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Petroleum Hydrocarbon Occurrence in Groundwater along the Trans-Niger Pipeline in Ogoniland, Rivers State, Nigeria

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Abstract:
The Trans Niger Pipeline (TNP) commissioned in 1965 traverses Ogonil and along three (3) main corridors, covering a total distance of 62km and evacuates about 150 thousand barrels of crude oil per day to the Bonny oil Terminal. There have been several episodes of oil spillages along the TNP caused by pipeline failures and third-party interdiction; of which 84 oil spill incidents were reported between 2012 and 2014 alone, spilling a total volume of about 17,957bbls of crude oil into the environment. The incessant spilling of petroleum hydrocarbons along the pipeline Right-of-Way has polluted groundwater within these corridors and adjoining communities. This paper highlights the occurrence petroleum hydrocarbon contaminants and heavy metal complexes in groundwater within the corridors of TNP Right-of-Ways. Groundwater samples were obtained from 133 Geo-referenced boreholes and water wells within 200m swath of the TNP in Ogoniland. The results of laboratory analyses reveal the presence of Polycyclic Aromatic Hydrocarbons (PAHs) in concentrations ranging from 0.06µg/l to 1.0µg/l, Total Petroleum Hydrocarbons (TPH) ranged from 1.39µg/l to 4.34µg/l; in groundwater. Furthermore, the following heavy metals: Barium, Chromium, Cobalt, Cadmium, Lead and Nickel were also found in concentrations ranging from 0.11 µg/l to 19.5 µg/l. Hence, the concentrations of the aforementioned pollutants in groundwater along the TNP heightens our concerns for the safety of the inhabitants of communities who rely on water wells contiguous to the TNP for their everyday use. Chronic exposures to these toxins will ultimately have deleterious health effects especially for children.

Keywords: *Trans-Niger pipeline, geo-reference, complexes, interdiction, chronic, deleterious*

1. Introduction

The Trans-Niger Pipeline (TNP), commissioned in 1961 has being in operation for over 50 years evacuating 150,000 bbls of crude oil per day from parts of the central Niger Delta through Ogoniland to the Bonny Oil Terminal. The TNP traverses Ogoniland along three (3) main corridors. Two (2) corridors run nearly East-West from Ajaokpori in Eleme to the Botem Manifold in Tai LGA, and from Aleto to the Bomu manifold in Gokana LGA. The third corridor runs North-South from the Botem manifold through Bodo to the Bonny Export Terminal. The TNP within these 3 corridors run through a total distance of 61.86 kilometers; occupying a total area of 1.2498 square kilometers, which is about 0.125% (percent) of the total landmass of Ogoniland.

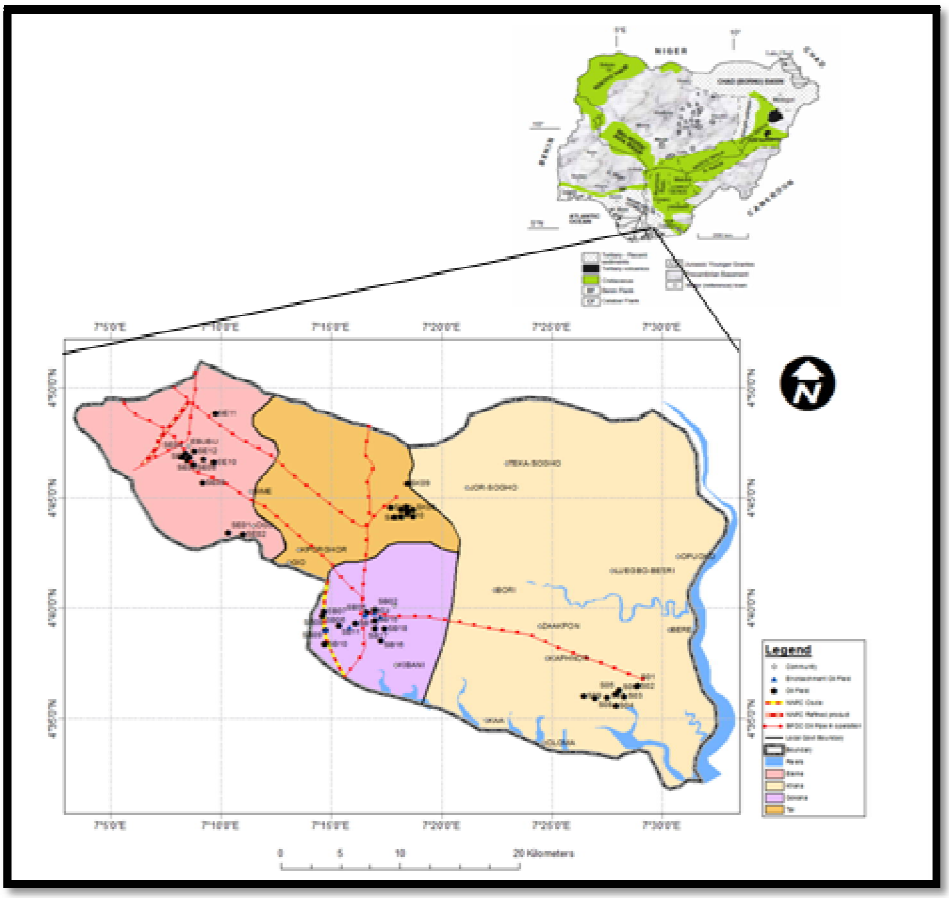

Figure 1: Map of Ogoniland Inset in Nigeria Showing TNP, Flow Lines and Oil Wells

In the year 2000, SGS Inspection Services Nigeria Ltd, undertook an integrity assessment of the TNP and recommended the replacement of this pipeline, due to its age and the length of service time of this crucial oil infrastructure; but interestingly this aged and badly corroded pipeline is still in operation, 19 years after the replacement recommendation was made. The TNP which evacuates crude oil at very high pressures (of up to 1,700kPa) is highly corroded, weakened and severally punctured after half a century of operation (See Figure 1). Hence, there have been several episodes of oil spillages along the TNP caused by pipeline failures and third-party interdiction; of which 84 oil spill incidents were reported between 2012 and 2014 alone, spilling a total volume of over 17,957bbls of crude oil into the environment.

Figure 2: L A Segment of Badly Corroded, TNP in Bodo, Gokana LGA (Source: Zabbey, N)

The incessant spilling of petroleum hydrocarbons along the pipeline Right-of-Way has polluted groundwater within these corridors and adjoining communities. In August and December 2008, for instance, two operational spills occurred along the Trans-Niger Pipeline in Bodo, Ogoni spilling over 300,000bbls of crude oil into the Bodo estuary. These spills were left unattended for over five weeks in each of the separate cases; and in an independent assessment of the spill carried out by a US oil spill consultancy firm Accufacts, it was estimated that a total of between 103,000 barrels and 311,000 barrels (as against 1640 bbls suggested by the operator of the pipeline in the JIV report) of crude oil was released into the environment over the period of the leak (Vidal, 2012). Accufacts arrived at the figure following analysis of video footage of the leak taken at the time. This suggested that between one and three barrels of oil were leaking every minute.
There is a worrisome trend of squatter settlers and land speculators encroaching into and building structures on the TNP ROW. It is noteworthy however, to state here that clear demarcation of the TNP is lacking along many stretches of the TNP ROW. Survey flags are not evenly spaced and are even absent at certain segments of the TNP ROW. This gives room to speculative squatters to encroach onto the ROW. Water wells in community homesteads along the TNP have been sited less than 20m from the pipeline ROW. Figure 3and Figure 3shows the location of homesteads and water wells within the TNP, ROW.

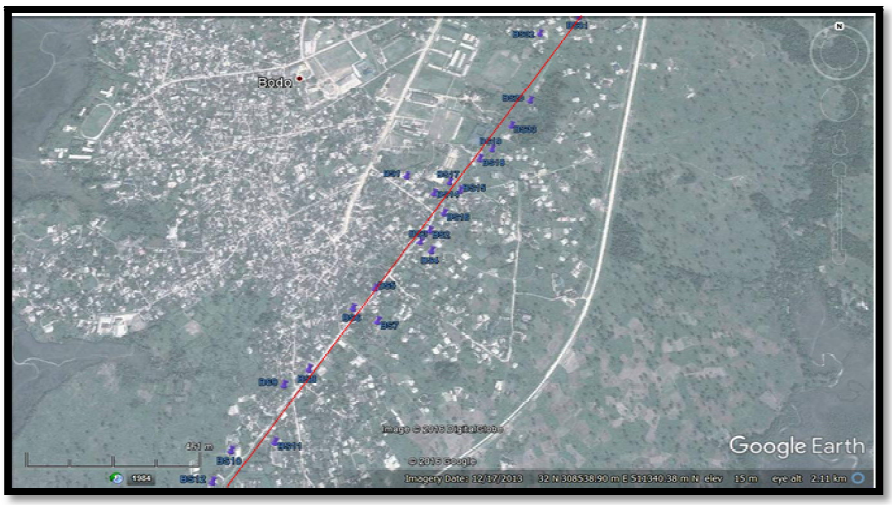

Figure 3: Shows A Segment of the TNP (Red Line) through the Bodo Community and Water Sampling Stations (In Blue)

Figure 4: A Community Homestead on the TNP ROW, Red arrow Shows the Survey Flag Demarcating the ROW (Structure More than 5m into ROW, Black Arrow Shows Direction of ROW)

2. The Vulnerability of Aquifers within the TNP Corridors to Petroleum Hydrocarbon and Heavy Metal Pollution

The geology of the region comprises of recent unconsolidated sediments which enhances the ease of contaminant migration in the subsurface. This underscores the vulnerability of her aquifers to petroleum hydrocarbon contamination. The Benin Formation is the main regional aquifer, consisting of over 60% sands, with regional transmissivity values: 1.05×10^{-2} to 11.3×10^{-2} m^2/sec (Amajor, 1991). Natural Gradient Tracer Tests carried out in the region reveals average groundwater velocity of $1.403 \times 10^{-3} ms^{-1}$ (Giadom, et al; 2015). These values further show that the aquifers in the Niger Delta region has very high potentials for contaminant transport.

The water table in the Ogoni area of the Niger Delta is very shallow with an average range that varies between 0.5m to 4m within the seasons. Thus, it becomes very easy that once oil is spilled, it finds its way to groundwater resulting to a contaminant plume that travels predominantly in the direction of groundwater flow. Hydrocarbon and heavy metal

contamination have been encountered in various homestead water wells, raising serious concerns for the toxicological implications of this situation for communities situate next to the TNP Right-of-Ways in Ogoniland.

3. Petroleum Hydrocarbon and Heavy Metal Toxicity to Man

Various studies have shown that the widespread presence of petroleum hydrocarbon contaminants in the bio-physical environment of Niger delta is capable of exerting acute and long-term adverse health and environmental effects. These contaminants of concern released into the environment, particularly groundwater from oil industry facilities such as the TNP has deleterious effects on the health and wellbeing of the community populations living close to the sources of these pollutants.

The persistence of spilled crude oil in groundwater within the TNP ROW could result not only in infertility, but also hemotoxicity, hepatotoxicity, and carcinogenesis through its effects on chromatin DNA. Other hazards include significant increases in the period prevalence for diarrhoea, sore eyes, itchy skin and occupational injuries. Known carcinogens such as Polycyclic Aromatic Hydrocarbons (PAH) found in water wells within the TNP ROW do not have any safe levels, as even a few molecules of these can be genotoxic. Heavy metals are natural constituents of the earth's crust, but indiscriminate human activities have drastically altered their geochemical cycles and biochemical balance.Prolonged exposure to heavy metals such as cadmium, copper, lead, nickel, and zinc can cause deleterious health effects in humans. Heavy metals disrupt metabolic functions in two ways: (1) They accumulate and thereby disrupt function in vital organs and glands such as the heart, brain, kidneys, bone, liver, etc. (2) They displace the vital nutritional minerals from their original place, thereby, hindering their biological function (Singh, et al; 2011).

4. Materials and Methods

Water wells situate within 200m (100m from the centreline on each side) of the Trans Niger Pipeline ROW were geo-referenced (see figure 1.2) and sampled for Gasoline Range Organics (GRO), Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAH) and Heavy Metals. The groundwater samples were obtained through bailing from the hand dug wells or obtained from boreholes directly from points nearest to the well head; after purging the well to avoid sampling water standing within the casing. Samples were carefully labelled, preserved, stored in cooling boxes and sent to the laboratory same day for analysis. Trip blanks were included to cross check sample integrity. All laboratory analyses were carried out within the scope of ISO 17025. Determination of Extractable Petroleum Hydrocarbons was by GC-FID (C10-C40) TM 061, Method for the determination of EPH, Massachusetts Department of Environmental Protection, 1998. Determination of Polynuclear Aromatic Hydrocarbons (PAH) by GC-MS in Waters, TM 178 modified US EPA Method 8100. Determination of Total Petroleum Hydrocarbon TM 172. Determination of Heavy Metal Concentration was by ICP-MS (Inductively Coupled Plasma Mass Spectrometry) TM 152.

5. Results and Discussion

5.1. Petroleum Hydrocarbon Contamination of Water Wells along TNP ROW

Petroleum hydrocarbon contamination in soils, surface water and groundwater in most parts of the Niger Delta and Ogoniland in particular has become a ubiquitous occurrence. This raises concerns about the impact of these contaminants of concern on public health and ecosystem of these communities housing oil infrastructure. Groundwater quality assessment with respect to petroleum hydrocarbon contamination within a 200m swath of the Trans Niger Pipeline ROW in Ogoniland is presented in Tables 1 and 2

S/N	Station ID	Coordinates (UTM)		TPH(µg/l)	PAH(µg/l)	GRO(µg/l)
		Easting	Northing			
1.	Bodo Stn 1	511102	308349	8.65	0.63	2.52
2.	Bodo Stn 10	510726	307961	12.6	0.4	2.89
3.	Bodo Stn 17	511548	308555	10.8	1.0	2.97
4.	Bodo Stn 21	512901	308821	11.9	0.64	1.95
5.	B. Dere Stn 1	517095	308158	5.12	0.41	0.66
6.	B. Dere Stn 2	517082	308236	5.19	0.3	1.51
7.	B. Dere Stn 4	516967	308274	10.8	0.63	1.3
8.	B. Dere Stn 8	516678	308528	5.96	0.36	1.24
9.	K. Dere Stn 3	515547	308785	3.48	0.21	0.48
10.	K. Dere Stn 4	515324	308789	3.0	0.21	0.55
11.	K. Dere Stn 5	515315	308765	3.45	0.16	0.51
12.	K. Dere Stn 6	515332	308872	5.03	0.35	0.61
13.	Eleme Stn 11	529468	293201	11.4	0.6	1.46
14.	Eleme Stn 16	530017	292603	12.4	0.77	2.46
15.	Eleme Stn 34	531050	290739	7.98	0.65	1.27
16.	Eleme Stn 37	531208	290510	8.13	0.53	3.01

Table 1: Petroleum Hydrocarbon Contaminants in Groundwater Wells within 200m Corridor of the Trans Niger Pipeline in Ogoniland

TPH is defined as the measurable amount of petroleum-based hydrocarbon in an environmental media. It is thus, dependent on analysis of the medium in which it is found (Gustafson, 1997). They are carbon chains in the range of C6 to C35. Since it is a measured, gross quantity without identification of its constituents, the TPH 'value' still represents a mixture. Breached pipelines are the commonest sources of TPH contamination of aquifers within the TNP ROWs. TPH in groundwater sampled varied between 3.0µg/l to 12.6µg/l. Gasoline Range Organics (GRO) alone, a class of TPH within the C6-C10 range, varied from 0.51µg/l to 3.01µg/l. Hence, it is being deduced that the Diesel Range Organics (C11 to C28) and the Lube Oil Range are the major TPH classes present in the water wells along the TNP ROW in Ogoniland. The Environmental Guidelines and Standards for the Petroleum Industry in Nigeria, EGASPIN sets out intervention values and target values for TPH in Groundwater to be 0.6µg/l and 0.05µg/l respectively. The TPHCWG has separated TPH fractions into surrogates based on their carbon number and aliphatic versus aromatic nature. Modelling indicates that C8-C12 aromatics are most likely to seriously impact groundwater due to their mobility and toxicity. The aliphatic of equivalent carbon number are less mobile and less toxic. Heavier weight aromatics also tend to be less mobile. The chromatogram presented in figure 5 below indicates the preponderance of the higher carbon numbers (C10-C40) with a particular spike at C35. Hence, the contaminants of concern will be relatively immobile and one can posit that they will be restricted to areas contiguous to the TNP ROW.

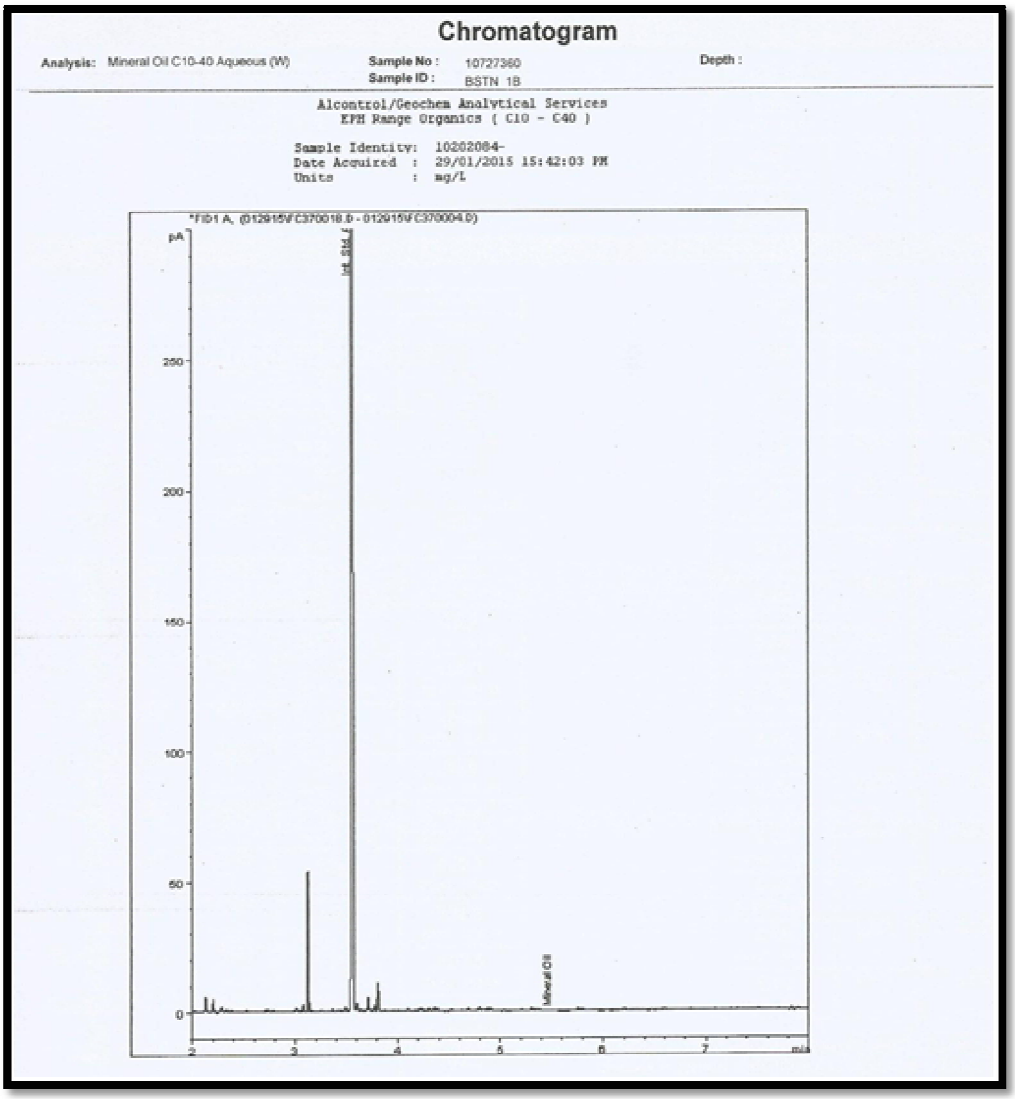

Figure 5: Chromatogram of Water Sample along TNP ROW

Polycyclic Aromatic Hydrocarbons are organic compounds that mostly colourless, white, or pale-yellow solids. They consist of several hundred chemically related compounds, environmentally persistent with various structures, varied toxicity and can be bio-accumulated. PAHs are possibly, probably carcinogenic to humans. Among these are benzo[a]pyrene, naphthalene, chrysene, benz[a]anthracene, benzo[k]fluoranthene and benzo[b]fluoranthene (Abdel-Shafy & Mansour; 2016). These substances found in water wells along the TNP ROW in Ogoniland raises serious concerns; as there are no safe levels, even a few molecules could be genotoxic. Some PAHs are well known carcinogens, mutagens and teratogens and therefore pose serious threat to the health and wellbeing of communities situate along the TNP. Chronic exposures due to prolonged ingestion of waters from this water wells exposes the community folks to health hazards which may include decreased immune function, cataracts, kidney and liver damage, breathing problems, asthma-like

symptoms and lung function abnormalities. EGASPIN Intervention and Target values for PAH in groundwater are 0.5µg/l and 0.002µg/l respectively.

All the samples presented in table 1 and figure 6 below exceed the EGASPIN target values; while about 45% of the samples exceed intervention values. The nature of TPH being a complex admixture of many organic compounds with different physico-chemical and toxicological properties makes the interpretation of their measurements imprecise. Thus, an evaluation of the potential health risks based a direct cause-effect relationship of their concentration and the health hazards associated with their presence is often difficult to establish. However, PAHs are indisputably hazardous and require action on the part of government and the operators of the pipeline to not only reduce or remove them from the environmental media, but also sensitize local communities on the dangers they face in utilizing waters contiguous to the TNP and provide alternate sources of water for those living next to these ROWs.

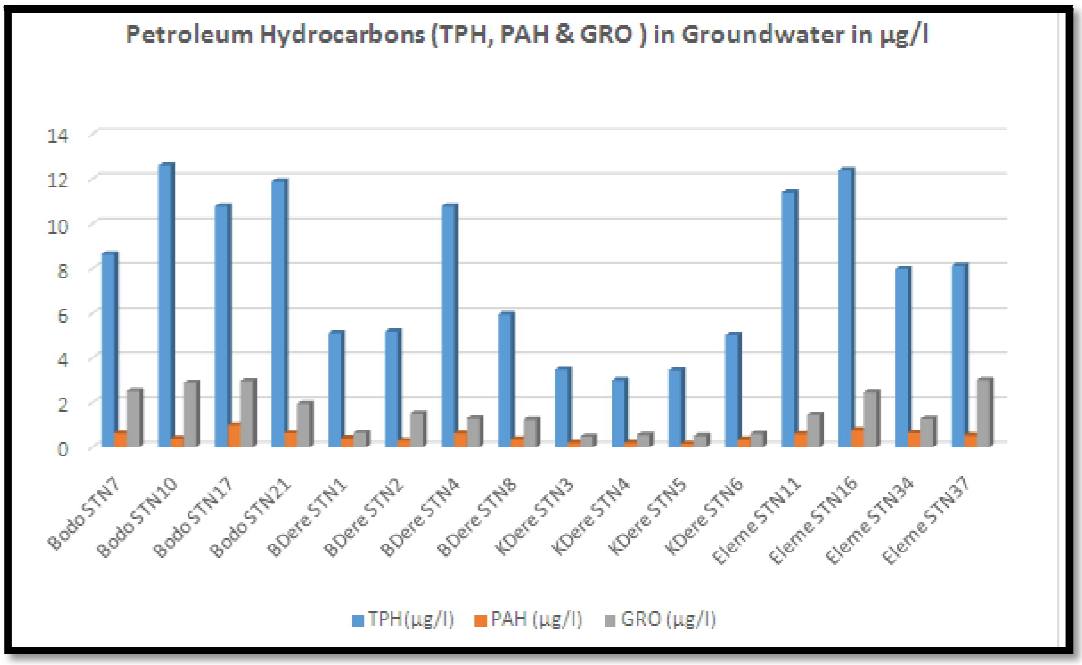

Figure 6: Petroleum Hydrocarbons in Groundwater along Segments of the TNP ROW in Ogoniland

5.2. Heavy Metal Occurrences in Groundwater along TNP ROW

The following heavy metals: Chromium, Cobalt, Cadmium, Lead, Nickel and Barium were analysed for their concentrations in water wells along the TNP.

S/N	Station ID	Coordinates	UTM	Chromium (µg/l)	Cobalt (µg/l)	Cadmium (µg/l)	Lead (µg/l)	Nickel (µg/l)	Barium (µg/l)
		Easting	Northing						
1.	Bodo Stn1	511102	308349	0.607	0.11	0.1	1.13	13.8	2.35
2.	Bodo Stn 2	511392	308498	0.916	0.078	0.1	0.106	1.24	4.06
3.	Bodo Stn 5	511206	308342	0.644	0.382	0.1	0.563	0.558	12.3
4.	Bodo Stn 9	510919	308096	0.605	0.146	0.1	0.831	0.367	8.46
5.	Eleme Stn 2	529048	293562	0.682	0.35	0.1	6.11	1.03	3.38
6.	Eleme Stn 3	529113	293522	0.553	0.097	0.1	18.9	0.738	1.28
7.	Eleme Stn 4	529190	293475	0.515	0.153	0.116	12.2	5.88	1.46
8	Eleme Stn 9	529323	293294	0.705	0.137	0.1	6.87	1.79	3.07

Table 2: Heavy Metal Concentrations in Water Wells along TNP in Ogoniland

All the heavy metals in the groundwater sampled indicated concentrations below the target levels of 15µg/l except in Eleme station 3 where the concentration of Lead (Pb) is 18.9µg/l, but still less than the intervention value of 75µg/l. Nickel however, indicated high concentrations of 13.8µg/l, still lower than the target value.

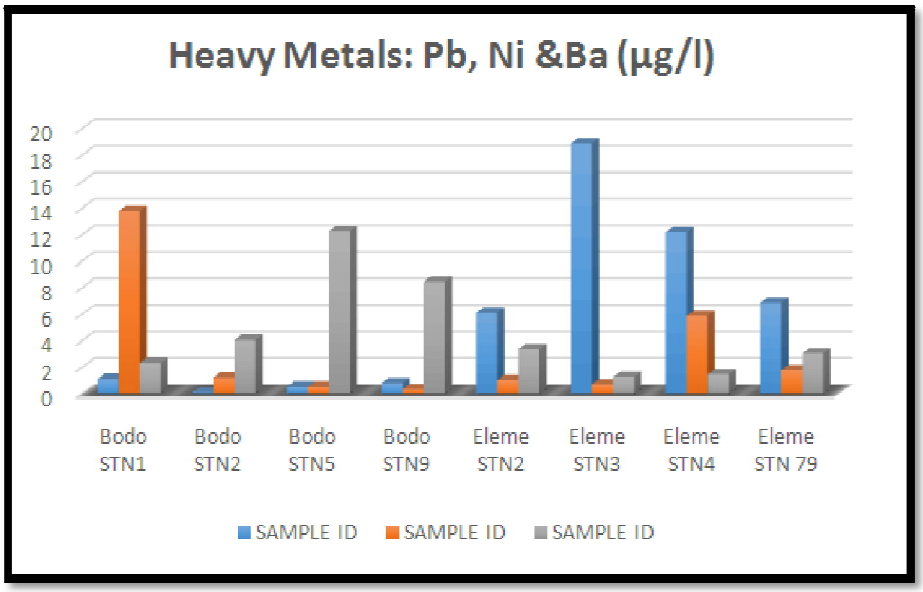

Figure 7: Heavy Metal Contaminants of Concern in Groundwater along TNP, Ogoniland

6. Conclusion

From the foregoing discussions, it is apparent that TPH concentrations are high, however the GRO contribution to this high concentration is very much lower than that of the higher carbon numbers. This suggests that the toxicity and mobility of this contaminant of concern will be low and will be restricted to the areas contiguous to the TNP ROW. PAH however, is very toxic and its presence and concentration in groundwater raises concerns. This is not unexpected due to the number of pipeline failures reported along the TNP and the presence of speculative squatters whose properties situate right on the TNP ROW make the situation more hazardous. Chronic exposure to PAH will be deleterious to the health and wellbeing of the local populations ingesting these waters. Heavy metal contamination indicated is less than the EGASPIN target levels for all the heavy metals except at Eleme station 3 where Lead exceeded the target level.

Government regulatory agencies and the operators of the TNP should enforce the integrity of the TNP ROWs. Survey flags demarcating the ROW should be evenly spaced and visible to discourage speculative squatters from encroaching into the pipeline ROW. Communities hosting the TNP should be sufficiently sensitized on the dangers associated with utilizing waters from wells contiguous to the ROWs and alternative sources of water be provided. It is believed that only proactive measures such as this will protect populations of people living next to the pipeline ROWs from slowly poisoning themselves through the utilisation of contaminated groundwater wells along the Trans Niger Pipeline in Ogoniland.

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