African Research Review
An International Multi-disciplinary Journal, Ethiopia
Vol. 10(2), Serial No.41, April, 2016: 123-143
ISSN 1994-9057 (Print) ISSN 2070-0083 (Online)
Doi: http://dx.doi.org/10.4314/afrrev.v10i2.8

Overview of Effective Geophysical Methods Used in the Study of Environmental Pollutions by Waste Dumpsites

Yusuf, T. U.
Department of Pre-ND Sciences,
College of Agriculture, Mokwa, Niger State, Nigeria
E-mail: tklokogoma@gmail.com
Phone: +234 806 8724 999

Abstract

The Application of various Geophysical Techniques for the assessment of the extent of environmental, groundwater and soil contamination by hazardous wastes have received the attention of a number of studies using various techniques some of which are ineffective. Consequently, this paper identified nine more effective Geophysical Methods used in the environmental and groundwater pollutions studies, which has been briefly discuss in relation to their general applications, data reduction requirement, basic principles, various advantages and limitations. The conclusion was that the successful use of any of this effective Geophysical Techniques depends on the careful design of the survey, site specification, use of combinations of technologies and combined data analysis techniques as a means to enhance the characterization effort. In addition, it is also dependent on the consideration of a number of key Geological and Cultural Factors (like; Nature of the Target, the Target Depth of Burial, Target size, Measurement Station Interval and Calibration of the Data) together with the Geophysical Data.

Introduction

The use of various Geophysical Techniques for the investigation of hazardous waste and ground water pollution sites is now at a rapid increase and cost-effective means of preliminary evaluation. The information obtained from a Geophysical Investigations can be used to determine the subsurface conditions at, and approximately, a site. Such conditions include; hydro stratigraphic framework, depth to bedrock, extent of concentrated ground water contaminant plumes, the location of voids, faults or fractures, and the presence of buried materials, such as steel drums or tanks. In recent years, the need to conduct ground water pollution investigations has coincided with improvements in the resolution, acquisition and interpretation of Geophysical Data. This process is ongoing; therefore, outlines of Geophysical Techniques and Procedures are subject to revision as improvements are made in the Instrumentation and Interpretation Algorithms.

Landfills, most of which are open and uncontrolled dumpsites, are the most common waste disposal systems in Nigeria. Most of these waste landfills which are improperly designed due to their low capital investment, thus allowing for Environmental Pollution by waste dumps in these areas. The Food Security, Health Risk, the effect on the quality of livelihood and others cause by this practice calls for a comprehensive approach to the Assessment of the Vertical extent using an appropriate and effective Geophysical Methods. Most researchers in Nigeria depend on either the Hydro chemical and Geochemical Analysis, Single Geophysical method in determining the level of environmental impact caused by this practice. These analyses some of which depend only on samples picked from the selected locations of the sites or use of ineffective Geophysical Method may not give true picture of the overall level of pollution in the Areas. This Paper therefore, seeks to discuss the most effective Geophysical Methods that can effectively deal with or detect environmental contamination by waste dumpsites.

Objectives

The followings are the specific set objectives for this paper:

1. To Identify Effective Geophysical Technologies that can be applied to metals, other organics and contaminant for characterizing contamination.
2. To identify more effective Geophysical Techniques used to characterize subsurface properties including stratigraphy, moisture, hydraulic conductivity, and porosity.
3. In conjunction with the effective Geophysical Technologies for characterizing contaminant distribution and subsurface properties, identify available

instruments useful in identifying Cultural Features that can affect the performance of Geophysical Technologies.

A Review of the Applications of the Effective Geophysical Techniques

Assessment and detection of Environmental Pollution by waste Dumps using Geophysical Methods have received the attention of a number of studies using various techniques. Some of these geophysical techniques applied had indicated their success, effectiveness and more efficacies when combined in a survey. Some of these recently applied geophysical techniques that has indicated such qualities includes; (Umar, Mark & Nur Atikah, 2014) who used 2D electrical resistivity imaging and Vertical Resistivity Profiling (VRP). (Adebayo, A. S., Ariyibi, Awoyemi & Onyedim, 2015) used combinations of Electrical Resistivity Method and Hydro-Chemical Techniques. (Jegede, Iserhien-Emekeme, Iyoha & Amadasun, 2013) applied two Geophysical Tomography Techniques - Electrical Resistivity and Seismic Refraction. (Abdullahi, Osazuwa & Sule, 2011), used an integrated geophysical methods involving 2D Electrical Resistivity /Induced Polarization Imaging, Very-Low-Frequency Eelctormagnetic (VLF), and Seismic Refraction Tomography. (Ahmed & Carpenter 2003; Andre et al., 2010) also used EM 31 and EMP400 respectively. Pantelis et.al., (2007) also used an integrated suite of environmental geophysical methods - 2D electrical resistance tomography (ERT), electromagnetic measurements using very low frequencies (VLF), electromagnetic conductivity (EM31), seismic refraction measurements (SR) and ambient noise measurements (HVSR). (Nováková, Karous, Zajíček & Karousová 2013) also combined the use of Ground Penetrating Radar (GPR) and Vertical Electrical Sounding (VES). (Murray, Last & Truex, 2005) used Gravity Method. (Yuhr, Benson, & Butler, 1993) also combined the use of Electromagnetics and Micro-Gravity. (Van Overmeeren, 1998) used a combined approach of Micro-Gravity and Seismic Refraction.

The analysis of results from all the above Geophysical methods clearly demonstrated their success and effectiveness particularly in the environmental pollution studies and in studying the subsurface properties of the landfill and the definition of the exact geometrical characteristics of the site under investigation.

Fundamentals of a Geophysical Survey

Different materials exhibit different parameter signatures such as their resistivity or its inverse, conductivity, acoustic velocity, magnetic permeability and density. The mineral type, grain packing arrangement, porosity, permeability, and pore content (i.e. gas or fluid type), influences these parameters. In general, no one property is unique to any material; rather ranges of each property describe a material. The summary of techniques, together with the physical parameters measured, general applications, advantages and limitations of identified effective techniques are shown in table 1.0.

Table 1. Summary of Evaluation of Geophysical Techniques used in Environmental Pollution by Waste Dumpsites Investigations.

Geophysical Method	Measured Parameter	Physical Property Model	General Application	Major Limitations	Major Advantages	Data Reduction Requirement
Ground Penetrating Radar (GPR)	Travel time & amplitude of EM waves	EM velocity model	Profiling & mapping, highest resolution of any method. Can detect both metallic & non-metallic target.	Penetration limited by soil type & saturation conditions, cost of site preparation necessary prior to performing the survey.	Can provide a continuous display of data along a traverse, which can often be interpreted qualitatively in the field, allow for quick evaluation of subsurface site conditions, can provide a good cross-sectional representation of the subsurface, and it is very effective in sandy soils.	Data Correction Required
Magnetics	Spatial variations in the strength of magnetic field of the earth	Model depicting spatial variations in mag.susceptibility of subsurface	Profiling & mapping geological structures and detect buried drums, tanks &	Only applicable in certain rock environs, limited by cultural ferruous metal features & its inability of interpretation	Survey is relatively low costs, very easy, completed in a short amount of time with little or no site preparation necessity & very cost effective method.	Data Correction Required

Table 1 Continued

			other metal objects.	methods to differentiate between various steel objects		
Garavity	Spatial variations in the strength of gravitational field of the earth	Model depicting spatial variations in density of subsurface	Profiling &Mapping, can determine any geologic structure involving mass variations	Very slow, requires wider coverage, extensive data reduction, sensitive to ground vibrations	Measurements are not as susceptible to cultural noise, gravity readings can be taken in virtually any location, even indoors & heavily populated areas.	Data Correction Required
Electrical Resistivity	Potential diff.& induced current	Elect.Resist. Model	Soundings or profiling and mapping. Can determine depth & thickness of geological layers	Requires good ground contact & long electrode arrays, Integrates a large volume of subsurface. Affected by cultural features (metal fences, pipes, buildings vehicles).	Possibility of quantitative modeling using either Computer Software or Published Master Curves can provide accurate estimates of depth, thickness subsurface layers.	Data Correction Required

Geophysical Method	Measured Parameter	Physical Property Model	General Application	Major Limitations	Major Advantages	Data Reduction Requirement
Induced Potential	Polarization diff.& induced current	Elect. Capacity model	Determine electrical conductive targets such as clay content or metallic	More susceptible to sources of cultural interference, heavier and bulkier field instruments, requires more power, cost, & complexity in the data interpretation, fieldwork labour intensive requires two to three field crew & require a fairly large area, free from power lines and grounded metallic structures such as metal fences, pipelines and railway tracks.	Can be collected during an electrical resistivity survey, its addition to a resistivity investigation improves the resolution of the analysis of Resistivity Data & can be used to distinguish geologic layers which do not respond well.	No Data Reduction Required
Electromagnetic (EM)	Bulk conductivity (the inverse of resistivity)	Published modelling or computer modelling.	Profiling, mapping & sounding, very rapid measurement	Affected by cultural features. EM (Time domain) does not provide measurement shallower than 150 feet, conductivity anomalies or lineation caused by Lateral variability in the geology features can easily be misinterpreted as a contaminant plume.	Most EM Equipment used in ground water pollution investigations is lightweight, easily portable, Rapid measurements with a minimum number of Field Personnel, capability to electronically store data, more accurate & faster than Analog Instruments.	No Data Reduction Required

Very-Low-Frequency (VLF) EM	In-phase and quadrature components of the ratio of Horizontal-to-Vertical Magnetic Field	Curve matching or Simple numerical forward modelling		Affected by all electrical conductors (power lines, wire fences, pipes, and so on), unscheduled VLF transmitting stations shut down or maintenance which halt data collection	Very effective for locating zones of high electrical conductivity, (such as mineralized or water-filled fractures or faults within the bedrock), can be used to optimally locate, monitor and/or treatment wells to intercept hydrologic conduits & data collection is fast, inexpensive and requires only one or two people field crew.	No Data Reduction Required
Seismic	Arrival of seismic waves with respect to time (voltage output versus time)	Graphical or Computer models	Profiling & mapping	Data collection can be labour intensive. Sensitive to ground vibrations, large line lengths are needed.	Can give; depth information at locations between boreholes or wells, Subsurface information between boreholes at a fraction of the cost of drilling & useful in buried valley areas to map the depth to bedrock or thickness of overburden. A differentiation between certain units with divergent seismic velocities, (such as Shale and Granites).	Data Correction Required

Consequently, the successful use of each Geophysical Technique is dependent not only on the careful design of the survey but also on the consideration of a number of key Geological and Cultural Factors together with the Geophysical Data. These Factors include:

1. ***Nature of the Target:*** The Target Geophysical Signature must be different to that of the background Geology or Hydrogeology.
2. ***Depth of Burial of Target:*** The Depth of Burial of the feature of interest is important as different techniques have different investigation ranges. The depth range is technique dependent; however, there is always a trade-off between penetration depth and resolution of the technique with respect to the feature of interest. A technique that will look deep into the earth generally has lower resolution than a technique that is only looking to shallow depths.
3. ***Target size:*** An estimation of the target size is necessary prior to selecting appropriate techniques. The size of the target should be considered in conjunction with the depth range for individual techniques.
4. ***Measurement Station Interval:*** This will depend on the burial depth, target size and technique selected. Geophysical Surveys have traditionally been conducted along Line Profiles or on Grids and therefore the station spacing along the lines must be calculated together with the line separation in order not to miss a particular target size or to result in spatial aliasing the target. A rough ***rule of thumb*** is that a Geophysical Anomaly will be approximately twice the size of the object causing the anomaly so this will give the maximum line and station spacing.
5. ***Calibration of the Data:*** The key to success of any Geophysical Survey is the Calibration of the Geophysical Data with both Hydrogeological and Geological ground truth information. Calibration Data may be provided by both down-hole Geophysical Logs in boreholes, samples derived from boreholes by continuous sampling and through measuring the groundwater flux.

The Identified Effective Geophysical Methods

Sequel to the previous discussions so far, it is now evident that each Geophysical Method has its advantages and limitations thus, the combination of two or more of these techniques in an integrated interpretation results in a reduction of the degree of ambiguity. A comprehensive knowledge of the local geology and site conditions is necessary in order to select an Effective Geophysical Method or Methods, to Plan a Survey, and to interpret the Data.

Therefore, for a successful extent assessment of Environmental Pollution by waste dumps, Performance Guidelines for the total of eight identified most Effective Surface Geophysical Methods, in addition to Borehole Methods so far identified are briefly discussed in this Paper. The surface methods include Ground Penetrating Radar (GPR), Magnetic, Gravity, Electrical Resistivity, Induced Polarization (IP), Electromagnetic (EM), Very-Low Frequency electromagnetic (VLF), and Seismic methods.

Preview of the Selected Effective Geophysical Methods

1. Ground Penetrating Radar (GPR)

Fundamentals

The Ground Penetrating Radar (GPR) method has the Best resolution and is one of the most highly used and successful geophysical method. It provides subsurface information ranging in depth from several tens of meters to only a fraction of a meter. When and where possible, the GPR technique should be integrated with other geophysical and geologic data to provide the most comprehensive site assessment.

The GPR method uses a transmitter that emits pulses of high-frequency electromagnetic waves into the subsurface. The transmitter is either moved slowly across the ground surface or moved at fixed station intervals. The penetrating electromagnetic waves are scattered at changes in the complex dielectric permittivity, which is a property of the subsurface material dependent primarily upon the bulk density, clay content and water content of the subsurface. The electromagnetic energy is reflected back to the surface-receiving antenna and is recorded as a function of time. The depth to reflector can be determined from

$$d_r = \frac{Ct_r}{2\sqrt{\varepsilon_r}}$$

Depth penetration of GPR is severely limited by attenuation and/or absorption of the transmitted electromagnetic (radar) waves into the ground. Generally, penetration of radar waves is reduced by a shallow water table, high clay content of the subsurface, and in areas where the electrical resistivity of the subsurface is less than 30 ohm-meters. Ground penetrating radar works best in dry sandy soil where a deep water table exists.

The plot produced by most GPR systems is analogous to a seismic reflection profile; that is, the data are usually presented with the horizontal axis as distance units (feet or meters) along the GPR traverse and the vertical axis as time units (nanoseconds).

Advantages

- It can provide a data along a traverse, which can qualitatively be interpreted isntantly in the field.
- It is capable of providing high-resolution data under favorable site conditions and it's very effective in sandy soils.
- Its real-time capability results in a rapid turnaround, and allows for a quick evaluation of subsurface site conditions.
- It can provide a good cross-sectional representation of the subsurface useful for a number of applications

Limitations

- It is a site-specific nature technique.
- The cost of site preparation necessary prior to performing the survey may be high.
- Most GPR units are towed across the ground surface.
- The quality of the data can easily be degraded by a variety of factors such as an uneven ground surface or various cultural noise sources (such as strong electromagnetic fields).

2. MAGNETICS

Fundamentals

A magnetometer is an instrument which measures magnetic field strength in units of gammas or nanoteslas (1 gammas = 1 nanotesla = 0.00001 gauss). Local variations, or anomalies, in the earth's magnetic field are the result of disturbances caused mostly by variations in concentrations of ferromagnetic material in the vicinity of the magnetometer's sensor. A buried ferrous object, such as a steel drum or tank, locally distorts the earth's magnetic field and results in a magnetic anomaly. The common objective of conducting a magnetic survey at a hazardous waste or ground water pollution site is to map these anomalies and delineate the area of burial of the sources of these anomalies.

Analysis of magnetic data can allow an experienced Geophysicist to estimate the regional extent of buried ferrous targets, such as a steel tank, canister or drum.

Advantages

- It is relatively very low costs effective and time saving in conducting and completing the survey.
- It requires very little, if any or no site preparation necessary.

- Surveying requirements are not as stringent as for other methods.
- It can be conducted just with a transit or Brunton-type pocket transit and non-metallic measuring tape.

Limitations

- It is very susceptible to cultural noise, which is detrimental to the quality of data.
- Inability of the interpretation methods to differentiate between various steel objects.
- The magnetic method does not allow the interpreter to determine the contents of a buried tank or drum.

3. GRAVITY

Fundamentals

The gravity method involves measuring the acceleration due to the earth's gravitational field. These measurements are normally made on the earth's surface. A gravity meter or gravimeter is used to measure variations in the earth's true Gravitational Field at a given location. These variations in gravity depend upon lateral changes in the density of the subsurface in the vicinity of the measuring point.

Advantages

- The gravity measurements are not susceptible to cultural noise.
- Gravity readings can be taken in virtually at any location, even indoors.

Limitations

- Each station has to be precisely surveyed for elevation and latitude control.
- It is costly and time consuming when surveying large areas.
- Many computations are involved in the reduction and interpretation of gravity data.

4. ELECTRICAL RESISTIVITY

Fundamentals

The Electrical Resistivity of a geologic unit or target is measured in ohmmeters, and is a function of porosity, permeability, water saturation and the concentration of dissolved solids in pore fluids within the subsurface. Electrical Resistivity methods measure the bulk resistivity of the subsurface, as do electromagnetic methods. The difference between the two methods is in the way that electrical currents are forced to flow in the earth. In the electrical resistivity method, current is injected into ground through surface electrodes, whereas in electromagnetic methods, currents are induced by the application of time-varying magnetic fields.

Considering a case where the current sink is a finite distance from the source as shown Figure 1.0. The potential V_0 at an internal electrode C is given by;

$$V_0 = V_A + V_B \qquad 7$$

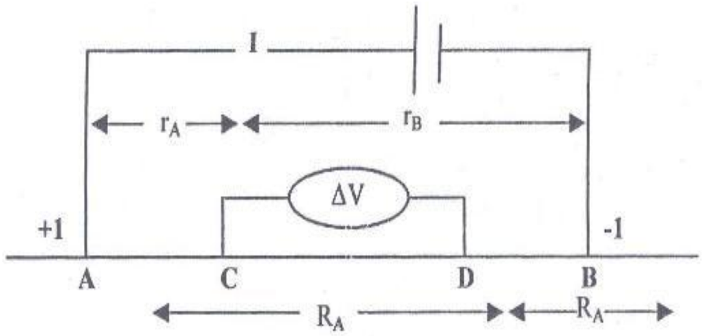

Figure 1.0: Generalized form of the electrodes configuration used in resistivity measurements

Since the absolute potentials are difficult to monitor, so the potential difference **ΔV** between electrodes C and D is measured as;

$$\Delta V = V_C - V_D = \frac{\rho I}{2\pi}\left\{\left(\frac{1}{r_A}-\frac{1}{r_B}\right)-\left(\frac{1}{R_A}-\frac{1}{R_B}\right)\right\} \qquad 8$$

Therefore;

$$\rho = \frac{2\pi\Delta V}{\left\{\left(\frac{1}{r_A}-\frac{1}{r_B}\right)-\left(\frac{1}{R_A}-\frac{1}{R_B}\right)\right\}} \qquad 9$$

Where the ground is uniform, the resistivity from the equation above should be constant and independent of both electrode spacing and surface location. When sub-surface is in-homogenous, the resistivity will vary with relative positions of the electrodes (Kearey & Hill, 2002). Any computed value is called apparent resistivity (ρ_a) and will be a function of the in-homogeneity.

$$\rho = \frac{2\pi\Delta V}{I}K \qquad 10$$

K is called the geometric factor, and is independent of the electrode configuration used during the field measurement.

Advantages

- Quantitative modeling is possible using either Computer Software or Published Master Curves.
- The models can provide accurate estimates of depth, thickness and electrical resistivity of subsurface layers and other possible interpretations.

Limitations

- Degradation of the quality of the measured voltages due to site characteristics, rather than in any inherent limitations of the method.
- It requirement for fairly a large area far removed from cultural noise precludes its use at many ground water pollution sites.
- The fieldwork tends to be more labour intensive than some other geophysical techniques.

5. INDUCED POLARIZATION

Fundamentals

The Induced Polarization (IP) method is an electrical geophysical technique, which measures the slow decay of voltage in the subsurface following the cessation of an excitation current pulse. An electrical current is imparted into the subsurface, as in the electrical resistivity method explained (section 4.4) in this Paper. Water in the subsurface geologic material (within pores and fissures) allows certain geologic material to show an effect called "induced polarization" when an electrical current is applied. During the application of the electrical current, electrochemical reactions within the subsurface material take place and electrical energy is stored. After the electrical current is turned off the stored electrical energy is discharged which results in a current flow within the subsurface material. The IP instruments then measure the current flow. Thus, in a sense, the subsurface material acts as a large electrical capacitor. The Induced Polarization method measures the bulk electrical characteristics of geologic units; these characteristics are related to the Mineralogy, Geochemistry and grain size of the subsurface materials through which electrical current passes.

Advantages

- IP data can be collected during an electrical resistivity survey, if the proper equipment is used.
- The addition of IP Data to a resistivity investigation improves the resolution of the analysis of Resistivity Data by resolving ambiguities encountered in thin stratigraphic layers while modelling electrical resistivity data, distinguishing geologic layers which do not respond well to an electrical resistivity survey and measuring Electrical Chargeability used to enhance a hydrogeologic

interpretation, such as discriminating equally electrically conductive targets such as saline, electrolytic or metallic-ion contaminant plumes from clay layers.

Limitation

- It is more susceptible to sources of cultural interference than the electrical resistivity method.
- Its equipment requires more power than resistivity-alone equipment – this translates into heavier, costlier and bulkier field instruments.
- Its complexity in the interpretation, the expertise needed to analyze and interpret its data may be too tasking.
- Fieldwork tends to be labour intensive and its surveys require a large area, far removed from cultural noise.

6. ELECTROMAGNETICS

Fundamentals

The electromagnetic method is a Geophysical Technique based on the physical principles of Inducing and detecting electrical current flow within geologic strata. Electromagnetic readings are commonly expressed in conductivity units of Millimhos/meter or milliseimens/meter (1 millimho = 1 milliseimen). It makes use of the response of the ground to the propagation of the electromagnetic fields which are composed of alternating electric intensity (**E**) and magnetic force (**H**) in a plane perpendicular to direction of travel. An electromagnetic field may be defined in terms of four vectors functions **E, D, H** and **B,** where **E** is the electrical field in V/m **H** is the magnetic field intensity A/m. **B** is the magnetic in Tesla. **D** is the dielectric displacement in Coulomb per square metre. Experimental evidence shows that all electromagnetic phenomenon obeys the following four Maxwell equations.

$$E = -{}^{\delta B}/_{\delta t} \qquad 11$$

$$H = J + {}^{\delta D}/_{\delta t} \qquad 12$$

$$D = 0 \qquad 13$$

$$D = q \qquad 14$$

Equation (11) is Faraday's law while equation (12) is Ampere's law. Equation (13) infers that lines of magnetic induction are continuous, there are no single magnetic poles, and equation (14) assumes that electrical fields can begin and end on electrical charges.

Advantages

- Its Equipment is mostly lightweight, easily portable and requires less labour.
- It is a technique commonly used on ground water pollution investigations.
- Its Instruments commonly in use now has the capability to; electronically store data, greater degree of accuracy and fast data collection.

Limitations

- It is more susceptible to sources of cultural interference.
- Lateral variability in the geology can also cause conductivity anomalies or lineation, which can easily be misinterpreted as a contaminant plume.

7. VERY-LOW FREQUENCY (VLF) ELECTROMAGNETICS

Fundamentals

The Very-Low Frequency (VLF) Electromagnetic method detects electrical conductors by utilizing radio signals in the 15 to 30 kiloHertz (kHz) range that are used for Military Communications. The VLF method is useful for detecting long, straight electrical conductors, such as moderate to steeply dipping water-filled fractures or faults. The VLF instrument compares the magnetic field of the primary (transmitted) signal to that of the secondary signal (induced current flow within the subsurface electrical conductor). In the absence of subsurface conductors, the transmitted signal is horizontal and linearly polarized. When a conductor is crossed, the magnetic field becomes elliptically polarized and the major axis of the ellipse tilts with respect to the horizontal. The anomaly associated with a conductor exhibits a crossover. As with other frequency domain electromagnetic systems, both the in-phase ("real" or "tilt-angle") and the out-of-phase ("imaginary," "ellipticity," or "quadrature") components are measured.

Advantages

- It is very effective for locating zones of high electrical conductivity.
- Its data can optimally locate, monitor and/or treat wells in order to intercept these hydrologic conduits.
- Data collection is fast, inexpensive and requires less field crew.

Limitations

- All electrical conductors affect it.
- The bearing or direction from the VLF transmitting station to the intended target must be located nearly parallel to strike (or long axis) of the conductor, or intended target for it to be detected.
- Very limited number of transmitting stations is available thereby limiting the direction that traverses can be collected.

- Sudden interruption in data collection due to break in transmission by stations for scheduled and unscheduled maintenance.

8. SEISMIC

Fundamentals

Surface Seismic Techniques used in ground water pollution site investigations are largely restricted to Seismic Refraction and Seismic Reflection Methods. The equipment used for both methods is fundamentally the same and both methods measure the Travel-Time of acoustic waves propagating through the subsurface. In the refraction method, the travel-time of waves refracted along an acoustic interface is measured. In the reflection method, the travel-time of a wave, which reflects off an interface, is measured.

Depth to geologic interfaces can be calculated using the velocities obtained from a seismic investigation (equation 15). The geologic information gained from a seismic investigation can then be used in the hydrogeologic assessment of a ground water pollution site and the surrounding area. The interpretation of seismic data can indicate changes in lithology or stratigraphy, geologic structure, or water saturation (water table).

$$z = \frac{1}{2}\sqrt{\frac{V_{2-}V_1}{V_{2+}V_1}}, \chi_{cros} , \qquad 15$$

Where the speed of sound in layer 1 and 2 respectively are v_1, v_2 and χ_{cros} is the crossover distance.

Seismic Refraction Advantages

- It can be used to determine the seismic velocity of a geologic horizon and precisely estimate the depth to different acoustic interfaces.
- It can easily determine the depth to the water table or bedrock, useful in buried valley areas to map the depth to bedrock or thickness of overburden, used to categorize geologic strata, determine thickness of geologic strata and Determine depth to water table.
- It can differentiate certain units with divergent seismic velocities, such as Shale and Granites.

Seismic Refraction Limitations

- The seismic refraction method is based on several assumptions.
- Its success depends on the following conditions;
    - The Seismic Velocities of the geologic layers increase with depth and that its contrasts between layers are sufficient to resolve the interface.

- The geometry of the Geophones in relation to the refracting layers will permit the detection of thin geologic layers.
- The apparent dip of the units or layers is less than ten to fifteen degrees.

- Data collection is labour intensive and large line lengths are needed — as a rule, the distance from the shot, or seismic source, to the geophone stations (or geophone "spread") must be at least three times the desired depth of exploration.

Seismic Reflection Method

In the Seismic Reflection Method, sound wave travels down to a geologic interface and reflects back to the surface. Reflections occur at an interface where there is a change in the acoustic properties of the subsurface material.

Seismic Reflection Advantages

It yields information that allows the interpreter to discern between discrete layers and map stratigraphy.

- Its data is usually presented in Profile Form and depths to interfaces as a function of time.
- Depth information can be obtained by converting time sections into depth from velocities obtained.
- It requires much less space and does not require long offsets as in refraction surveys.
- In some geologic environments, its data can yield acceptable depth estimates.

Seismic Reflection Limitations

- The precise depth determination cannot be made.
- It is labour-intensive and the data acquisition is more complex than refraction data.
- It places higher equipment capabilities requirements.
- It requires a large amount of data processing time and lengthy data collection procedures.
- The use of high-resolution reflection seismic methods places a large burden on the resources of the Geophysicist, in terms of computer capacity, data reduction and processing programs, resolution capabilities of the seismograph and geophones, and the ingenuity of the interpreter.

9. BOREHOLE GEOPHYSICAL METHODS

Fundamentals

Various borehole tools, probes, or sounds can be used for logging wells. Most borehole methods are based on the same principles as surface Geophysical Methods. It is recommended that Borehole Geophysics be done on all wells drilled, and kept as a permanent record. The two most commonly used borehole methods in the water well industry are Natural Gamma Ray and Resistivity Logs.

Advantages

- It supplies an abundance of subsurface information like; stratigraphy, hydrogeology and contamination of ground water.
- It can sometimes be used to monitor the remediation of a site.

Limitations

- Borehole Logging is expensive.
- If subsurface conditions vary between wells, discrepancies have to be qualitatively evaluated and Logging tools must be used in uncased or ungrouted wells.
- Certain logging tools require different borehole conditions, which must be considered when planning the investigation.

Conclusion

The use of these more effective Geophysical Methods in the study of environmental and groundwater pollutions by hazardous wastes has now been at an increase and very economical means of evaluation to determine the subsurface conditions at the vicinity of a site. In these present days, the need to conduct such pollution investigations has coincided with improvements in the resolution, acquisition and interpretation of Geophysical Data through technological advancement. This process is ongoing; therefore, outlines of these effective Geophysical Methods and Procedures are subject to dynamic revision as improvements unfold in the Instrumentation and Interpretation Algorithms. However, each Geophysical Method has its advantages and limitations. The combination of two or more of these effective Geophysical Techniques in an integrated interpretation, which has resulted in a reduction of the degree of ambiguity, is an encouragement over the need for such adoption in subsequent surveys. In addition, comprehensive knowledge of the local geology and site conditions are necessary in order to select effective geophysical method or methods, plan a survey, and interpret the data.

The resistivity method and Electromagnetic (EM) Methods proved to be the most popular owing to their inherent ability to; detect changes related to variations in fluid content, clarify the subsurface structure, delineates contaminated zones of groundwater, chemical composition & temperature in the subsurface, and the minimum capital & labour outlay required to use them in small-scale surveys.

Finally, the successful use of any of these effective Geophysical Technique is dependent not only on; the careful design of the survey, site specification, use of combinations of technologies and combined data analysis techniques as a means to enhance the characterization effort, but also on the consideration of a number of key Geological and Cultural Factors (like; Nature of the Target, the Target Depth of Burial, Target size, Measurement Station Interval and Calibration of the Data) together with the Geophysical Data.

References

Abdullahi, N. K., Osazuwa, I. B., & Sule, P. O. (2011). Application of integrated geophysical techniques in the investigation of groundwater contamination: A case study of municipal solid waste leachate. *Ozean Journal of Applied Sciences,* 4 (1), 1-12.

Adebayo, A. S., Ariyibi, E. A., Awoyemi, M. O., & Onyedim, G. C. (2015). Delineation of contamination plumes at olubonku dumpsite using geophysical and geochemical approach at Ede town, southwestern Nigeria. *Geosciences Scientific & Academic Publishing,* 5 (1), 39 – 45. doi:10.5923/j.geo.20150501.05

Andre, F. Saussez, S., Van Durmen, R., Van Leeuwen, C., Moghadas, D., Delvaux, B., Vereecken, H., & Lambot, S. (2010). *AGU Fall Meeting*. San Francisco, USA.

Jegede, S. I., Iserhien-Emekeme, R. E., Iyoha, A., & Amadasun, C.V.O. (2013). Near-Surface Investigation of Groundwater Contamination in the Regolith Aquifer of Palladan, Zaria using Borehole log and Tomography Techniques Research. *Journal of Applied Sciences, Engineering and Technology*, 6(4), 537-544.

Kearey, L., Brooks, M., & Hill, I. (2002). *An introduction to geophysical exploration.* Third edition. Backwell Science Ltd.

Murray, C. J., Last, G. V., & Truex, M. J. (2005). Review of geophysical techniques to define the spatial distribution of subsurface properties or contaminants national. Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, 22161 (800), 553-6847. Retrieved March 1, 2016, from http://www.ntis.gov/ordering.htm.

Nováková, E., Karous, M., Zajíček, A., & Karousová, M. (2013). Evaluation of ground penetrating radar and vertical electrical sounding methods to determine soil horizons and bedrock at the locality Dehtáře. *Soil & Water Resources*, 8, 105–112.

Pantelis, S., Nikos, P., Ilias, P., Maria, K., Filippos, V., Apostolos, S., & Thrassyvoulos, M. (2007). Application of integrated methods in mapping waste disposal areas

Environ Geology, *Imacpt Factor*, 1(13), 1-15. DOI 10.1007/s00254-007-0681-2

Umar, H., Mark, J., & Nur Atikah, M. (2014). Electrical resistivity techniques and chemical analysis in the study of leachate migration at Sungai Sedu Landfill. *Asian Journal of Applied Science*, 7, 518-535. DOI: 10.3923/ajaps.2014.518.535

van Overmeeren, R. A. (1998). Radar Facies of Unconsolidated Sediments in the Netherlands: A Radar Statigraphy Interpretation Method for Hydrogeology." *Journal of Applied Geophysics,* 40, 1–18.

Yuhr, L., Benson, R., & Butler, D. (1993). Characterization of Karst features using electromagnetics and microgravity: A strategic approach. *Symposium on the Application of Geophysics to Environmental and Engineering Problems*, 208-209.