

# Seismic Explosive Energy Sources and the Possible Impact on Groundwater Quality in the Niger Delta Area of Nigeria

Madu<sup>1</sup>, A. J. C Eze<sup>2</sup>, C. L.

1. Department of Physics/Geology/Geophysics, Faculty of Science and Technology, Federal University Ndufu-Alike-Ikwo, Ebonyi State, Nigeria

2. Institute of Geosciences and Space Technology, Rivers State University of Science and Technology, Port Harcourt, Nigeria

## Abstract

The possible impact of the use of seismic explosive energy sources on groundwater quality in the Niger Delta Area of Nigeria was investigated. A 3-Dimensional seismic survey was carried in OML X in the Niger Delta area using dynamite as the energy source. A total of 116,349.2 kg of dynamite was detonated in 60,398 source points in an area of 771.26 square kilometres, an equivalent of explosive densification of 150.85 kg/km<sup>2</sup>. Each shot point was loaded with a charge of 2kg of dynamite and a piece of electrical detonator. The possible impact of these dynamite shots on the groundwater was monitored using 7 boreholes evenly distributed in the area. The average coefficient of permeability of the soil of the area collected from the depths of 25m and 50m were 0.019cm/s and 0.55cm/s respectively. Water samples from the boreholes were analysed using standard methods. Control samples were taken from the borehole stations a day before detonation of dynamite. Another sampling was carried out 10 days after dynamites detonation. During the study there was regular rainfall and 10 days was considered sufficient for any pollutant resulting from the detonation of the explosives to travelled to the commonly exploited aquifers in the area considering the permeability of the soil. A comparison of the analyses results showed that the detonation of dynamite did not have any noticeable impact on the groundwater quality of the area.

**Keywords:** seismic, explosive, groundwater contamination, Niger Delta

## Introduction

The use of explosives as seismic exploration energy source in the Niger Delta over the years has generated some fears and concerns to the inhabitants as to the effects on buildings and the entire environment. Generally the seismic method utilizes the propagation of waves through the earth (Adeoti *et al.*, 2012). These waves are often generated by the detonation of explosives such as dynamite. Eze and Okara (2014) noted that the guidelines applied on the use of explosives by the exploration companies were based on standards developed in countries whose soil types and geology are different from what obtains in the Niger Delta. As a result of increasing population, in relation to the legal and health implications amongst the inhabitants of the area, there have been more speculative assertions on the damages to surface and underground structures as well as deterioration of groundwater quality by the blast of seismic explosives in the area during seismic surveys. Sikora *et al.*, (1998) noted that explosive residue has been a serious source of groundwater pollution in many mining areas such as Utah Tracts.

## Explosive as Source of Seismic Energy

Explosives are mainly used as the seismic energy source on land. The explosives are substances or devices capable of producing a volume of rapidly expanding gas, in an extremely brief period that exerts sudden pressure on its surroundings (Dionne *et al.*, 1986). They are mixture or compounds of different chemical substances such as carbon, hydrogen, nitrogen and oxygen plus other components used for special purposes, which are combined together to cause an explosion when ignited or detonated. They are designed for either military or industrial used and can explode by mechanical, nuclear or chemical process or reaction (Santis *et al.*, 1995).

### *Dynamite*

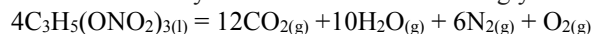
One of the major explosive sources of energy in hydrocarbon exploration by seismic method is dynamite. It is commonly used in the oil industry because of its efficiency. It is however known to pose some safety and environmental problems. Dynamite consists of a combination of the explosives such as nitroglycerin (C<sub>3</sub>H<sub>5</sub>N<sub>3</sub>O<sub>9</sub>) and glycoldinitrate (C<sub>2</sub>H<sub>4</sub>N<sub>2</sub>O<sub>6</sub>) mixed with diatomaceous earth and a small admixture of sodium carbonate to give a gletinous material (Ziolkowski and Bokhorst, 1993).

### *Nitroglycerin (C<sub>3</sub>H<sub>5</sub>N<sub>3</sub>O<sub>9</sub>)*

Nitroglycerin, also known as nitroglycerine, trinitroglycerin, and glyceryltrinitrite is a heavy, colourless, oily, explosive liquid obtained by nitrating glycerol and that detonates if heated to about 200°C or if subjected to mechanical shock (Dick, 2000).

The explosive power of nitroglycerin is related to several factors. Glycerin contains both the fuel and oxidizer bonded together. Each molecule of nitroglycerin contains three nitrate groups, which serve as oxidizing

agents for the hydrocarbon groups to which they are bonded. The hydrocarbon groups provide the fuel and the nitrate groups provide the oxidizer necessary for combustion (Sapko *et al.*, 2002). The decomposition is highly exothermic. Many reactions occur when nitroglycerin detonates, but the overall process can be written as:



Every mole of nitroglycerin that detonates releases about 1.5 MJ of heat (Pichtel, 2012).

*Glycoldinitrate* ( $\text{C}_2\text{H}_4\text{N}_2\text{O}_6$ )

Glycoldinitrate is a colorless to yellow, oily, odourless liquid. It is an explosive ingredient of dynamite where it acts as a strong oxidizing agent. It also reduces the freezing point of nitroglycerin and of mixtures of nitroglycerin with other materials (Saiz *et al.*, 2011).

#### *Diatomaceous*

Diatomaceous earth consists of fossilized remains of diatoms, a type of hard-shelled algae. The typical chemical composition of diatomaceous earth is 86% silica, 5% sodium, 3% magnesium and 2% iron (Dick, 2000).

### **Detonation Process and Products**

The bursting power of an explosive results from large quantities of rapidly expanding hot gases produced as it detonates. Ideally, a detonation produces only steam ( $\text{H}_2\text{O}$ ), carbon dioxide ( $\text{CO}_2$ ), and nitrogen ( $\text{N}_2$ ). It has however, been found that detonation also produces nitrogen dioxide ( $\text{NO}_2$ ), nitric oxide ( $\text{NO}$ ), and carbon monoxide ( $\text{CO}$ ) (ISEE, 1998). The end products of detonation are determined primarily by the oxygen balance of the explosive. As in other combustion reactions, a deficiency of oxygen favours the formation of carbon monoxide ( $\text{CO}$ ) and unburned organic compounds and produces little, if any, nitrogen oxides. An excess of oxygen causes more nitrogen oxides and less carbon monoxide and other unburned organics (Roy, 1978). All explosives produce some measure of  $\text{CO}$  but dynamites are oxygen- balanced and produce very little  $\text{CO}$ . Nitrogen oxides ( $\text{NO}$  and  $\text{NO}_2$ ) are produced at moderate quantity. Particulates are produced as well, from the shattering of the earth.

(Dowding and Hryciw, 1986) calculated that 1kg of Ammonium Nitrate Fuel Oil (ANFO) will produce approximately  $1.0\text{m}^3$  of gas at standard temperature and pressure. Some of the gases will immediately escape to the surface while some will either dissolve or condense in the presence of cooling groundwater and the rest, mostly nitrogen, will be trapped in the soil for some time. There is the possibility of the trapped gas forming weak acid with soil water and lowering the pH of groundwater water, an effect that is equivalent to acid rain. This effect could be significant depending on the amount of detonation per unit area.

### **Methodology**

#### *Study Area*

This study was carried out in Oil Mining Lease (OML) X in Niger Delta, Nigeria. The vegetation of the area is generally dominated by dense rain forest. The total area covered by this study is about  $1,305.41\text{ km}^2$ .

#### *Detonation of Explosive*

A three dimensional seismic survey was conducted in OML X in Niger Delta, Nigeria. The energy source was the high explosives dynamites (TNT) and 6m electric detonators loaded in 5-hole pattern source array. In dry areas, the holes were drilled to depths of 4m while in flooded/marshy terrain they were drilled to depths of 6 metres. Each pattern hole was loaded with 0.4kg and primed with one seismic electric detonator. Hence a total of 116,349.2 kg of dynamite was detonated in 60,398 shotpoints (1 shotpoint =  $0.4\text{kg} \times 5$ ) in an area of 771.26 square kilometres, an equivalent of  $150.85\text{ kg}/\text{km}^2$ .

#### *Monitoring Boreholes*

Seven boreholes coded BH1 to BH7 were drilled within the OML. The boreholes were primarily used for the acquisition of low velocity layer data but were later adapted for groundwater monitoring. Each borehole was drilled to 60m depth using rotary method and flushed continuously for 20 minutes to enhance stability. After the acquisition of the seismic data the boreholes were capped to prevent rainfall and debris from entering the hole. The coordinates and elevation of the boreholes were established by the seismic survey crews.

The borehole lithology was sampled every 5m or at any change in lithology. A typical lithology of the area for the total drilled depth of 60m is shown in Figure 1. The top soil up to 2.0m is mainly clayey sand. From 2.0m to a depth of 5.0m is composed mainly of intercalation of silt and fine sand. From this depth the lithology shows downward coarsening starting from medium grained sand between 13m and 42m to gravelly sand from 42m to the total drilled depth. Most of the boreholes in the locality abstract water for all domestic purposes including drinking from shallow aquifers ranging in depth from 50m-70m.

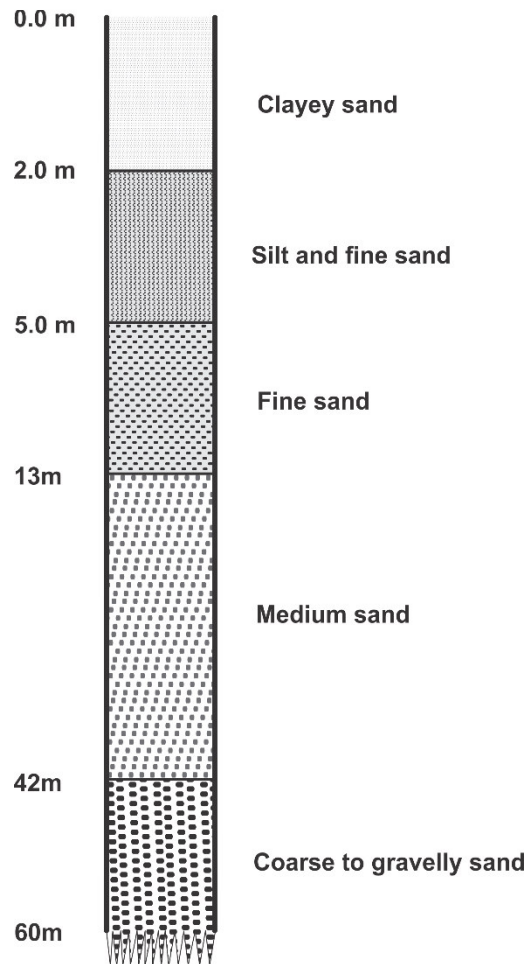


Figure 1: Lithology of a Typical Borehole in the Study Area

#### *The Soil Permeability*

The permeability of a soil depends to some extent on the particle size of the soil. The grain size analysis was accomplished using sieve method for the sands (Table 1 and 2). The coefficient of permeability of a soil describes how easily a liquid will move through the soil. Coefficient of permeability is therefore important in examining the movement of contaminants through the soil. The rate of infiltration of any potential pollutant from detonation of explosives depends on the porosity and permeability between the depth of detonation and the depth of pollution.

Coefficient of permeability was measured at 25m within the medium sand interval and 50m within the gravelly sand interval using the constant head method.

By Darcy's Law:

$$Q = A(ki)t \quad (1)$$

where

$Q$  = volume of water collected

$A$  = area of cross section of the soil specimen

$k$  = coefficient of permeability

$i$  = hydraulic gradient in the direction of flow

$t$  = duration of water collection

Tables 1 and 2 present the results of the Coefficient of Permeability at depths of 5m and 10m respectively.

Table 1: Grain size and Coefficient of Permeability at 5m Depth

Sample Number	Depth (m)	Grain Size Distribution (Percent Passing Sieves) (mm)							Coefficient of Permeability (cm/s)
		0.08	0.15	0.30	0.60	1.18	2.36	5.00	
BH1	25	0	8	38	85	94	99	100	0.020
BH2	25	7	8	38	70	91	95	100	0.021
BH3	25	3	7	40	85	93	99	100	0.025
BH4	25	7	9	38	86	91	99	100	0.018
BH5	25	7	8	39	83	93	99	100	0.023
BH6	25	7	9	39	85	92	99	100	0.023
BH7	25	4	7	41	83	94	100	100	0.023
Average									0.019

Table 2: Coefficient of Permeability at 10m Depth

Sample Number	Depth (m)	Grain Size Distribution (Percent Passing Sieves) (mm)							Coefficient of Permeability (cm/s)
		0.085	0.15	0.30	0.60	1.18	2.36	5.00	
BH1	50	3	4	27	83	93	99	100	0.20
BH2	50	7	8	39	77	95	96	100	0.45
BH3	50	3	7	42	87	94	99	100	1.29
BH4	50	7	9	37	85	91	99	100	0.42
BH5	50	7	8	37	81	94	99	100	0.50
BH6	50	7	9	37	81	94	99	100	1.08
BH7	50	4	7	40	78	95	100	100	0.45
Average									0.55

Based on the soil permeability classification of Bear, (1972) the permeability of the soil from 10m depth to the shallow aquifers is regarded as medium to high. By this permeability any potential pollutants resulting from the detonation of dynamite at a depth of 4m will require only about 70 hours to travel down to the shallow aquifers at depths of 40-70m provided there is sufficient precipitation that would act as the pollutant transport. The coefficient of permeability is expected to improve downward as the soil particle size and sorting coefficient increase

### Groundwater Sampling and Analysis

Water samples were collected and analysed from each borehole before the commencement of dynamite detonation. The results of the analyses served as control for water quality (Table 3). The water in the boreholes were sampled again 10 days after the detonations. It was expected that by this time the pollutants resulting from detonation of dynamite, if any, would have reached the aquifers and also that the effect of any of such pollutant would not have been diluted by rain. The water samples were analysed for the same parameters as in the controls using the same standard methods. The results obtained from the analyses of the samples were compared with the results obtained before detonation (Table 3).

Table 3: Groundwater Quality before and 10 after the Detonation of Dynamite

	BH 1		BH 2		BH 3		BH 4		BH 5		BH 6		BH 7		Mean	
	BD	AD	BD	AD	BD	AD	BD	AD	BD	AD	BD	AD	BD	AD	BD	AD
pH	7.87	7.67	8.25	7.39	6.77	7.10	7.64	7.65	6.72	5.81	8.24	8.18	8.46	8.46	7.71	7.47
Turbidity (NTU)	2.55	2.34	5	5	5	5	6	6	5	5	4	4	4	4	3.94	4.48
Total Dissolved Solids (mg/l)	60.40	61.30	62.61	61.00	63.19	61.19	62.18	62.18	63.19	61.19	60.40	61.30	62.61	61.00	62.08	61.31
Chloride (mg/l)	11.60	11.75	12.01	12.10	11.87	12.00	11.06	11.01	11.00	11.02	10.20	10.20	11.60	11.75	11.33	11.4
Nitrate (mg/l)	2.15	2.35	2.40	2.42	2.37	2.35	2.57	2.57	2.57	2.83	2.70	2.81	2.61	2.66	2.48	2.57
Nitrite (mg/l)	0.01	0.03	0.01	0.03	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02
Ammonia (mg/l)	0.06	0.10	0.07	0.09	0.04	0.01	0.04	0.06	0.06	0.10	0.07	0.09	0.06	0.10	0.06	0.08
Sulphate (mg/l)	2.27	2.27	1.67	1.67	1.67	1.67	1.8	1.8	1.33	1.34	1.8	1.8	1.53	1.53	1.72	1.73
Total Hardness (mg/l)	31.44	31.44	31.44	31.44	31.44	31.44	3.94	31.44	4.16	4.16	0.98	0.98	1.15	1.15	14.94	18.86
Iron (mg/l)	0.18	0.10	0.20	0.18	0.03	0.04	0.21	0.17	0.22	0.21	0.23	0.21	0.43	0.34	0.21	0.18
Copper (mg/l)	0.02	0.02	0.02	0.02	0.03	0.04	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Magnesium (mg/l)	0.01	0.01	0.19	0.17	0.01	0.01	0.08	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.04
Calcium (mg/l)	0.37	0.37	0.16	0.16	0.48	0.48	1.93	1.93	1.83	1.82	0.39	0.39	0.48	0.48	0.8	0.8
Chromium (mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zinc (mg/l)	0.02	0.03	0.05	0.05	0.05	0.05	0.02	0.02	0.002	0.02	0.02	0.15	1.15	0.15	0.045	0.046

BD = Before Detonation

AD = After Detonation

## Results and Discussions

The variation between the control pH values and the values obtained 10 days after detonation is only 0.24. This variation is not significant enough for the detonation of dynamite to be inferred to have impacted on the pH value of the groundwater. The values of the heavy metals in the groundwater before detonation of dynamite and 10 days after the detonation of the dynamite remained practically constant. The same applied to the nutrients where the highest recorded variation was in the nitrate which was 2.48mg/l before the detonation of dynamite and 2.57mg/l 10 days after detonation of dynamites. Every other parameter monitored shown noticeable variation in the groundwater before and after the detonation of dynamite.

## Conclusions

The use of dynamite as seismic energy source in the present concentration as currently practiced was not found to impact the groundwater quality in the Niger Delta Area of Nigeria.

## References

- Adeoti L., Alile O. M., Uchegbulam O. and Adegbola R.B. (2012). Seismic Refraction Prospecting for Groundwater: A Case Study of Golden Heritage Estate, Ogun State. *Research Journal of Physics* (6): 1-18.
- Bear, J. (1972). Dynamics of Fluids in Porous Media. New York: *American Elsevier Publishing Company*: 687-701
- Dick, R. A., (2000). "Factors in Selecting and Applying Commercial Explosives and Blasting Agents." International Society of Explosives Engineers, IC8405, 144pp.
- Dionne, B. C., Rounbehler, D. P., Achter, E. K., Hobbs, J. R. and Fine, D. H. (1986). Vapour pressure of explosives. *Journal of Energetic Materials*, 4(1-4): 447-472
- Dowding, C. H. and Hryciw, R. D. (1986). A Laboratory Study of Blast Densification of Saturated Sand. *Journal of Geotechnical Engineering* 112(2): 187-199.
- Eze, C. L. and Okara, L. C. (2014). Determination of Seismic Blast Vibrations and Damage to Structures in the Niger Delta Region of Nigeria using Peak Particle Velocity. *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)* 5(3): 207-210
- International Society of Explosives Engineers (ISEE). 1998. *ISEE Blasters' Handbook TM*, 17th Edition, p. 48. ISEE, Cleveland, OH.
- Pichtel, J. (2012). Distribution and Fate of Military Explosives and Propellants in Soil: A Review. *Applied and Environmental Soil Science*: 33pp.
- Roy V. C. (1978). "Emissions From The Open Burning Or Detonation Of Explosives", Presented at the 71st Annual Meeting of the Air Pollution Control Association, Houston, TX, June.
- Saiz, J., Bravo, J. C., Torre, M., Garcia-Ruiz, C., (2011). Determination of ethylene glycol dinitrate in dynamites using HPLC: Application to the plastic explosive Goma-2 ECO. *Journal of Separation Science* 34: 3352 – 3358
- Santis, L., Rowland, J., Viscusi, D., and Weslowski M.(1995). The large Chamber Test for Toxic Fumes Analysis of permissible Explosives. Paper in the Procurement of the 21st Annual conference on Explosives and Blasting Technology, (1): 5-9.
- Sapko, M., Rowland, J., Mainiero, R., and Zlochower, I., (2002). "Chemical and Physical Factors That Influence Nox Production During Blasting - Exploratory Study." Paper in the Proc. of the 28th Annual Conf. on Explosives and Blasting Technique, Las Vegas, NV,; 10-13.
- Sikora F. J., J., Almond, R. A., Behrends, L. L., Hoagland, J. J., and D.A., Kelly, (1998). *Demonstration Results of Phytoremediation of Explosives Contaminated Groundwater Using Constructed Wetlands at the Milan Army Ammunition Plant, Milan Tennessee*. 1-3: U.S. Army Environmental Center:112-233
- Ziolkowski, A. M. and Bokhorst, K. (1993). Determination of the signature of dynamite source using the source scaling law. *Geophysics*: 1174-1194.