

# The Impediments to Nigeria Understanding Oil Production Volumes, Losses and Potential Solutions

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## Abstract

The issue of the quantity of oil produced or missing has traditionally been played down in Nigeria. This is evident as no one in or outside Nigeria is able to quote a totally reliable production volume or loss figure. The aim of this study is thus to search for the root causes as to why there are difficulties in ascertaining the quantity of crude oil produced or missing per day and for potential solutions. The research assesses the present situation and problems requiring solution concerning Nigerian oil and gas measurement control. This is achieved through an intensive review of each of the notified bodies responsible for Nigeria's oil and gas measurement control, using secondary resources. The bodies reviewed in this study are the Department of Petroleum Resources and the Weights and Measures Department. The study has identified knowledge impediments among the designated bodies. Also discovered were inadequate measurement equipment and absence of measurement guidelines, thus, no mechanisms were in place to address any mismeasurements or losses that are discovered. Provision of comprehensive training to the regulatory body to provide it with the necessary "teeth" to ensure effective delivery of its regulatory function has therefore been recommended as the key solution.

**Keywords:** Nigeria, Oil and Gas, Measurement, Regulation, Training

## 1. Introduction

Crude oil production in Nigeria is the mainstay of the economy. The oil and gas industry is the single largest industry in the production sector and the main source of Gross Domestic Product (GDP) in Nigeria (Wilson, 2014). Presently, oil and gas is produced in almost every part of southern Nigeria, mostly in the Niger Delta area (US Energy Information, 2016), ranging from onshore production to offshore developments. Figure 1 is an illustration of the Nigerian oil and gas hydrocarbon flow and the measurements value chains. Although there is a wide range of sizes and layouts, most production facilities have many of the same processing systems shown in this simplified overview.

Each onshore and shallow offshore well is connected by a Flow-line to a Flow Station while the offshore wells distant from land are connected to production platforms. The gases are separated from the liquid at the Flow Station or Production Platforms before the liquid is pumped into the oil terminal where the water is removed. The oil is stored in tanks before being pumped through fiscal meters to supply the refineries or into an oil tanker for export (NEITI, 2006).

To able to ascertain that the quantities of the oil and gas produced or exported are accurately measured and ascertain that royalties are pay on the correct quantities, the Ministry of Petroleum Resources verifies the quality and quantities of oil and gas through the Department of Petroleum Resources service. Recognising metrology as the science of measurement and its application, the Nigerian government also incorporated the Weights and Measures Department (Legal Metrology Department) to complement the effort of the Department of Petroleum Resources in terms of verification of the measuring system. However, despite the existence of these bodies, there are still shortcomings in the production volume accountability.

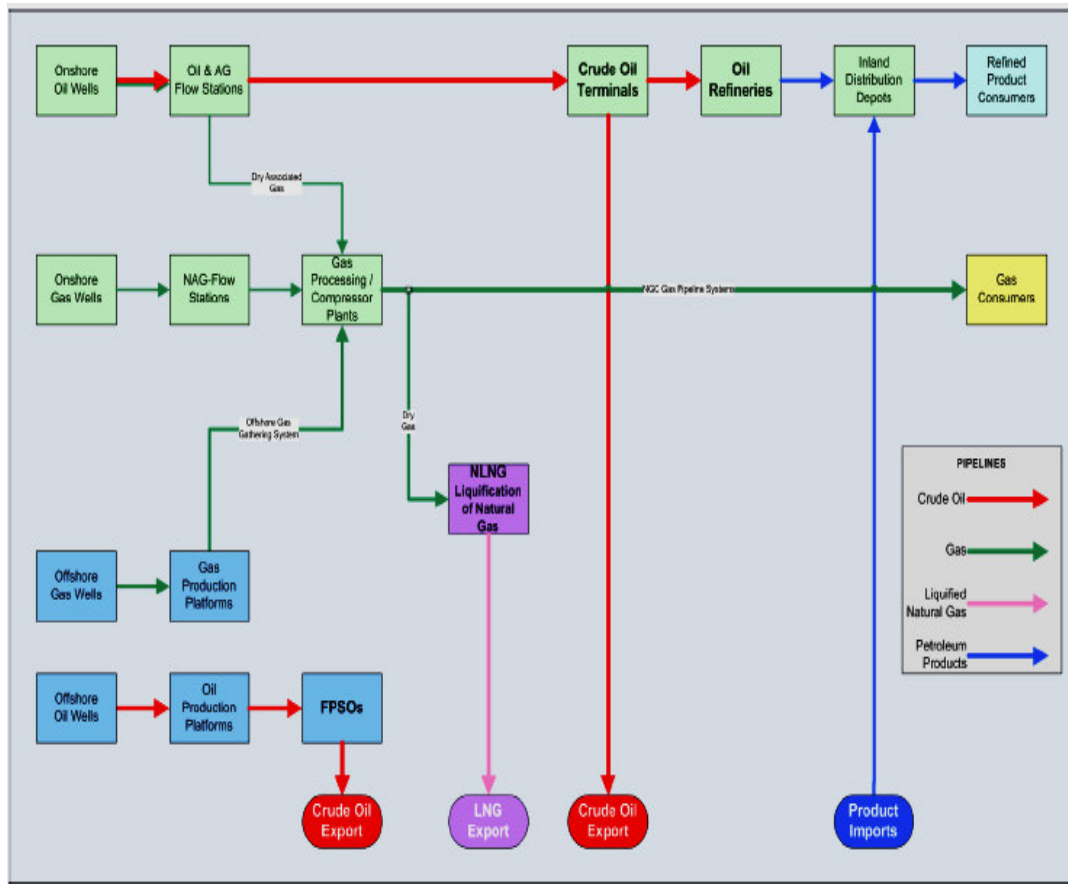


Figure 1: Diagrammatic mapping of hydrocarbon flows in Nigeria (NEITI, 2006)

## 2. Review of the Conflicting Figures for Nigerian Daily Crude Oil Production and Missing volume

The quantity of oil produced or lost has been an opaque issue in Nigeria. This is evident as, up to the present, no one can say with confidence how much crude oil Nigeria is producing per day (Izeze, 2014; Umejei, 2015). Distinct pictures of the trade surface depending on which figures one accepts. The point of biggest controversy regarding Nigerian crude oil is the actual figure for oil missing. It is certainly known that the quantity of crude oil missing through oil theft is considerable. Oil theft comprises any activity relating to the theft or sabotage of crude oil, the facilities or installations, pipeline vandalism, fuel scooping, illegal refining, etc. Illegal oil bunkering is the most commonly known form of oil theft. It is an illicit trade that involves the stealing of crude oil and its derivative products through a variety of mechanisms (NEITI, 2016). Oil bunkering which is a necessity for maritime shipping becomes illegal when it is carried out without requisite statutory licenses, valid documents or in violation of the rules and regulations of the Nigerian maritime authorities. Oil theft has been identified as occurring in three categories (NEITI, 2016):

- Small scale theft of condensate and petroleum products destined for local markets.
- Large scale theft of crude oil involving international maritime tankers and transported to the international market.
- Excess lifting of crude oil beyond the licensed quantity.

But how much oil goes missing? The short answer is no one knows. There have been conflicting estimates with regards to the missing figures.

In 2012, according to Wallis (2012) and NEITI (2016), immediate past Finance Minister, Ngozi Okonjo-Iweala put the figure for losses at 400,000 barrels per day. Assuming a typical price of \$120 per barrel, this results in a loss of \$1.44bn per month. Shell Petroleum Development Company of Nigeria (SPDC) estimated their own losses alone to be around 150,000 to 180,000 barrels per day (Donovan, 2012 & Izeze, 2014). The estimation of Global Financial Integrity, a Washington-based non-profit organisation, after conducting another credible report on behalf of the Central Bank of Nigeria, said Nigeria lost 232,000 barrels of oil to theft in a day in 2013 (Umejei, 2015). The London-based research group, Chatham House, by its own derivation estimated that, “an average of 100,000 barrels is stolen daily” (Katsouris and Sayne, 2013). The former Group Managing Director of the Nigerian National Petroleum Corporation (NNPC), Andrew Yakubu, said during a keynote address at the 2014 Nigerian oil and gas conference in Abuja, that in 2013 alone the country lost 300,000 barrels

of crude oil per day (Izeze 2014). Conversely, the Director of the Nigerian Navy Transformation Office, Austen Oyagha, estimated an average of 55,210 barrels per day or monthly average of 1,656,281 barrels (Izeze (2014)). The present Nigerian President, Muhammadu Buhari claimed recently that about 1 million barrels of crude oil were stolen a day under the last government, while the president’s special assistant on media and publicity, said, “The official position on the quantity of crude oil stolen per day is 250,000 barrels” with no proof or evidence (Umejei, 2015). In 2015, Sunny Ofehe, founder of the Netherlands-based Hope for Niger Delta Campaign queried the general manager of NNPC’s public affairs, Ohi Alegbe asking, “If you don’t know the daily crude oil production quantity, how is the quantity stolen being known?” The response was, “I don’t have the figures, nobody is sure of the missing volume” (Umejei, 2015). Up till now, since the actual production volume is not known, no one can say with confidence exactly how much goes missing. These conflicting figures are clearly shown in Figure 2.

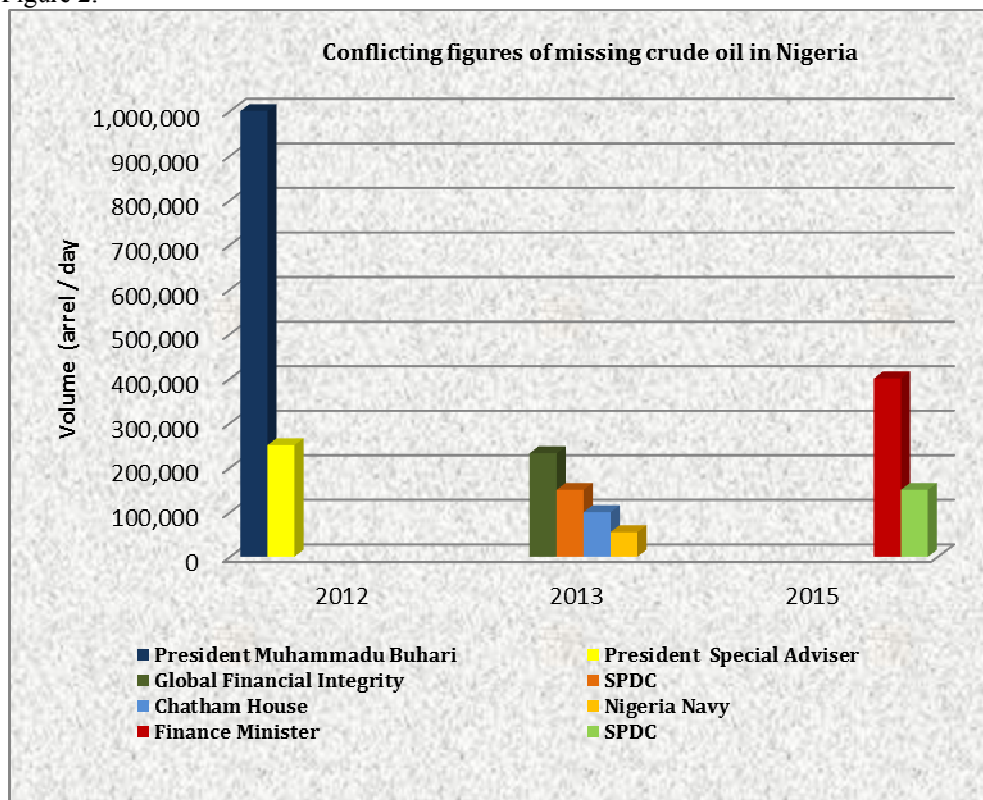


Figure 2: Conflicting figures of daily missing crude oil (Source: Wallis, 2012; Donovan, 2012; Katsouris and Sayne, 2013; Reporting oil and gas, 2014; Umejei, 2015)

The important question that needs to be answered is, why is it difficult for Nigeria to come up with the production figure? According Katsouris and Sayne (2013), without better knowledge of the problem, any government hoping to solve the problem could find themselves out of their depth. Also, the International Organisation of Legal Metrology, (OIML D1 2004) laid emphasis that, “Public authorities must pay special attention to measurement results especially when there are conflicting benefits in those results”. In this respect, these studies seek to explore the problem and the potential solutions.

### 3. Why the Conflicting Figures?

This study sets out to investigate the main reasons for the inability to get a reliable figure for the quantity of Nigerian daily crude oil production or losses, and potential solutions, through the following sources:

- Information gathered from NEITI audit of the period 1999 to 2016.
- Information gathered from publicly available sources relating to the Nigerian oil and gas sector.

#### 3.1. Nigeria Extractive Industry Transparency Initiative (NEITI)

The Extractive Industry Transparency Initiative (EITI) is a global initiative established in 2002 to promote and support improved governance in resource-rich countries, through the full publication and verification of company payments and government revenues from oil, gas, and mining (The International Bank for Reconstruction and Development and The World Bank, 2008). The Nigeria Extractive Industries Transparency Initiative (NEITI) is therefore a subset of the global Extractive Industries Transparency Initiative (EITI).

NEITI is concerned that Nigeria does not know how much crude oil it actually produces or loses daily

(NEITI, 2016), as they consider the measurement of crude oil production to be grossly inadequate. Information on crude oil production from the well head, through the flow station to the terminal is not reliable and this is where the majority of oil theft takes place. NEITI has previously embarked on an investigation to ascertain the shortcoming of this process because of its negative implications and huge revenue loss to the Federation. NEITI then issued questionnaires to the Oil and Gas industries and the Department of Petroleum Resources (DPR) to enabling data from both sources to be verified (NEITI, 2006).

DPR is the regulatory agency of the Ministry of Petroleum Resources. This Department is the core body responsible for the day-to-day monitoring of the petroleum industry, supervising all the petroleum industry operations carried out under licences and leases in the country. Its objective is ensuring compliance with the applicable laws and regulations in line with good oil field practices. The discharge of these responsibilities involves monitoring of operations at drilling sites, producing wells, production platforms and flow stations, as well as crude oil export terminals and all pipelines carrying crude oil, natural gas and petroleum products. The Law and regulations that empower DPR include:

- i. Petroleum ACT 1969 Act Cap. P10 LFN 2004
- ii. Petroleum Regulations 1967
- iii. Petroleum Drilling and Production Regulations 1969

The complete scope of NEITI's questionnaire encompassed the mapping of oil and gas flows, the assessment of the quality of procedure systems, the technical assessment of measuring hydrocarbon streams, the volumetric analysis and reconciliation of data (both physical and financial), recommendations for improvements and reporting templates, and the aggregate reporting of hydrocarbons produced and fiscalised. This questionnaire was structured to address the oil and gas flows shown in Figure 1.

From the questionnaire feedback, the main reason for the difficulties in ascertaining the quantity of crude oil produce or missing per day has been attributed to insufficient measurement control (NEITI 2006 & 2009). As revealed by NEITI (2006), the Department of Petroleum Resources (DPR) which is the regulatory body in charge of Nigeria Oil and Gas measurement control has no system for measuring production, other than through monitoring terminal receipts. In consequence, DPR has no data from which possible product losses between the production point and the terminal can be estimated, measured or inferred. The body has neither custody transfer guidelines nor any corresponding guide for upstream measurement at wellheads and flow stations. The only set of measurement procedures they have according to NEITI (2006) is the Manual of Procedure Guides for the Petroleum Inspectorate, of which the so called guidelines contain only two measurement guidelines: one on meter proving and the other on ship to shore differences. The manual does not specify the accuracy of the metering at any of the stages e.g. wellhead, flow station or custody transfers. All that is specified is the maximum ship to shore difference.

As revealed by NEITI (2006), the personnel involved in measurement lacked the general knowledge of how to calculate the royalty volume. The DPR response to the definition of volume to be used for the royalty calculation was found to be inconsistent in the questionnaire responses. Since there is no guidance from DPR, the industry has no consistent practice regarding the point at which production is measured for royalty purposes, hence there have been definition issues surrounding the volumes to be used for calculation of royalties. The law is unclear on this point. DPR has not promulgated a standard interpretation. Also the method employed for the hydrocarbon mass balance was found to be insufficient to determine unaccounted oil or to estimate oil theft. There are no procedures to cope with mismeasurements. Moreover, there is no consistency in measurements of quantities and presentation of volume (NEITI 2006).

NEITI (2006 & 2009) also revealed that the use of standardised definitions is not in any way adhered to by the industries, thus leading to conflicting interpretations. Most operators of the oil companies and the DPR personnel declared not to know the uncertainty of measurements for wellheads and flow stations. The only one declared to be known is the ship to shore measurement difference. The metering infrastructure and the records stipulated do not allow the hydrocarbon balance (oil, gas and water) to address the question of unaccounted oil. There is a range of issues on the definitions and practices to be applied in arriving at the report mass balance.

As the Nigerian upstream oil and gas industry developed, the amounts of gas being flared were on increased. This lead to increasing political pressure on Nigeria to reduce flared gas in order to minimising waste and pollution. The solution to resolve the gas flaring problem lead to the development of local gas markets and Liquefied Natural Gas projects. Presently in Nigeria, there is an increasing recognition that accurate fiscal metering is an important factor in the development of an integrated, robust gas industry. A number of shortcomings highlighted by NEITI (2006) below do not facilitate this development:

- According to NEITI (2006), both the regulator and the operators appeared to lack the understanding of some of the key fundamental principles relating to gas flow measurement such as calorific value, and the impact of temperature and pressure variations.
- The absence of gas measurement and gas quality regulations results in a lack of coherence in terms of gas flow metering calibration and maintenance, the approval of meters, or adherence to a particular

standard.

- No locally enforceable technical standards exist in Nigeria. For this reason, there is no formal mechanism for checking the accuracy of gas meters, nor are there any standards for the quality and standard of meters installed.

The weakness of DPR was perhaps unsurprising because, proper management of the measurement activities in the oil and gas industry by the designated bodies is a challenge in most parts of the world particularly the upstream sector of the industry. Even a developed country like the USA has a similar case based on a United State Government Accountability Office audit report. The United States Government Accountability Office (2010) said “The Department of the Interior’s oil and gas production verification efforts do not provide reasonable assurance of accurate measurement of production volumes”. Found to be similar to the Nigerian case, the United State Government Accountability Office (2010) further recommended to the Department of the Interior to augment the consistency and timely revising of measurement regulations and policies, elucidate jurisdictional authority over gas plants and pipelines, and provide suitable training for main measurement staff. Considering the global challenges of lack of skilled personnel and manpower in the oil and gas industry, Global Energy (2013) also suggested training should be made highly efficient in various parts of the world to help staff understand how to manage the operations most especially the upstream sector.

### 3.2. Publicly Available Sources

Although DPR was created in 1970 to enhance Nigeria’s regulatory functions and enforcement in ensuring compliance within the oil and gas industry, according to Nwokeji (2007), DPR is extremely backward in carrying out its regulatory function. On royalties alone, Nwokeji (2007) revealed DPR uses different criteria from the operating companies to calculate the royalty payments. The impediment of DPR in this area was also highlighted by NEITI (2006). Nwokeji’s (2007) study further revealed that DPR relied on monthly figures supplied by Nigerian National Petroleum Corporation to both DPR and oil companies, while in most cases the oil companies unilaterally determined the royalty payment they paid, often based on export rather than production figures (NEITI, 2006 cited in Nwokeji 2007). Aderalegbe (2006) also questioned the competency of DPR, alleging that the regulatory powers of DPR are suspect. Nwokeji (2007) attributed the DPR drawbacks to lack of skilled personnel.

As the measurement problems associated with Nigeria’s oil and gas industry escalated, the Federal government came under intense pressure to involve the Weights and Measures Department in measurement control within the oil and gas industry. The Weights and Measures Department (the National Legal body) is the regulatory agency in charge of weights and measures in all the sectors of the Nigerian economy. It is the only government agency with the mandate to issue type approval and verification certificates as well as carry out verification exercises on weighing and measuring devices to ensure accuracy and conformity of such devices when used for trade or official purpose in the Federal Republic of Nigeria. The Department is empowered by the following Law and regulations (Federal Ministry of Commerce and Industry, 2009 & Alli, 2012):

- i. Weights and Measures Act CAP W3 LFN 2004 (Formally Weights and Measures Act CAP 467 LFN 1999)
- ii. Pre-shipment of Export Decree No.10 of 1996 Act CAP P25 LFN 2004
- iii. Weights and Measures Standardization of Indigenous Measures Regulation, 1992
- iv. Weights and Measures (Legal Metrology and Related Services) Regulation 2012.

According to the former Minister of the Federal Ministry of Industry, Trade and Investment, Olusegun Aganga, the department was empowered to verify, certify, and check the compliance of all measuring and weighing equipment in oil and gas industry, which includes inspection of their measuring equipment. This includes enforcement of the Pre-shipment Inspection of Export Act, which ensures that the quantity of crude oil produced, missing or exported out of the country is accurately known (Alli, 2012). This statement by Olusegun Aganga regarding the need to ensure accurate metering and measurement across all the sectors prompted the then President Goodluck Jonathan to re-invigorate the Weights and Measures Department to work with the oil and gas industries stakeholders to tackle the problem. The government sees this as a clear demonstration of federal government’s seriousness in entrenching transparency, accuracy and fairness in the Nation’s oil and gas sector (Alli, 2012). Olusegun Aganga said the implementation of an accurate metering and measurement policy by the Weights and Measures Department is expected to save the country about \$4.8 billion per month (Akinsuyi, 2013, April 23).

However, the technical and metrological knowledge of the National Legal Metrology body was also found to be questionable, as Anudu and Edeh (2015) declared Nigeria to be losing \$25 billion annually in oil sector due to uncontrolled weights and measures. Anudu and Edeh (2015) stated that \$ 7.5 billion is lost yearly in the oil and gas sector due to measurements not controlled by the Weights and Measures Department, while \$17.4 billion is stolen due to the absence of credible measurement in the industry even after the implementation of legal metrology.

With the power conferred by the Weights and Measures Act - CAP. W3 L.F.N. 2004 section 48(2), the Minister of Industry, Trade and Investment created the Weights and Measures (Legal Metrology and Related Services) Regulation 2012 for the purpose of implementation of the task bestowed on the department regarding oil and gas measurement control. However the regulation contains no enforceable technical standards or any laid down measurement system requirement. The only detail specified in the regulation is the level of fees to be paid by the oil and gas operators.

The weakness of the Weights and Measures Department is unsurprising as it is common that, according to CIPM (1998), in most national governments, as legal metrology expands it is likely to involve fields of measurement that are new to national legal metrology organizations, and this is the case for the Weights and Measures Department. For this reason, one can attribute their weakness to the fact that the field is new to the organization and there is neither substantial expertise in existence nor training in place to empower the officers.

#### 4. Potential Solutions

To maximise the country's economic income recovery from its hydrocarbon resources, it is necessary to ensure full value is received by government for its share of crude oil and petroleum product sales through correct royalty calculation. This is limited by the ability to determine the production and missing volume effectively. To address this, the following solutions are proposed.

##### 4.1. Department of Petroleum Resources

- i. According to NEITI (2006), there is a range of issues on definitions and practices to be applied in arriving at the report mass balance. Also, the method employed for the hydrocarbon balance is not sufficient to highlight unaccounted oil or to estimate oil theft. Moreover, there is no consistency in measurements of quantities and presentation of volume. The use of standardised definitions is also not adhered to by the industries, thus leading to conflicting interpretations. All these problems can be attributed to the lack of measurement guidelines.

Although there has been the addition of Revised Crude Oil Terminal Operations Procedure Guide version 2016, many of the gaps highlighted by NEITI are yet to be bridged.

For the gap to be bridged, the guidelines should:

- contain important information on the design, construction and operation of fiscal/custody transfer measurement systems for which the Ministry of Petroleum Resources is responsible under laws and regulations
- be interpreted as the minimum requirements to enable consideration of alternative techniques, i.e. those capable of a similar or better level of uncertainty, accuracy and reliability.
- ensure all produced and injected fluids are to be measured and, where appropriate, allocated in accordance with a flow system and flow calculation and allocation procedures
- ensure that, where liquid and gaseous hydrocarbons products are transferred between facilities via a pipeline that serves as a common transportation route for a number of Oil and Gas Operators, the "method of measurement" should include the measurement of hydrocarbons at the terminal serving the relevant pipeline as well as the allocation procedures used to determine each contributing field's share of the petroleum used at or exported from the terminal
- specify the purpose of each measurement required, as this is the first task in determining the suitability of proposed measurement systems
- define the categories of measurement and the associated accuracy requirements.
- specify reference standard documents which the facilities and operation are expected to meet
- specify the documentation requirements such as flow system and flow calculation procedures
- specify the requirement for the application of the flow system, flow calculation procedure and allocation procedure approval
- specify documentation required for daily production records
- specify the requirement to attain overall plant balance
- specify the requirements for the fiscal quality measurement of liquid hydrocarbons
- specify the requirements for field or platform allocation measurement of liquid hydrocarbons
- specify the requirements for well allocation of liquid hydrocarbon management
- specify the level of accuracy required for measuring liquid hydrocarbon flow at different points in the system.
- specify the requirements for secondary measurement. This is particularly important as confusion can arise if the requirements specified for all related equipment (beyond the basic meter), and how these secondary measurements will be used to correct the basic meter reading, are not spelled out and clearly understood so that volumes are given out on the same basis. These requirements are vital since interested government parties and the parties to the contract may record

- data on a difference base calculation in their plant quantity reports (Lanasa and Upp, 2014). To ensure effective implementation of the guidelines, the following will be required.
- The application of the measurement code for Fiscal/Custody Transfer measurements should be made mandatory for all Oil and Gas Operators engaged in the production, refining, transportation and distribution of related hydrocarbon products which pass between their facility battery limits in Nigeria, including the imports and exports of hydrocarbons.
  - International Standards and recognised Measurement Procedures should be incorporated into the code and enforced by the regulator (Department of Petroleum Resources)
  - All produced and injected fluids are to be measured and, where appropriate, allocated in accordance with a flow system, flow calculations and allocation procedures as approved by the Ministry of Petroleum Resources
  - Royalties should be levied directly on production
  - In order to satisfy the Minister of Petroleum Resources that no unauthorised alterations to the approved flow system and flow calculations and allocation procedures have been made, throughout the producing life of the field, inspectors from the Department of Petroleum Resources should, at their discretion, physically inspect metering systems at any stage from construction through commissioning into operation.
  - The operator and the DPR Board should, at the early discussion stage, agree on the categorisation of a measurement system and the associated accuracy requirement
  - The accurate recording and reporting of petroleum volume is critical to the calculation of the royalty share. For this reason, the officer of the Department of Petroleum Resources should reserve the right to fully participate in any inspection, witnessing and approvals of custody transfer Meters.
  - An update/review should be carried out on the measurement code every two years
  - The use of third part audits such as NEITI Audits should be incorporated
  - Most importantly, training is required for the DPR staff on the contents of the guidelines to ensure effective enforcement capable of enhancing oil and gas operator compliance.
- ii. According to NEITI (2006), both the regulator and the operators appeared to lack the understanding of some of the key fundamental principles relating to flow measurement. The operators and DPR need to be trained on the principles and practice of flow measurement being the regulator and the enforcement authority. This is particularly important, because knowledge of principle and practice of flow measurement is the basis of custody transfer measurement. No useful result can be achieved without the knowledge of flow measurement in the oil and gas industry.
- iii. Lack of knowledge of measurement uncertainty is another barrier. Training the DPR personnel on the knowledge of measurement uncertainty will help to bridge this barrier.
- iv. As revealed by NEITI (2006), the metering infrastructure and the records do not allow the hydrocarbon balance (oil, gas and water) to address the question of unaccounted oil. For these reasons, the metering arrangements are important. DPR should spearhead the arrangement for monitoring the entire hydrocarbon balance of the sector, reinforcing the arrangement from wellhead to terminal, export or refinery. NEITI (2006), NEITI (2009) and NEITI (2016) also suggested installation of robust metering infrastructure at both the flow stations and the terminals in line with international best practices. Correspondingly, according to Lanasa and UPP (2014), a metering station must be properly installed and maintained in order to provide accurate measurement. As equipment calibration may change over a period of time, both parties have to take active part in the periodic testing of the metering system (Lanasa and UPP, 2014). To enhance effectiveness according to NEITI (2006 and 2009), training is required for all operational staff and the DPR inspectors so that they can understand the operational issues surrounding metering, maintenance and the operation of the flow system. This is particularly important because, according to Canada-Newfoundland & Labrador Offshore Petroleum Board and Canada-Nova Scotia Offshore Petroleum Board (2011), whatever the class of measurement system, the target uncertainty will only be met if adequate supporting measures are taken. The Iraq Ministry of Oil (2007) also has the same view.

#### 4.2. Weights and Measures Bureau (Legal Metrology Bureau)

As the department lacks enforceable technical standards, there is no formal mechanism for checking the accuracy of gas meters, nor does it have any standards for the quality and standard of meters installed. The absence of locally enforceable technical standards by the department results in a lack of coherence in terms of gas flow metering calibration and maintenance, the approval and verification of types of meters, or adherence to a particular standard. Thus, the Minister should enact regulation with recommended technical standards. The standard should be written to be theoretically accurate and completely instructive. Training must also be provided for the personnel responsible for the enforcement to enhance compliance.

Custody transfer measurement is one of the key applications of flow measurement. Taking the Weights and

Measures (Legal Metrology and Related Services) Regulation 2012 enacted for the purpose of the oil and gas sector into consideration, one can easily draw out that the Bureau lacked the knowledge of flow metrology which should be a prerequisite for the effective metrological control of the sector. Thus the Weights and Measures Department should be trained on the principles and practices of flow measurement, flow metrology and the general legal metrology knowledge required for effective contribution of measurement control to the sector.

## 5. Conclusion

The summary of the vital issues responsible for the conflicting figures of Nigerian oil and gas measurement can be highlighted as follows:

- Lack of understanding of some of the key fundamental principles relating to oil and gas flow measurement
- Lack of technical and metrological knowledge of flow measurements systems
- Lack of measurement guidelines and standards hence no mechanism in place to address any mis-measurements or losses that are discovered.
- Inadequate measurement equipment (meters, sampling equipment, temperature and pressure equipment).
- Absence of regulatory enforcement over a variety of activities relating to assessment and reporting of quantities of crude oil and petroleum products
- No culture of striving to follow international best practice
- Lack of Laws and Regulation relating to gas production.

Provision of measurement guidelines, technical standards, installation of robust metering infrastructure and comprehensive training to the designated bodies to provide it with the necessary “teeth” to ensure effective delivery of the statutory function of the designated bodies are therefore all recommended.

Considering the global challenges of lack of skilled personnel and manpower in the oil and gas industry, training should be made highly efficient in various parts of the world to help staff understand how to manage the operations most especially the upstream sector.

## References

- Adaralegba. (2006,). Nigeria: DPR's regulatory powers are Suspect. *Thisday*, May 9, 2006, p.1. Retrieved from <http://allafrica.com/stories/200605090244.html>
- Akinsuyi, Y. (2013). Aganga: FG to save N755bn from implementation of legal metrology. *ThisDayLive*, 2013, April 23, 2013, p. 1-2. Retrieved from <http://www.thisdaylive.com/articles/dpr-has-no-system-for-measuring-crude-oil-production-says-neiti/182973/>
- Alike, E. (2014). DPR has no system for measuring crude oil production, says NEITI. *ThisDay*.
- Alli, F. (2012, October 18). Weights, measures to be introduced across all sectors of the economy – FG. *Vanguard*, July 8, 2014, 1-2. <http://www.vanguardngr.com/2012/10/weights-measures-to-be-introduced-across-all-sectors-of-the-economy-fg/>
- Anudu, O. & Edeh, H. (2015,). Nigeria loses \$25bn in oil and gas sector to uncontrolled weights, measures annually. *Business Day*, October 02, 2015.
- Asia-Pacific Legal Metrology Forum (2009). *Legal Metrology: Accurate measurement, good business, fair trade and safety*. Retrieved from [http://www.aplmf.org/uploads/5/7/4/7/57472539/02\\_aplmf\\_guide\\_to\\_legal\\_metrology.pdf](http://www.aplmf.org/uploads/5/7/4/7/57472539/02_aplmf_guide_to_legal_metrology.pdf). [Accessed 17 February 2017].
- Asia-Pacific Legal Metrology Forum (2010). *Guide 1: National Infrastructure for Legal Metrology*. Retrieved from [http://www.aplmf.org/uploads/5/7/4/7/57472539/01\\_aplmf\\_guide\\_to\\_national\\_infrastructure\\_for\\_legal\\_metrology.pdf](http://www.aplmf.org/uploads/5/7/4/7/57472539/01_aplmf_guide_to_national_infrastructure_for_legal_metrology.pdf). [Accessed 11 January 2017].
- Avery, A. (2010). *Daniel offer custody transfer measurement and control in standardized package*. [pdf]. Retrieved from <http://www2.emersonprocess.com/siteadmincenter/PM%20Daniel%20Documents/ARCview%20for%20Emerson> [Accessed 19 March 2017].
- Canada-Newfoundland & Labrador Offshore Petroleum Board and Canada-Nova Scotia Offshore Petroleum Board (2011). *Measurement guidelines*. (ISBN #978-1-927098-05-9).
- Denovan, J. (2012). Nigeria is losing \$1 billion a month to oil theft while fraudulent natural gas deals with international companies cost the country \$29 billion over the past decade. *Royal Dutch Shell plc .com.* Retrieved from <http://royaldutchshellplc.com/tag/niger-delta/page/7/>. [Accessed 19 November 2016].
- Fluke Corporation. (2005). *Principles of metrology*. Retrieved from 4. [http://support.fluke.com/calibration-sales/download/asset/2548139\\_a\\_6001\\_eng\\_w.pdf](http://support.fluke.com/calibration-sales/download/asset/2548139_a_6001_eng_w.pdf). [Accessed 11 September 2016].
- Global Energy. (2013). *Challenges and Solutions in an Upstream and Downstream Oil and Gas Operation*. Think Oil. Retrieved from <http://globalenergy.pr.co/65678-challenges-and-solutions-in-an-upstream-and->



- downstream-oil-and-gas-operation. [Accessed 22 January 2017].
- Hill, K. B. & Ritter. (2014). *Oil + gas law for beginners: differentiating between production wells + injection wells*. Retrieved from <http://www.lexology.com/library/detail.aspx?g=744a210a-660b-4bcb-ae85-0ffaae97ac7f>. [Accessed 11 September 2016].
- International Bank for Reconstruction and Development and the World Bank. (2008). *Implementing the Extractive Industries Transparency Initiative - Applying Early Lessons from the Field*. (1 2 3 4 5 11 10 09 08). Washington: The World Bank
- International Committee for Weights and Measures. (1998). *National and international needs relating to metrology: International collaborations and the role of the BIPM*. Paris: Intergovernmental Organization of the Convention of the Metre
- International Energy Agency (2016). *NNPC Monthly Petroleum Information*. Retrieved from <https://www.iea.org/oilmarketreport/>. [Accessed 13 November 2016].
- International Organisation of Legal Metrology. (2004). OIML D1 (E): *Elements for a law on metrology*. France: OIML.
- Izeze, I. (2014). Crude oil theft: does Nigeria know the actual volume it loses per day? *Sahara Reporters*, November 9, 2014. Retrieved from <http://saharareporters.com/2014/11/06/crude-oil-theft-does-nigeria-know-actual-volume-it-loses-day-ifeanyi-izeze> . [Accessed 30 November 2016].
- Katsouris, C. & Sayne, A. (2013). *Nigeria's criminal crude: international options to combat the export of stolen oil*, pp. 1 -39.
- Ladan, M.T. (2008). The limits of legal and enforcement/regulatory frameworks in consumer protection against counterfeit and pirated products: - products: -The Nigerian experience. *Review of Nigerian Law and Practice Review of Nigerian Law and Practice*, 2 (1), 1-34.
- Lanasa, P.J. & UPP, E.L. (2014). *Fluid flow measurement - A practical guide to accurate flow measurement* (3rd ed.). UK: Elsevier's Science & Technology Rights, pp. 31 -44.
- Nigeria Extractive Industries Transparency Initiatives. (2006a). *Report of the physical audit 1999 – 2004, Metering*.
- Nigeria Extractive Industries Transparency Initiatives. (2006b). *Report of the physical audit 1999 - 2004*.
- Nigeria Extractive Industry Transparent. (2016). *Combating oil theft and illegal refining: A multi-stakeholders*. Lagos. <http://neiti.org.ng/index.php?q=documents/combating-oil-theft-and-illegal-refining-multi-stakeholders-approach-ag-executive-secretar> [Accessed 11 September 2016].
- Nigeria National Petroleum Corporation (2015). *NNPC Monthly Petroleum Information*. Retrieved from <http://www.nnpcgroup.com/PublicRelations/OilandGasStatistics/MPIFigures/MonthlyPetroleum/tabid/130/FolderID/193/Default.aspx>. [Accessed 27 September 2016].
- Nwokeji G.U. (2007). *The Nigeria National Petroleum Corporation and the development of the Nigeria oil and gas industry. History, strategies and current situation*. Berkeley: The James A. Baker III Institute for public policy of Rice University.
- Standards Organisation of Nigeria (2015). *National metrology institute to the rescue*. Retrieved from <http://son.gov.ng/national-metrology-institute-to-the-rescue/> [Accessed 11 December 2016].
- Umejei, E. (2015, September 10). How many barrels of oil stolen a day in Nigeria? Buhari in right ballpark with 250,000. Retrieved from <https://africacheck.org/reports/how-many-barrels-of-oil-stolen-a-day-in-nigeria-buhari-may-be-in-right-ballpark-with-250000-claim/>. [Accessed 11 September 2016].
- Wallis, W. (2012). Nigeria losing \$1bn a month to oil theft. *Financial Times*, June 26, 2012. Retrieved from <https://www.ft.com/content/61fb070e-bf90-11e1-a476-00144feabdc0?mhq5j=e2>. [Accessed 19 November 2016].
- Wilson, G. (2014). The Nigeria state and oil theft in the Delta region of Nigeria. *Journal of Sustainable Development in Africa*. 16 (1), 69-81.