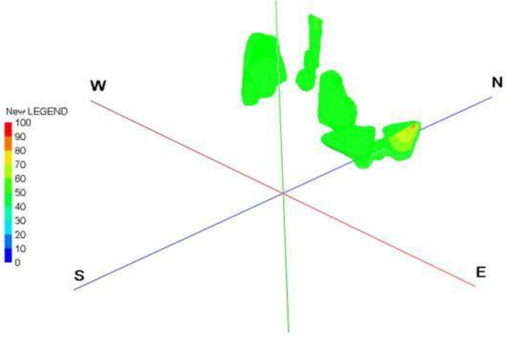


Figure 10: Solid subsurface model, depicting areas with TPH greater than 60% of the maximum value

Figs. 9 and 10 are solid models depicting the partial and 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.

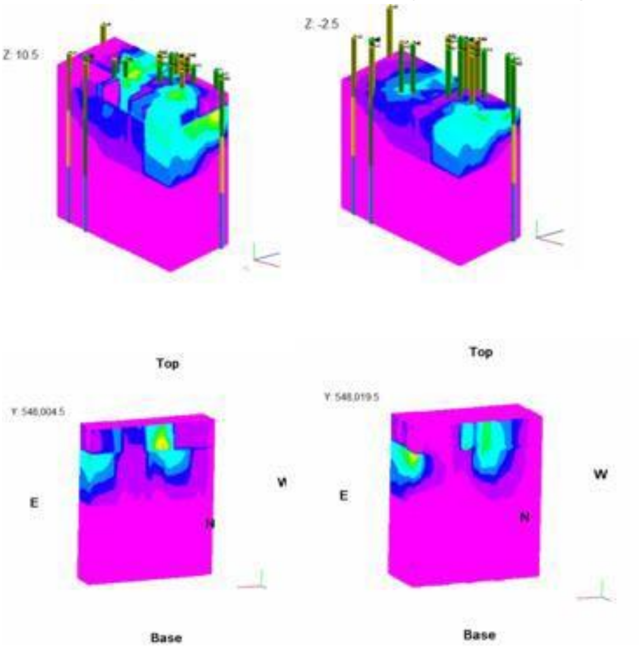


Figure 11: Depthwise and vertical cross section slides

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

6. Conclusion

A comparative study of innovations mentioned in this study and the contemporary spill assessment method as adopted in the United Nation Environment Program on the Environmental Assessment of Ogoniland indicates added advantages in the use of advance 2D and 3D models. Advantages includes view of patches and accumulations in the subsurface; Vertical and lateral slides profiles; Precise knowledge of GPS locations of emplaced patches and accumulated oils in the isosurface for appropriate application of remediation/cleanup options. The possible application of risk based corrective action (RBCA) is critical advantage.

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