Nigerian Journal of Engineering Science Research (NIJESR).
Vol. 6, Issue 04, pp.09-23, December, 2023

ISSN: 2636-7114
Journal Homepage: https://www.iuokada.edu.ng/journals/nijesr/

Mothballing, Manifold, Pipeline installation and Impact Assessment in existing Saghara Gas solution Flowstation Facility, Warri, Niger Delta, Nigeria

[1*]Ibrahim O.I., [2]Ngozi-Chika C.S., [2]Okanigbuan P.N., [3]Abdulraheem K.K., and [4]Bilqees D.

[1]Design and Hydrogeology units, Lower Niger River Basin Development Authority, Ilorin, Kwara state.
[2] Department of Geology, Dennis Osadebay University, Asaba, Delta State.
[3]Civil Engineering Department, University of Ilorin, Kwara State, Nigeria
[4]Chemistry Department, Faculty of Physical Science, University of Ilorin, Nigeria

Corresponding Author: ibroibrahim72@gmail.com* **(+2348038364251)

Manuscript History
Received: 19/11/2023
Revised: 20/12/2023
Accepted: 26/12/2023
Published: 30/12/2023

Abstract: *The Saghara field is located in OML 43, Warri South of greater Forcados area in the coastal swamp depobelt. It has a total of 8 wells of which two wells have been abandoned. Gross oil production to Saghara flowstation is 30,000 barrels per day. The Saghara associated gas is part of the wider Otumara node associated gas solution project conceived to reduce gas flaring. Otumara oil wells producing into Saghara flowstation were re-routed back to Otumara flowstation. The methodology for the study involved mothballing of the existing flowstation through the installation of new inlet manifold. Fabrication of bulk and testlines done offshore with associated tie-ins and manifold. Major findings of the project study included new bulkline of 6" x 5km and testline of 4" x 5km laid for Saghara flowstation. This was connected into Otumara flowstation including all associated tie-ins and manifold works to harvest associated gas from the Saghara field. Installation of 21km fibre optic cable from Saghara wells to Otumara Central Processing Facility was for data transmission from the wells. Welding of the bulklines, flowlines, tie-ins and hook ups done with floatation method. The pipeline was routed through salt marsh, mangrove, phoenix swamp of Sagbara area. Mothballing, in-situ preservation of the flowstation and the 8" oil delivery line from Saghara to Trans-Forcados Pipeline (TFP) fabricated offshore installed. 4" and 6" pig launching, receiving facilities and tie-in at Saghara flowstation facilitated comingling of the wells. The bulk and flowlines were hydrostatically tested with no leakage recorded. SPM ranged from 0.62-1.62 μg/m³ in the wet season compared to 9.56-22.14 μg/m³ in the dry season, Furthermore, TSP ranged from 0.98-2.00 μg/m³ in the wet season compared to 14.09-30.01 μg/m³ in the dry season. Gas flaring will reduce to almost few thousand scf/d from the 1,750,000 scf/d with this new technological innovation and if replicated in this Sagbara or other areas with little or no environmental effects.*

Keywords: *Suspended Particulate Matter, Total Suspended Particulate, Mothballing, Flowstation, Manifold and Flowline.*

INTRODUCTION

Climate change is currently a pandemic ravaging the global community and the need for nations to adjust towards cleaner sources of environmentally and eco-friendly energy is the focus of stakeholders in the energy industry, national, international gathering and indeed this article. The Niger Delta basin, also referred to as the Niger Delta province (Figs. 1 and 2) is an extensional rift basin located in the apex of the Gulf of Guinea on the passive continental margin near the western coast of Nigeria with proven access to Cameroon, Equatorial Guinea, São Tomé and Príncipe. The Saghara associated gas solution project is part of the wider Otumara Node Associated Gas Solution Project that aim to effectively stop routine gas flaring in the area (Fig. 3). Before now, most of the associated gas produced at the Saghara flowstation was flared. All Otumara oil wells currently producing into Saghara flowstation were re-routed back to Otumara flowstation. The remaining Saghara oil wells were comingled at low pressure and allowed to flow freely with the associated gas to Otumara flow station. More importantly, the current administration in Nigeria is also working in line with international and national regulations. This is to reduce carbon emission and greenhouse gases by removal of oil subsidy and rolling out compressed natural gas infrastructure (CNG) to convert vehicles from Premium Motor Spirit (PMS) based to gas based, cleaner, safer, cheaper and more environmentally friendly fossil fuel. It is worthy of note that most oil producing companies are expected to key into these real geoscientific dynamics shaping the world energy landscape. Before now, most oil producing nations flare the associated gas with impunity which has serious consequential harm on the ecosystem with attendant serious health implications on communities. Gas utilization has increased tremendously in the day-to-day socio-economic activities as a cleaner fuel ranging from domestic cooking gas, alternative source of powering generators to generate electricity and abundant gas-powered stations, gas industries, compressed natural gas in our vehicles etc. These are due to new Technological and Geoscientific innovations springing up globally to reduce carbon footprint (Ibrahim *et al.,* 2023).

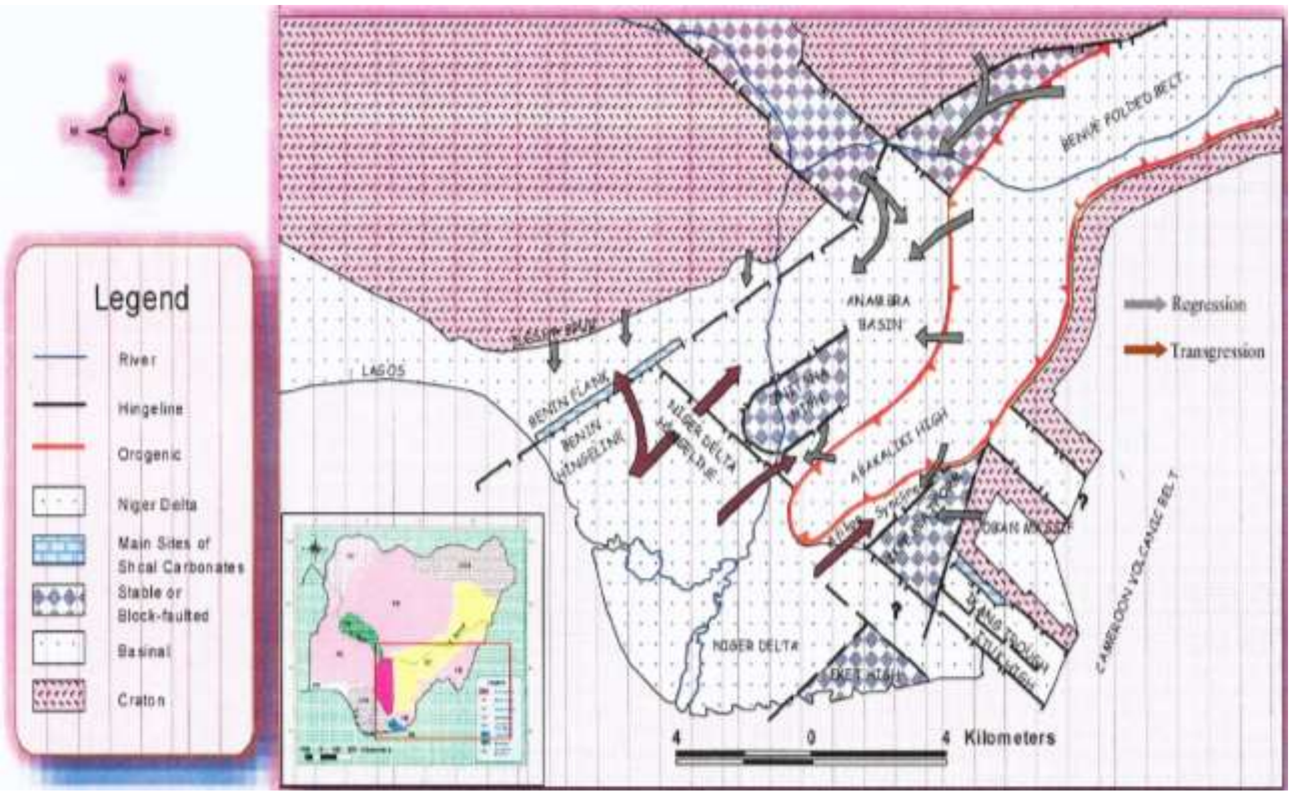

Fig. 1. Tectonic map of Niger Delta area, showing the transgressive and regressive water (Ekweozor and Daukoru, 1994)

It is the energy need of today and the future in developing and developed world. In a nutshell, flaring it, is throwing away energy and wealth that is crucial for the industrialization of Nigeria, Africa and the international community. The study aim therefore is to come up with technological innovations with analysis of attendant environmental effects and impacts to drastically reduce the flaring of the associated gas during oil production in Saghara area.

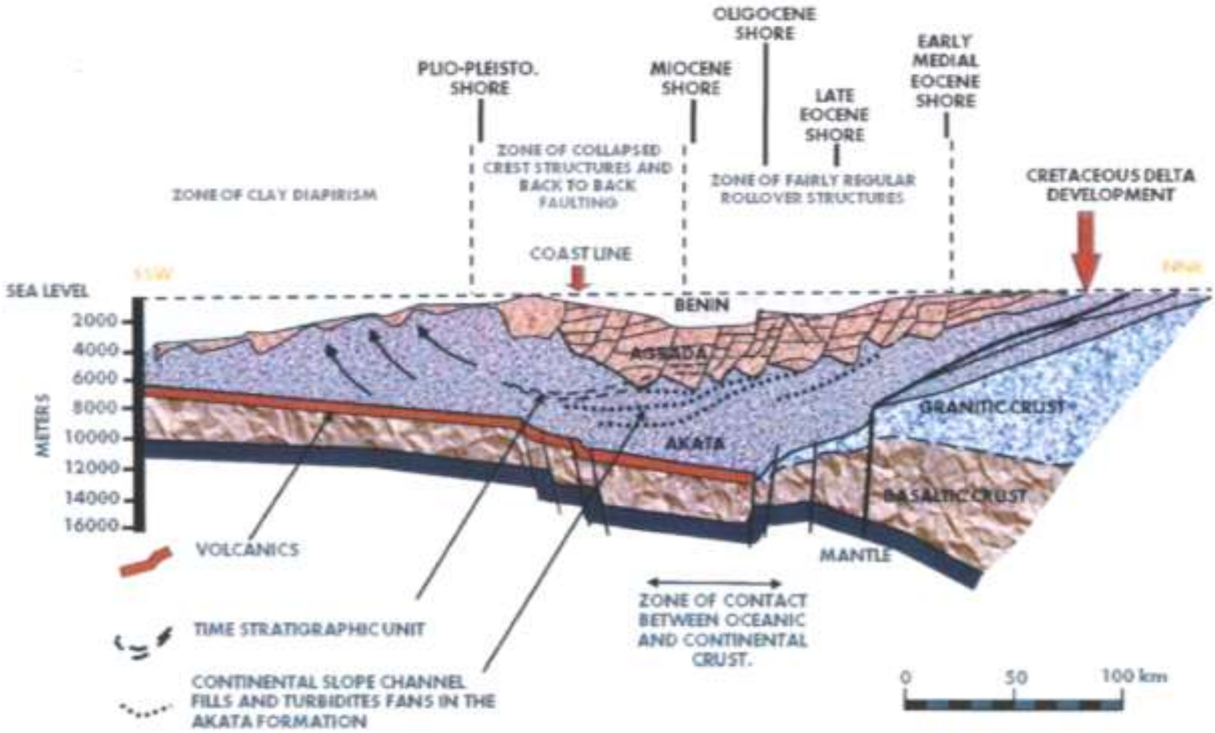

Fig. 2. Dip Section of the Niger Delta deposit showing different zones of formation (Weber and Daukoru, 1975)

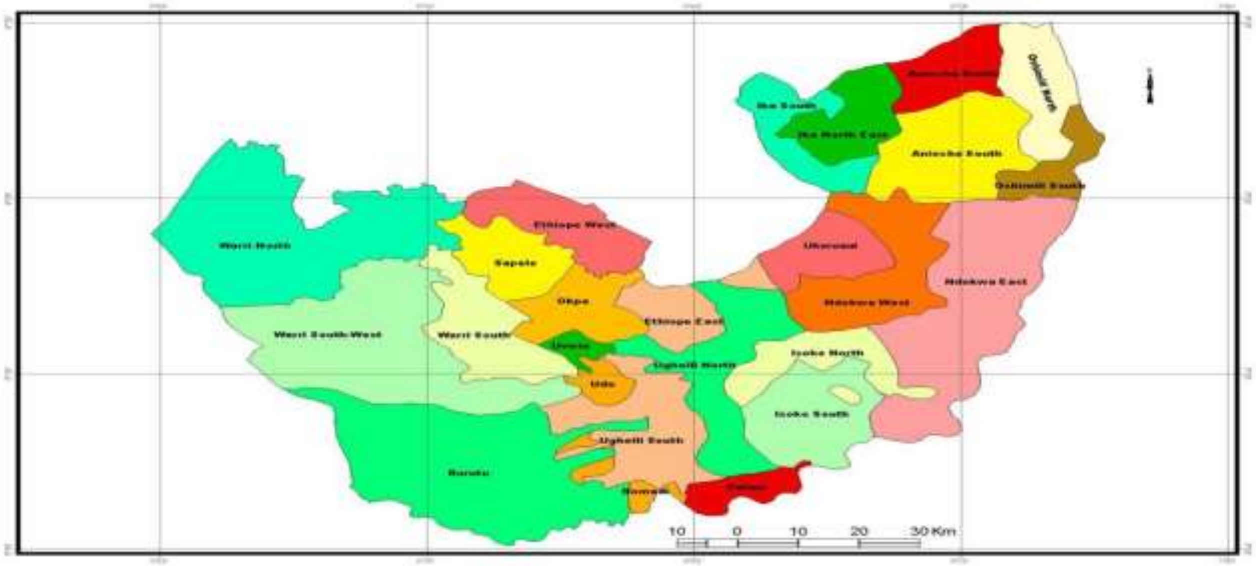

Fig. 3. Map of Delta State showing Saghara Associated Gas Solution Project Area

Geomorphology of Nigeria and Niger Delta Region

Nigeria has a coastal line of approximately 85km towards the Atlantic Ocean lying between latitude 4°15' to 4°50' and longitude 5°25' to 7°37' with a land mass of about 28000sq/km area within the coastal region. The surface area of the continental shelf is 46300sq/km. The coastal areas consist of freshwater swamp, mangrove swamp, beach ridges, sand bars, lagoons marshes and tidal channels. Nigeria has a total land mass of 923,768sq/km; 918,768sq/km being terrestrial land and 13000 sq/km being aquatic (Nton, 2009). The coastal area is humid with a mean average temperature of 24-32°C and coastal area has an average annual rainfall ranging between 1,500-4,000m (Obaje, 2005). Nigeria has two large rivers; the Niger-Benue and the Chad River (Fig. 1). There are several rivers that channel into the Atlantic Ocean directly, all other water flow into the Chad basin or into the lower Niger to the sea eventually (Opara *et al.,* 2011). The Niger Delta is located in the Atlantic coast of Southern Nigeria and is the world's second largest Delta with a coastline of about 450km which ends at Imo River entrance (Awosika and Folorunsho, 2002). The region is about 20,000sq/km as it is the largest wetland in Africa and among the third largest in the world (Doust, 1989, Ejedawe *et al.,* 1984 and Ekwe *et al.,* 2012). 2,370sq/km of the Niger Delta area consists of rivers, creeks, estuaries and stagnant swamps cover approximately 8600sq/km. The Delta mangrove swamp spans about 1900sq/km as the largest mangrove swamp in Africa (Awosika, 1995). The Niger Delta is classified as a tropical rainforest with ecosystems comprising of diverse species of flora and fauna both aquatic and terrestrial species. The region can be classified into four ecological zones; coastal inland zone, freshwater zone, lowland rainforest zone, mangrove swamp zone and this region is considered one of the ten most important wetlands and marine ecosystems in the world.

Location, Geology and Lithological Facies of the Area

The Otumara field is situated on the coast, North of Escravos facility. The field has been developed by slot dredging and the areas traversed by Shell Escravos facility and third-party pipelines. The project study area has flat terrain with elevated land bounding the eastern margin. The elevation is less than 10m above sea level while the slope is below 2°. Dreding activities and dumping of dredge spoil have slightly raised the banks of the slots. However, the landscape is usually water-logged during the wet season mainly because of rain and tidal ranges on the rivers which vary from 0.3 m to 1.3 m. Although the areas are generally freshwater swamp. They are drained by the Escravos river in the East and Saghara creek in the West with the Saghara Creek flowing into the Escravos river which ultimately enters into the Atlantic Ocean (Fig. 2). Sea water intrusion is prevalent on the Southwest margin of the area along slots and creeks. During the wet season, saltwater intrusion into the freshwater zone is retarded because of the considerable volume of freshwater discharged into the area via the creeks and rivers as rainfall runoff. Naturally, this result in the displacement of the saline water-freshwater interface further downstream. The morphology of Niger Delta changed from an early stage spanning the Paleocene to early Eocene to a later stage of Delta development (Figs. 2 and 4). The early coastlines were concave to the sea and the distribution of deposits were strongly influenced by basement topography as reported by (Doust and Omatsola 1989). The study facility and its adjoining fields (Saghara and Escravos) are part of the geologic sequence of the Quartenary and Tertiary formations of the Niger Delta, consisting of three main geological formations – the Benin formation (the topmost unit), the Agbada and the Basal Unit, the Akata formations (Fig. 4). Lithological units of the study area are composed of sands, silty sands and clay. The land surface of the study area is characterized by low lying plains typical of the modern Niger Delta. This area carries high economic value as it contains a very productive petroleum system (Fig. 2). The Niger delta basin is one of the largest subaerial basins in Africa and Sagbara area is very prolific in the hydrocarbon production. It has a subaerial area of about 75,000 km^2, a total area of 300,000 km^2, and a sediment fill of 500,000 km^3. The sediment fill has a depth between 9–12 km and its highly prolific in hydrocarbon production of liquid and gas content. Depending on sea level changes, local subsidence and sediment supply, the delta experienced phases of regressions and transgressions as dictated by its system tracts pattern. They are composed of bands of sediments about 30–60 km wide with lengths of up to 300 km (Figs. 2 and 4).

They contain major fault–bounded sequences which is ofshore alternating sand/shale sequence limited at the proximal end by a major boundary growth fault and at the distal end by a lithofacie change and as attested by (Ibrahim et al., 2019 and Ibrahim et al., 2020). Late stages of deposition in the area began in the early to middle Miocene, as these separate eastern and western depocenters merged. In Late Miocene, the delta prograded far enough that shorelines became broadly concave into the basin. Accelerated loading by this rapid delta progradation mobilized underlying unstable shales. These shales rose into diapiric walls and swells, deforming overlying strata. The resulting complex deformation structures caused local uplift, which resulted in major erosion events into the leading progradational edge of the study Sagbara area. These plains have swamps that are commonly flooded during the peak of the rainy season. The area slopes imperceptibly in the Southern direction towards the Atlantic Ocean and is drained by a network of Escravos river and the adjoining creeks, mangrove swamps, marshes and dredge slots. In the Niger delta, this sequence is modified by the numerous transgressions which have occurred from time to time, breaking the continuity of the main overall regression and becoming stratigraphically superimposed (Ibrahim *et al.,* 2020). The thick wedge is considered to consist of three units of Benin, Agbada and Akata formations (Fig. 4).

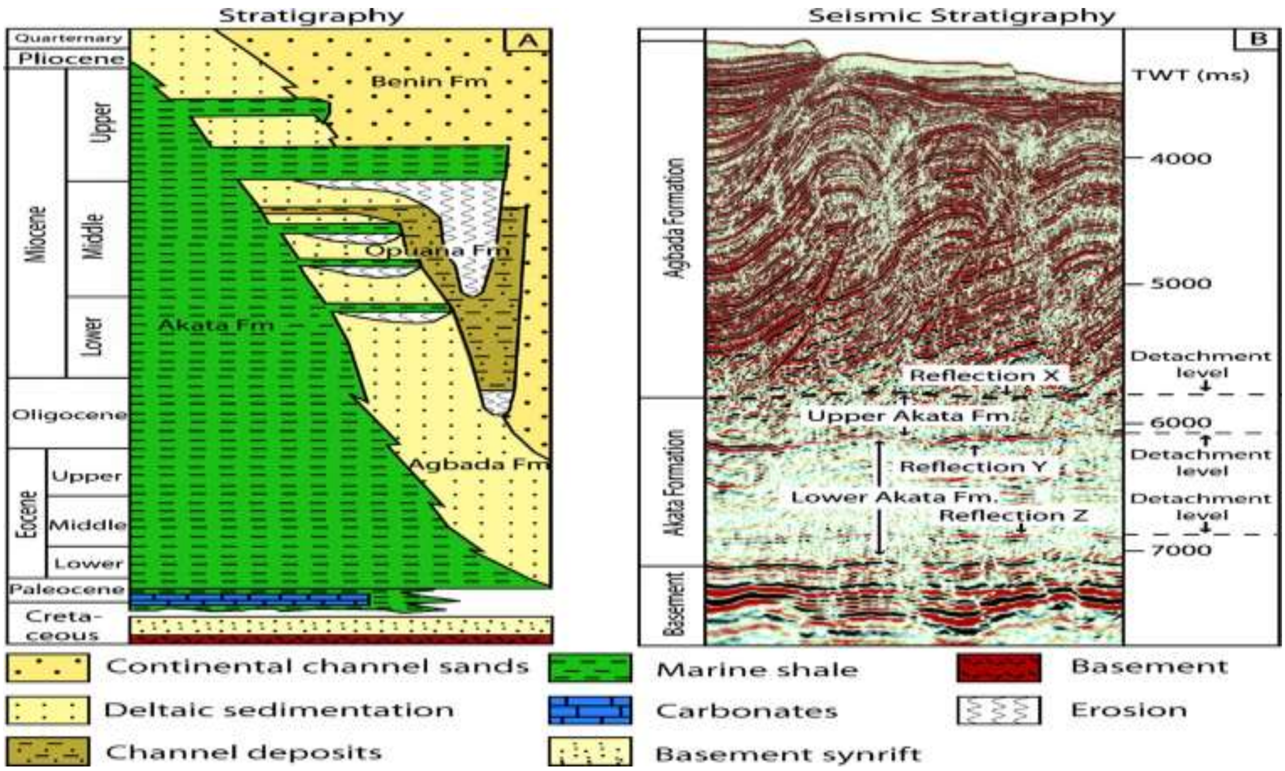

Fig. 4 Lithostratigraphic chart of Niger Delta deposit (Lawrence *et al.,* 2002)

MATERIALS AND METHODS

The following materials were deployed for the work and included Surveying equipment - Theodolite, levelling instrument and echo sounder used for measuring the riverbed elevation and many more. Ditching, trenching and dredging activities were preceded with centre line survey to define actual alignment of the flowlines and probing to identify location of all existing facility interfaces and possible crossings. Excavations around existing facility crossing was carried out manually while mechanical excavation was utilized in all other areas. Several minor creek crossings and one major river crossing were performed as part of the bulkline/flowline construction and the dredging technique to be used and handling of dredge spoil was designed to minimize impact on the environment.

Dredging is required for only major river crossings. Minimum depth cover was not less than 1m below natural bottom level of river or creek bed. All pipelines (test and bulk lines) conformed to design and engineering codes. Evaluation of combined stresses on the pipeline was carried out for the assurance of mechanical strength in conformance with relevant codes. The detailed design also covered plant layout, surveys, soil investigation, foundation and piping tie-ins including interface to the existing facilities. To analyse pipeline systems, the following loads were taken into consideration as a minimum at construction phase and included, internal pressure loads (hoop stress), Sustained Loads (soil loads, soil frictional force, self-weight), Live (axial) loads (vehicle traffic), thermal loads (changes in operating/installations temperatures), test loads (hydrostatic testing) and vortex induced fatigue. This activity involved welding of the bulklines, flowlines, tie-ins and hook ups. The floatation method was used where the pipeline was laid from a single laybarge moving through a channel (burial trench) cut along the right of way. The line pipes were procured as offshore materials with capped bevel ends with pipe storage barge moored next to the laybarge. After welding of pipes, the pipelines were treated with three-layer polyethylene coating to provide external corrosion protection. Field joints were coated with shrinkable sleeves. All welds were 100% radio-graphed as per code requirement. All fillet welds were tested using dye penetration test. Visual inspection and100% radiography (non-destructive testing) of the welds were done as the welding progressed.

RESULTS AND DISCUSSION

The following results were obtained from the study that entailed field, pipe laying, mothballing, manifold installation and environmental impact assessment result of the gas flaring reduction in Sagbara area.

A. Mothballing of Saghara Flowstation

The Saghara associated gas solutions facility was mothballed and re-routing exercise of Saghara wells back to Otumara flow station done with the remaining Saghara oil wells comingled at low pressure and allowed to flow freely (with the associated gas) to Otumara flow station. Some of the existing facilities, (generators & export pumps) within the flow station were decommissioned and preserved. The project does not involve drilling of new oil wells. The work comprised of engineering review and verification, fabrication of materials, construction and installation of a new bulkline (6" x 5km) and testline (4" x 5km) for Saghara flowstation (Figs. 5 and 6). This was allowed into Otumara flow station including all associated tie-ins and manifold works. The setup enabled re-routing of Otumara wells currently producing to Saghara flowstation to Otumara flowstation. The work which was carried out in the Saghara flowstation was done with the only existing flowline Right of Way (RoW) throughout the construction and installation. The work included the installation of 21km long fibre optic cable from Saghara wells to Otumara Central Processing Facility for **d**ata transmission from the wells (downhole data gathering) and communication with the wells (ability to control instruments on the wellheads) (Figs. 5 and 6).

B. Welding and Radiography (Non-Destructive Testing)

This activity entailed welding of the bulklines, flowlines, tie-ins and hook ups. The floatation method was used where the pipeline was laid from a single laybarge moving through a channel (burial trench) cut along the right of way. The line pipes were constructed with capped bevel ends with pipe storage barge moored next to the laybarge. After welding of pipes, the pipelines were coated with three-layer polyethylene coating to provide external corrosion protection. Field joints were coated with shrinkable sleeves. All welds were 100% radio-graphed as per code requirement. All fillet welds were tested using dye penetration test. Visual inspection and100% radiography (non-destructive testing) of the welds were done as the welding progressed. Weld repairs were carried out where necessary, prior to pipeline pressure testing for leakage of gas.

Waste generated from welding and Non-Destructive Testing activities were safely disposed. Successful welds were laid on already prepared trenches as specified in the survey exercise.

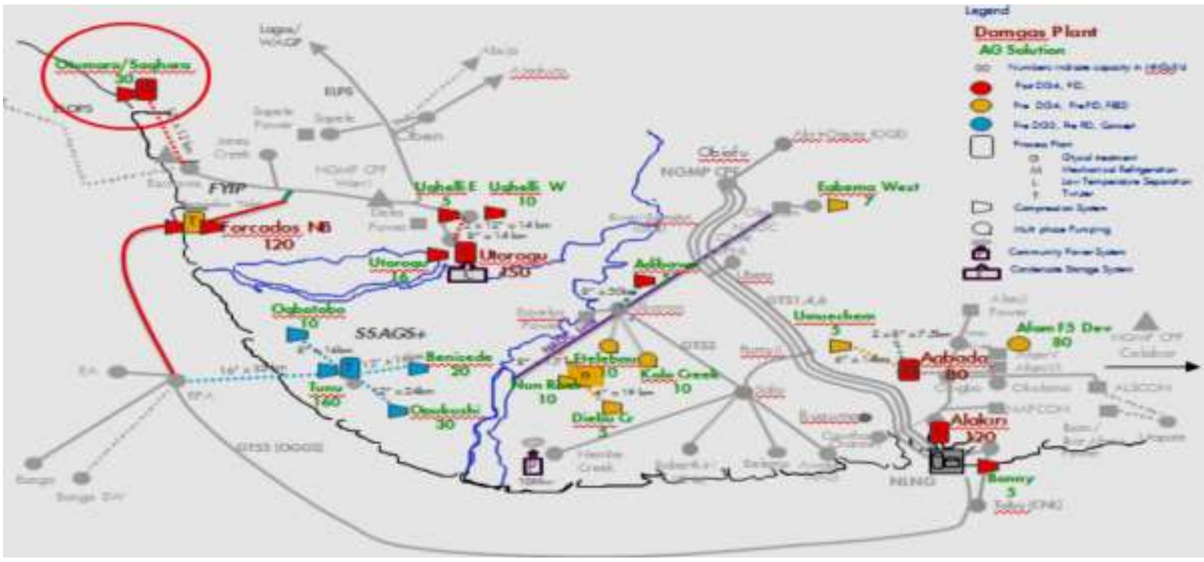

Fig. 5. Saghara Associated Gas Solution Project and other Gas Portfolio Projects

C. Pipeline Survey, Manifold Construction and Installation

The pipeline construction was routed mainly through salt marsh, mangrove swamp, phoenix swamp and fresh water swamp forest of the Sagbara area. (Fig. 6). The pipelines were properly anti-corrosion coated and weight coated for most of the route passageway. The pipelines were provided with permanent pig launching and receiving facilities at Otumara, Saghara and ELPS tie-in point was done at the Nigeria Gas Company manifold respectively. Construction of new bulking manifold was done offshore and transported to Saghara area for installation, Tie-ins. process piping, vent, drain lines and flush line along with supports were constructed and installed. Installation of process piping/valves from tie-in points along with pipe supports were done with maximum safety. Mothballing, in-situ preservation of existing Saghara flow station and the 8″ oil delivery line from Saghara to Trans-Forcados Pipeline (TFP) were fabricated offshore and successfully installed (Figs. 5 and 6). Prior to ditching, metal detectors were utilized to probe for the identification and location of existing flowlines, pipelines along the flowline right of way (RoW). Positions of such flowlines, pipelines were properly marked out as part of the pre-ditching investigations to avoid pipeline burst during installation. The actual positions of the identified lines were done using reflective yellow buoys (on water) or pegs (on land). During excavation and pipe laying activities in the field, the following safety measures were adopted:

1. The pipe trench followed the pipeline route surveyed/opened;
2. The trench was excavated to minimum widths in relation to pipe sizes;
3. Mechanical equipment was used for the excavation
4. The finished trench was free of roots, stones or other hard objects, which may damage the pipe or pipe coating;
5. Provision was made for dewatering, as may be required;
6. The pipes were lowered into the trench such that it lies naturally and is continually supported along its entire length in the bottom of the trench. Where the floatation method is used, the pipe was floated into position and lowered into place with adequate floats or pontoons as necessary;
7. After the pipes were properly placed in position ie installed, the floats were carefully removed to prevent damaging to the coating and
8. The pipes were now filled with filtered, clean water for flushing and pressure testing.

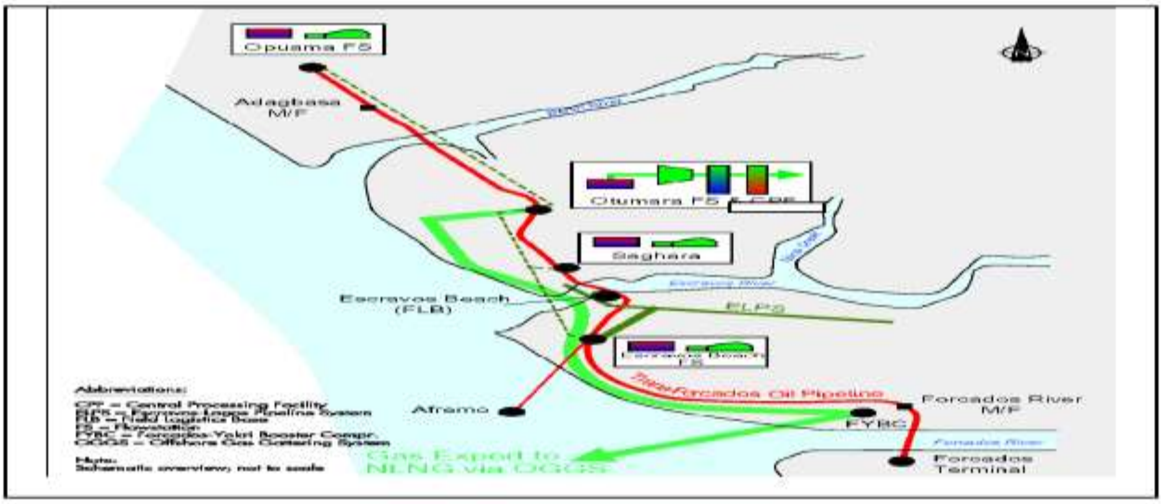

Fig. 6. Pipeline route to Trans Forcados Oil Pipeline

Replacement/re-routing of eleven (11) 4'' flow lines from seven wells in Otumara currently flowing to Saghara manifolds to Otumara flow station inlet manifold was done.

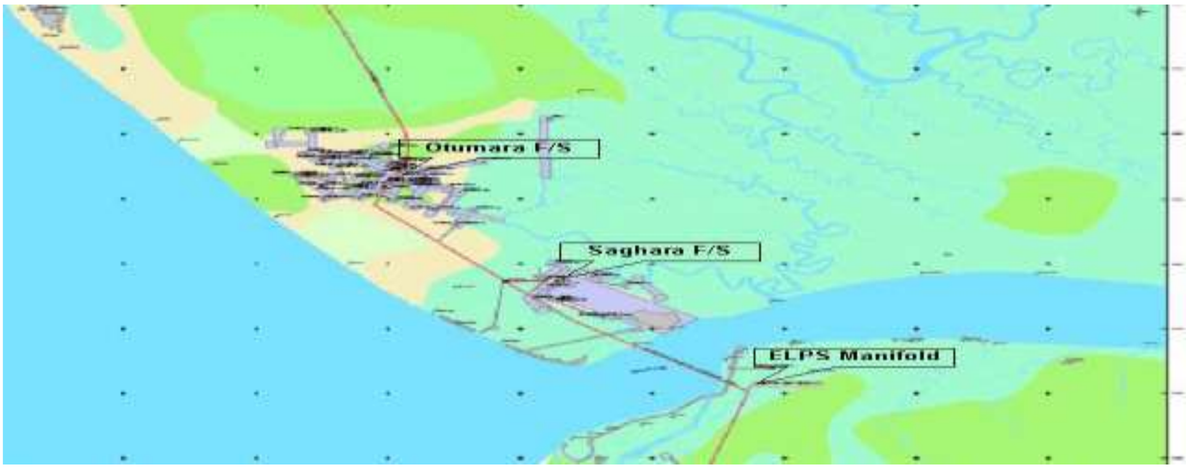

Fig. 7. Flow-station pipeline between Sagbara and Otumara gas facility

D. Bulkline, Testlines, Flowlines and Site Preparation

Laying of new test line (4″ x 5km) from Saghara flowstation to Otumara flowstation was done and laying of new bulk line (6″ x 5km) from Saghara flowstation to Otumara flowstation allowed for drastic reduction of flared gas in the area (Fig. 7). This section describes the construction activities for the proposed Saghara facility, bulklines and testlines. It included, pipeline route surveys and soil investigations of the area. Installation of 2″ x 5km corrosion inhibition lines from Otumara CPF ie central processing facility (Figs. 6 and 7) to Saghara flowstation manifold was done with installation of 4″ x 5km oil testline from Saghara flowstation inlet manifold to Otumara flowstation inlet manifold (Fig. 7). Installation of 6″ x 5km oil bulkline lines from Saghara flowstation inlet manifold to Otumara flowstation inlet manifold allowed re-routing of 4″ x 5km oil flowline lines from Saghara wells to Otumara flowstation inlet manifold (Figs. 6 and 7). Installation of 4″ and 6″ pig launching and receiving facilities and tie-in at Saghara flowstation was done with installation of 21km fibre optic cable from Otumara CPF to Escravos through Saghara flow stations. Tie-ins to existing inlet manifolds/hook-ups also allowed installation of cathodic protection system. Fabrication of new manifolds and launchers was done offshore and transported for installation at the flow station.

Generally, RoW and site clearing tend to remove the canopy over soil, leading to trans-evaporation, with consequent soil dryness. Fortunately, the soils of the project area have high moisture content, therefore canopy removal will have negligible impact on soil dryness. Following the tie-in/hook up process the manifold was integrated with the existing facility required for mothballing the Saghara flowstation. The bulklines and flowlines were hydrostatically tested for leakage after construction to prove the strength and integrity of the lines. The test water for the various pipelines was from ground water (borehole within the area) and evacuated to Forcados terminal through the flowstation. The strength test verified that the pipeline meets the requirements for mechanical strength and the leak tightness test verified that the pipeline meets the requirements for tightness.

E. Impact Assessment

Significant negative impacts during the installation phase were recorded which included trenching and backfilling, coating and wrapping of pipes, welding and non-destructive testing and river crossing. Trenching and backfilling increased surface water sediment loading and suspended solids. River crossing promoted shoreline erosion. Other negative impacts included irreversible soil compaction of the right of way (RoW) which altered the topography of the drainage pattern. Salt water intrusion into ground water was noticed and obviously will spread to different aquifers in the areas. This will have 2 main effects of polluting underground water source for the inhabitants and reducing the lifespan of installed facilities through hydraulic seepage around the circumference of the pipes but this was largely reduced and curtailed with coating of the pipes. Exposure to radioactivity from non-destructive Testing of pipe welds and release of toxic fumes and impairment of vision from arc welding greatly polluted the quality of the air in the area but this is temporary as this is just a potential occupational health hazard. Improper disposal of lay barge deck drainage contaminated surface water and sediment altered the ecosystem of the area. Discharge of untreated hydrotest water into the receiving environment, disaggregation of benthic habitats resulting in loss of benthic organisms, shoreline erosion and improper disposal of backfill residue all altered the morphology of the area and impeded drainage pattern of the Sagbara area. Contamination of water resulted from the use of paints, corrosion inhibitor, leaks and spills of diesel fuel and lubricants into large water bodies that has infiltrated into aquifers of the area.

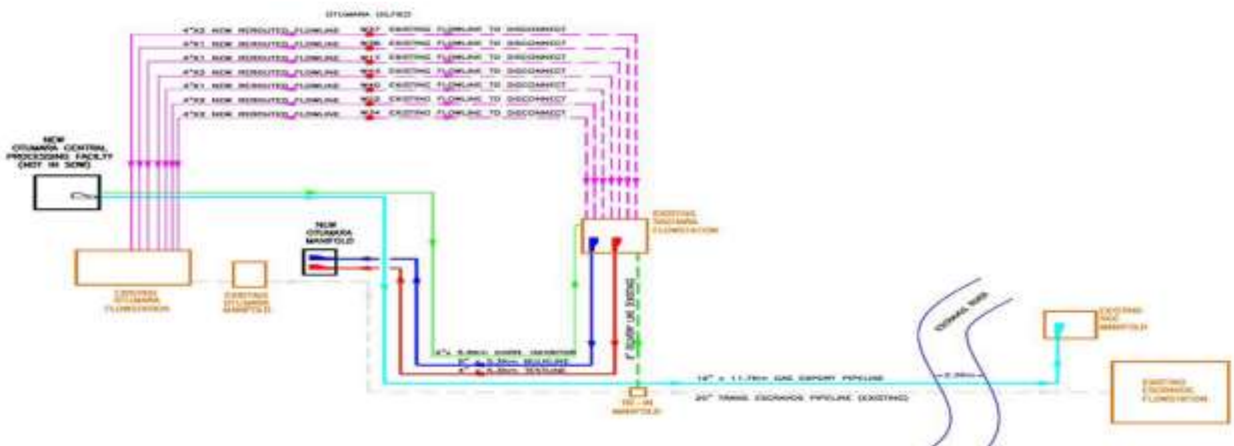

Fig. 8. Schematics diagram of Sagbara pipeline

F. Environmental impact on climate and Air Quality

Tiny airborne particles or aerosols that are less than 100 micrometers are collectively referred to as Total Suspended Particulates (TSP).

These particles constantly enter the atmosphere from many sources. Suspended Particulate Matter (SPM) on the other hand, constitute the sum of all solid and liquid particles suspended in air, ranging in size from 0.1 micrometer to about 30 micrometers in diameter, many of which are hazardous. This complex mixture contains for instance dust, pollen, soot, smoke and liquid droplets. Flaring of gas in the area has greatly impacted the quality of air with these pollutants.

G. Total Suspended Particulates (TSP) and Suspended Particulate Matter (SPM)

These two terminologies are often used interchangeably, but there is some subtle difference (Tables-2 and 4). It appears to be a matter of size. Ambient particulate matter is responsible for harmful effects on health, even in the absence of other air pollutants. Both fine and coarse particles have been shown to affect health, in particular the respiratory system. Fine particles are more dangerous than coarse particles. Apart from the size of the particles, other specific physical, chemical and biological characteristics that can influence harmful health effects include the presence of metals, PAHs, other organic components or certain toxins. A detailed environmental impact assessment exercise was drafted and put together for publication putting into consideration more crucial parameters on the well-being of the people in Sagbara and the ecosystem of the area. This shall be made available soon for publication.

Table-1 Wet season air quality measurement result in Sagbara area

Location ID	Coordinates		Air quality (ppm)						
	Northing	Easting	NO_2	SO_2	CO	H_2S	NH_3	CH_4	VOC
AQ1S	305892	179170	0.09	0.01	1.68	0.01	0.01	0.01	1.80
AQ2S	304966	179858	0.07	0.01	2.03	0.01	0.01	0.01	7.70
AQ3S	179064\	304767	0.04	0.12	1.34	0.01	0.01	0.01	0.70
AQ4S	305641	179845	0.07	0.01	1.99	0.01	0.01	0.01	11.4
AQ5S	306884	178429	0.04	0.01	4.54	0.01	0.01	0.01	1.60
AQ6S	177860	304648	0.06	0.20	1.18	0.01	0.01	0.01	1.02
AQ7S	304582	180480	0.06	0.01	1.84	0.01	0.01	0.01	2.10
AQ8S	305985	180652	0.08	0.01	1.99	0.01	0.01	0.01	6.90
AQ9S	303028	186262	0.23	0.09	0.23	0.01	0.01	0.01	6.20
Mean value			0.082	0.052	1.868	0.01	0.01	0.01	4.38

SPM ranged from 0.62-1.62 μg/m³ in the Wet Season to 9.56-34.10 μg/m³ in the Dry Season, (Tables 2 and 4) whereas TSP ranged from 0.98-2.0 μg/m³ in the Wet Season to 14.09-55.02 μg/m³ in the Dry season. (Tables 2 and 4). These ranges were well within regulatory limits, indicating the receiving atmospheric environment had not been compromised by the flowstation operations. However, the time interval and seasons of collecting the data varied a great deal during the assessment exercise with short averaging sampling times (5 -10 mins) used in this study, compared to the averaging times of 8-24 hours used for regulatory limits. On the other hand, it is equally probable that these concentrations may remain at these levels over longer periods. Fortunately, there will be no air quality problem in Saghara field, since the flowstation is to be mothballed.

H. Sulphur Dioxide (SO_2)

In discussing air quality results, one must be mindful of the averaging sampling time. Much higher concentrations are tolerable over shorter averaging time. For this reason, the WHO (2005) stated that controlled studies with exercising asthmatics indicate that some asthmatics experience changes in pulmonary function and respiratory symptoms after periods of exposure as short as 10 minutes (Tables-1 and 3).

Based on this evidence, it is recommended that a value of 500 µg/m³ (0.175 ppm) for SO_2 should not be exceeded over averaging period of 10 minutes.

Table-2 Wet season Noise quality measurement result in Sagbara area (Ibrahim *et al.,* 2023)

Location ID	Coordinates		Noise level	SPM	TSP
	Northing	Easting	dB(A)	ug/m³	
AQ1S	305892	179170	62.8	1.02	1.38
AQ2S	304966	179858	56.1	1.20	1.65
AQ3S	179064\	304767	55.0	1.23	1.61
AQ4S	305641	179845	56.2	0.74	1.12
AQ5S	306884	178429	65.2	0.62	0.98
AQ6S	177860	304648	58.0	0.80	1.04
AQ7S	304582	180480	60.0	1.12	1.46
AQ8S	305985	180652	48.5	0.86	1.04
AQ9S	303028	186262	54.0	1.62	2.00
Mean value			**57.311**	**1.023**	**1.364**

On the basis of the WHO guideline, it can be deduced that the SO_2 concentration of 0.2 ppm measured at AQ6 during the wet season and 0.29 ppm measured at AQ4 during the dry season, are non-compliant with National and International limits. This sampling point AQ4 is about 400 meters North East and downwind of Saghara flowstation and may have been influenced by the exhaust emissions from internal combustion engines.

Table-3 Dry season air quality measurement result in Sagbara area (Ibrahim *et al.,* 2023)

Location ID	Coordinates		Air quality (ppm)						
	Northing	Easting	NO_2	SO_2	CO	H_2S	NH_3	CH_4	VOC
AQ1S	305892	179170	0.20	0.01	1.68	0.01	0.01	0.01	1.80
AQ2S	304966	179858	0.064	0.01	2.03	0.01	0.01	0.01	7.70
AQ3S	179064	304767	0.064	0.12	1.34	0.01	0.01	0.01	0.70
AQ4S	305641	179845	0.062	0.01	1.99	0.01	0.01	0.01	11.4
AQ5S	306884	178429	0.048	0.01	4.54	0.01	0.01	0.01	1.60
AQ6S	177860	304648	0.079	0.20	1.18	0.01	0.01	0.01	1.02
AQ7S	304582	180480	0.079	0.01	1.84	0.01	0.01	0.01	2.10
AQ8S	305985	180652	0.090	0.01	1.99	0.01	0.01	0.01	6.90
AQ9S	303028	186262	0.23	0.09	0.23	0.01	0.01	0.01	6.20
Mean value			0.101	0.052	1.868	0.01	0.01	0.01	4.38

I. Nitrogen Dioxide (NO_2)

Many chemical species of nitrogen oxides exist, but the air pollutant species of most interest from the point of view of human health is nitrogen dioxide (NO_2), Nitrous Oxide, N_2O being a major contributor to global atmospheric warming potential (Tables-1 and 3). The major source of anthropogenic emissions of nitrogen oxides in Sagbara area into the atmosphere is the combustion of fossil fuels in stationary sources, (gas flares, heating, power generation) and in motor vehicles (internal combustion engines). Results obtained showed that concentrations at sampling points AQ1 (0.20 ppm, Dry Season) and AQC1 (0.23 ppm, Wet Season), were above the regulatory daily hourly range of 0.04-0.06 ppm.

Given that the measured concentrations were averaged over a period less than 5 minutes, these values do not necessarily translate to non-compliance, because a 15-minute concentration of 2716 µg/m^3 (1.44 ppm) was recorded for a home with an unvented gas space heater, without any detectable negative health effect (Koontz *et al.,* 1988). However, such value should be of concern because even though averaging times were short, it is probable that such conditions could remain for much longer periods. Although no host communities are within 2 km of Saghara flowstation, if these concentrations persist for longer periods, they could pose occupational health hazards on inhabitants.

Table-4 Dry season noise quality measurement result in Sagbara area (Ibrahim *et al.,* 2023)

Location ID	Coordinates		Noise level	SPM	TSP
	Northing	Easting	dB(A)	ug/m3	
AQ1S	305892	179170	58.9	14.06	26.10
AQ2S	304966	179858	61.0	22.14	30.01
AQ3S	179064	304767	58.6	18.36	26.40
AQ4S	305641	179845	56.1	11.89	23.08
AQ5S	306884	178429	68.5	34.10	55.02
AQ6S	177860	304648	62.0	24.60	49.34
AQ7S	304582	180480	68.0	13.89	18.14
AQ8S	305985	180652	62.0	9.56	14.09
AQ9S	303028	186262	68.4	12.16	22.60
Mean value			62.611	17.862	29.42

J. Noise

The baseline outdoor noise levels within and around the proposed project areas has revealed the level of noise pollutants of the area (Tables-2 and 4) during the dry and wet seasons. The noise level measurements were made at the same points as air quality. In wet season it ranges from 48.5 to 62.8 dB(A) with a mean of 57.311 dB(A). A mean noise range of 56.1-68.4 dB(A) in the Dry Season. 62.611 dB (A was recorded as the mean. Noise levels were generally higher in the Dry Season, than in the Wet Season, as would be expected, due to higher ambient temperatures and outdoor activities during the Dry Season. All noise measurements were within the regulatory guideline of 90 dB(A). Akpofure and Ojile (1999) reported 63.9 and 49.2 dB(A) for wet and dry seasons.

Table-5 WHO Guidelines for maximum Exposure to the major pollutants and effects

S/N	Pollutants	Possible effects	WHO Guidelines
1	Sulphur dioxide (SO_2)	Worsening respiratory illness from short term exposure, increased respiratory symptoms, including chronic bronchitis, from long-term exposures	40-50 µg/m3 (annual mean); 100-150 µg/m3 (Daily average)
2	Suspended Particulate Matter (SPM)	Pulmonary effects are associated with the combined exposure to SPM and SO_2	Black: 40-60 µg/m3 (Annual mean). 100-150 µg/m3 (Daily average) Total SPM: 60-150 µg/m3 (Annual mean); 150-230 µg/m3 (Daily average)
3	Nitrogen dioxide (NO_2)	Effects on lung function in persons suffering from asthma from short-term exposures	150 µg/m3for 24 hr mean; 400 µg/m3: Not to be exceeded
4	Carbon Monoxide (CO)	Reduced oxygen - carrying capacity of blood	10 µg/m3 (for 8 hr); not to be exceeded. 10 µg/m3 (for 8 hr); not to be exceeded.

The results in Tables 1 and 3 show negligible levels of particulates at all sampled points (compared to National and WHO limits in Table 5. SPM ranged from 0.62-1.62 μg/m^3 in the Wet Season compared to 9.56-22.14 μg/m^3 in the Dry Season, Furthermore, TSP ranged from 0.98-2.00 μg/m^3 in the wet season compared to 14.09-30.01 μg/m^3 in the Dry season. These ranges were well within regulatory limits, indicating the receiving atmospheric environment had not been compromised by the flowstation operations. As would be expected, owing to temperature effect, all the measured parameters were higher in the dry season, than in the wet season. A study carried out (Ordinioha and Sawyer 2011) revealed impacts of similar project on inhabitants and titled: A survey of the community water supply of some rural riverine communities in the Niger delta region, Nigeria: Health implications and literature search for suitable interventions.

Table-6 Summary comparison of the mean field concentrations of air quality indicators

S/N	PARAMETER	Saghara Dry Season Field Mean (Jan, 2013)	Saghara Wet Season Field Mean (Aug, 2012)	FMEnv
1	SPM [ug/m^3]	1818.6	1.02 1.02	250.0 – 230.0 (150.0)
2	TSP [ug/m^3]	30.3	1.36	-
3	SO2 [ppm]	0.11	0.05	0.1
4	NO2 [ppm]	0.08	0.08	0.04-0.06
5	CO [ppm]	3.26	1.87	10.0
6	H2S [ppm]	0.01	0.01	0.006
7	CH4 ppm	1.14	0.01	-
8	VOC ppm	14.36	4.38	-
9	CO2 ppm	-	-	-
10	NH3 [ppm]	0.01	0.01	0.29
11	Noise [dBA]	62.6	57.3	90

K. Impacts of Pipeline Sabotage

The probable impact of corrosion leakage of installed underground gas pipe is given in the unlikely event of gas pipeline sabotage, wherein it will be assumed that the pipe is accessed after excavation to a depth of at least 1.2 m and sawed or drilled, the scenario is akin to that of a fluid bursting through an orifice (if drilled) under infinite pressure, to atmospheric conditions, or through a slit (if sawed). It is expedient to consider the orifice scenario. A gas explosion will result in a hyperbolic gas plume with increased temperature and pressure leading to catastrophic consequences for the perpetrators of the act and other life in the neighbourhood.

L. Impact on the ecosystem

Saghara facilities are in Brown Fields where ROWs already exist and most pipeline works will take place along the ROWs. Bush clearing and de-stumping for pipeline route from Saghara to Nigeria Gas Company Manifold in Escravos, re-routing existing Saghara Wells to Otumara Flowstation, connecting Bulk lines and Test lines from Saghara Flowstation to Otumara Flowstation, are all activities that will involve trenching and backfilling. The impacts of these activities are inundation of the water bodies with suspended solids and increased turbidity. These impacts will be wide spread as the debris are redistributed by tidal waves to adjoining water bodies, but of medium significance and short duration.

CONTRIBUTION TO KNOWLEDGE

BLEU measures the closeness of the machine translation to human reference translation taking translation length, word choice, and word order into consideration. After applying the developed Nupe BLEU System on the collected data, the results of the study have showed an accuracy of 92%.

CONCLUSION

Reduction in gas flaring of Sagbara area and other oil production platforms is crucial to the economic development of any oil production nation with appropriate monetization and job creation potential. Mothballing of the Saghara flowstation and construction of new 6″ x 5 km bulkline and 4″ x 5 km testline from Saghara to Otumara is a noble and highly novel project study that will add great value to massive reduction in amount of flared gas in the area and create anticipated wealth. Because of the close proximity of the Saghara and Otumara fields, sampling nomenclature and coordinates began with Saghara and ended with Otumara. At present, most of the associated gas produced at Saghara flowstation is worth 1750000scf daily. With the project completed, it will reduce gas flaring to almost few thousand scf/day ie standard cubic feet/day. The project will enhance air quality and drastically reduce Nigeria's contribution to global warming potential and an improvement on the Gross Domestic Product (GDP). All construction activities took place on the existing RoW, hence no additional land was required. Moreover, suspended particulate matter ranged from 0.62-1.62 μg/m^3 in the wet season compared to 9.56-22.14 μg/m^3 in the dry season, Furthermore, Total suspended particulate ranged from 0.98-2.00 μg/m^3 in the wet season compared to 14.09-30.01 μg/m^3 in the dry season and will have little or no harm on the environment of the area.

CONFLICT OF INTEREST

The research work was carried out by all authors listed and there is no conflict of interest associated with it.

ACKNOWLEDGEMENT

Special thanks to the staffs of Lower Niger River Basin Development Authority, especially the planning, Investigation and Design (PID) department for allowing the valuable time spent on this research outside work schedules. The co-authors for the insightful contribution to the study.

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