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Regulatory mechanisms for underground waste disposal in Nigeria: review and implications for environmental management.

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ABSTRACT: The Federal Ministry of Environment and the Department of Petroleum Resources control underground disposal of wastes in Nigeria with three principal regulations: Guidelines and Standards for Environmental Pollution Control in Nigeria, National Guidelines on Waste Disposal through Underground Injection and the Environmental Guidelines and Standards for the Petroleum Industry of Nigeria. The review shows that in general, the design and materials specifications for injection wells, monitoring wells and landfills lack precision and as a result allow too much latitude in interpretation. Furthermore, the laws place inordinate reliance on waste facility owners to ascertain crucial parameters for example, well casing integrity and in the case of landfills, liner integrity which regulators do not have the capacity or resources to verify. This problem recurs in all aspects of the regulations including environmental impact assessments and environmental management plan monitoring. The regulations also allow no role for resident communities in environmental monitoring. Runoff injection into near surface aquifers is unregulated as it is not covered by existing rules. Therefore, regulatory reforms are needed if aquifers are to be adequately protected should underground waste disposal gain universal acceptance and applicability in Nigeria's emerging waste management industry. It is recommended that the reform agenda be driven by the Federal Ministry of Water Resources which currently plays no active role in underground waste disposal control although empowered by the Water Resources Act to manage and protect the nation's water resources. @JASEM

Key words: underground waste disposal; waste injection; urban runoff management; waste management regulations; ground water protection

The underground disposal of wastes in geological formations is universally accepted practice. Human beings through time have always disposed of the dead, domestic waste and, excrement in this manner. The soil and geological formations that are the waste receptors have naturally been assumed to possess the capacity to treat and convert these wastes into to harmless states and sometimes more useful forms. With the increase in populations, attention must be given to the carrying capacity of these soils and near surface geological formations so they can continue to perform these essential functions.

Industrialization with attendant production processes also continuously and inexorably generate large amounts of wastes that are disposed of on the land surface as well as directly or indirectly underground. Many of these wastes or their geochemical derivatives are harmful to the human physiological condition as well as to the general ecosystem. This is one of the reasons "*Nigeria is committed to a national policy that will ensure sustainable development based on proper management of the environment...which demands positive and realistic planning that balances human needs against the carrying capacity of the environment"* (Presidency 1999, p.1).

Geological reservoirs are being used universally for the disposal of industrial wastes, urban wastewater and storm runoff as well as for aquifer storage and recovery. In the United States for example, waste injection practice dates back to the early 1930's and USEPA (2010) reports that more than nine billion gallons of waste are injected into geological formations in the continental United States annually. This is exclusive of a further and additional daily injection of more than two billion gallons of brine from oil and gas production operations. Existing legislation in Nigeria recognizes and recommends the use of approved land application and underground waste disposal. While underground waste injection is more prevalent now in the petroleum industry, this will probably not continue to remain so for long. This is because waste management in Nigeria is a major problem for both government and industry and there are indications that waste injection is already being considered a viable option for disposing wastes. In Edo state for example, injection of urban storm water runoff is being used, albeit in its crudest form, as a realistic and practical alternative for acute urban flood management problems. Lagos State which generates up to one and one half billion gallons of waste water daily is presently seeking partnerships with the private sector for the management of waste water (Alao 2011). Fortunately, sedimentary reservoirs do exist in Nigeria that can accommodate large amounts of these wastes (Akpoborie et al. 2005).

However, there is some concern about the regulatory environment as well as standards for

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managing underground waste disposal in Nigeria in view of potential risks to the pollution of aquifers. For example, Akpoborie (1998) noted that existing federal rules lacked sufficient detail, allowed too much latitude in facility design to project proponent and were therefore inadequate to be used for the review of an environmentally sensitive sanitary landfill permit application and instead elected to use the United States Environmental Protection Agency (USEPA 1989) standards and guidelines in recommending amendments to the submitted designs. The primary objective of this paper is thus to identify, describe and critically review the existing institutional arrangements, regulations and regulatory mechanisms that currently guide underground waste disposal practice in Nigeria. Examples from practical rule application in regulatory agency project permitting review processes, preparation of environmental impact assessments, environmental management project execution and regulatory reform advocacy are used to illustrate lapses in institutional arrangements and the existing rules that could have negative impacts on ground water protection if remedies are not provided.

REGULATORY ENVIRONMENT

***Institutions*:** At federal level two agencies, namely, the Federal Ministry of Environment (FMEnv) which evolved from and subsumed the former Federal Environmental Protection Agency (FEPA) and the Department of Petroleum Resources (DPR), an agency of the Presidency play the primary role of regulating underground waste disposal in Nigeria. The Federal Ministry of Water Resources (FMWR) also bears the responsibility of managing and protecting the quality and integrity of water resources. However a full eighteen years after the enactment of the Water Resources Act (Decree 101, 1993), regulations for its implementation have not been developed as a result of which FMWR plays no role in ground water quality protection from underground waste disposal. Beyond this, several individual states have initiated procedures for establishing appropriate guidelines for environmental management that are suited to their specific physiographic settings. States are encouraged to do this by the FMEnv provided the states maintain existing federal guidelines and standards as the basic minimum. It may thus be expected that with growing awareness of the potential for injection technology for managing large amounts of wastes, individual states might develop more stringent standards to guide implementation. Many states now have a dedicated ministry of environment although some like Lagos and Delta have in addition, specific and semi-autonomous waste management agencies. Edo and Lagos states appear to be in the forefront of recognizing the potential of underground injection of wastes: while Edo is actually injecting storm water underground (Omozeje 2011; Oteze 2011), Onisarotu (2011) lists the technology as an option for waste management in Lagos state.

Furthermore, civil society also plays an important and active role as watchdogs of the environment. Environmental Rights Action/ Friends of the Earth Nigeria a nongovernmental organization (NGO) for example actively works in collaboration with the Nigerian Institute of Advanced Legal Studies to review existing environmental laws as well as promote and advocate for appropriate legislative reform (Ojo 2010). Another NGO, Social and Economic Rights Action Center (SERAC) has been in litigation at the Federal High Court for several years on behalf of the Ozoro, Delta State community with respect to an ill conceived (Akpoborie and Dinwanbor 2007) waste injection well facility that is located in the community.

Regulations: The land application of any waste is prohibited in Nigeria except as authorized by permit and according to guidelines and regulations. The three explicit regulations guiding the disposal of wastes underground in Nigeria are the Guidelines and Standards for Environmental Pollution Control in Nigeria (FEPA Guidelines), the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) and the National Guidelines on Waste Disposal through Underground Injection (DUI).

1. *The Guidelines and Standards For Environmental Pollution Control In Nigeria, 1991 (FEPA Guidelines):*

The FEPA Guidelines (FEPA, 1991a) prohibit any underground disposal of wastes except as authorized by permit. The General Guidelines for Pollution Abatement in Industries states in Part 1, Section 0.2, subsections 16 and 17 that: *" All discharges of effluent with constituents beyond permissible limits into public drains, streams, rivers, lakes, sea or underground injection are unacceptable and are prohibited unless a permit is obtained in writing from FEPA…" and " Solid wastes generated by industry including, sludge and all bye-products resulting from the operation of pollution abatement equipment shall be disposed of in an environmentally safe manner as prescribed in these guidelines. Under no circumstance should any of these substances be co-disposed in any municipal landfill" (page 16).*

The permitting process includes an Environmental Evaluation Report (EER) for existing facilities that are already in use and an Environmental Impact Assessment (EIA) for new sites and facilities. Waste categories are as classified in Regulations S.I.8 (FEPA, 1991b), S.I.9 (FEPA, 1991c) and S.I.15 (FEPA, 1991d). In addition to the permit, Chapter 3 of Part II of the Guidelines provides detailed specifications for ground water protection from listed waste disposal facilities and which list includes: surface impoundments, waste piles, land treatment units and landfills. Guidance for the application of each of these methods is further provided in Chapters 4-8 of the same Part. No guidance is provided in the document for underground waste injection.

2. *National Guidelines On Waste Disposal Through Underground Injection (DUI)***:**

FMEnv issued the 14-page DUI in 1999. The DUI guidelines govern waste injection practice for all industries including the petroleum industry. The guidelines cover the underground injection of hazardous and non-hazardous wastes. Relevant waste categories are classified as before in FEPA Regulations S.I.15, S.I.8 and S.I.9. Wells are also further classified into two categories: Class A and Class B. Class A wells are those wells used for disposal of Non hazardous oil field waste and non hazardous industrial waste. Class A wells are classified further into Class A1and Class A2 wells on the basis of volumes of wastes being injected. Class A1 wells are permitted to inject less than 20,000 barrels within a specified period of less than 30 days. Class A2 wells are dedicated wells that inject larger volumes over an unspecified period. Class B is the category of wells for disposing of Naturally Occurring Radioactive Material usually encountered in the Oil and Gas industry and other hazardous industrial wastes. Section IV provides guidance for location, construction, operation and testing while Sections V, VI and VII deal with permitting requirements/ applications, monitoring requirements and area permitting respectively.

3. Environmental Guidelines And Standards For The Petroleum Industry Of Nigeria (EGASPIN):

Established in 1981, and revised in 1991 and 2003 by DPR, the EGASPIN is a distilled version published in a single volume of the complex set of regulations controlling wastes arising from the petroleum and petrochemical industries and which regulations are dispersed in several legislative Acts and Decrees. The document contains detailed guidance for underground waste disposal of all categories of wastes generated in the oil and gas industry.

The EGASPIN applies exclusively to the petroleum industry and prohibit the land application of all wastes that are generated in the upstream and downstream sectors of the industry except by permit. The document is sub divided into the six parts that constitute the major operations of the industry: exploration and development, production, terminal operations, processing, transportation and marketing. Expected waste streams from the relevant operations are identified and guidance for waste management and disposal is provided. For example, with respect to underground disposal related to exploration and development operations which make up Part II of the document, the regulations provide guidance on the disposal of wastes into pits, temporary retention ponds as well as underground injection in Section E which deals with environmental management. Detailed guidance and specifications for waste and retention pit liners, land filling, land farming and backfilling are provided in Section E. This arrangement is retained for all upstream and downstream operations. Part VIII addresses Standardization of Environmental Abatement Procedures and contains detailed guidance on EIA and EER processes. Appendix VIII-C3 of this part is devoted to guidance and regulations for the Drilling and Production waste injection operations. Waste types are classified and injection criteria and specifications including permitting requirements, record keeping and reporting formats are provided. Section 4 of the Appendix is devoted to monitoring requirements of the injection well, and which monitoring procedures include and is limited to annular pressure testing, radioactive tracer surveys, Temperature Falloff and Pressure Falloff testing at specified intervals.

REVIEW OF GUIDELINE FRAMEWORK

Akpoborie (2005) critically reviewed the FEPA 1991 Guidelines and EGASPIN against the background of injection well design specifications contained in Warner and Lehr (1977) and Geraghty & Miller Inc. and Booz, Allen & Hamilton Inc. (1983) and concludes that of the two documents, the EGASPIN although of limited application to a specific industry is the more comprehensive. The following perceived shortcomings were identified.

- Specific design and materials stipulations for injection wells are not explicitly defined in the EGASPIN.
- Stipulations for monitoring wells and injection well integrity testing which are contained in

Appendix VIII-C3 Section 4.0 of EGASPIN are without precision: subsection 4.3 for example specifies sampling intervals and parameters for monitor well samples in the absence of a prior and specific requirement and guidance for the location, design, drilling and completion of monitor wells. The DUI regulations have the same problem. Furthermore, both regulations place complete reliance on the operator of an injection facility to demonstrate mechanical integrity with only general criteria without providing for checks by the regulator.

- Injection well abandonment and closure after injection is only accorded superficial treatment in EGASPIN as well as the DUI. Because badly abandoned injection wells can constitute a continuous source of pollution to underground sources of drinking water, closure specifications and guidelines are crucial and cannot be subject to whimsical interpretation by potential operators. The history of well abandonment in the Niger Delta is not generally good: there are no records of the number and distribution of the abandoned wells in this petroleum province.
- The depth of waste disposal wells is a fundamental issue that is treated with inconsistency in both regulations. While EGASPIN stipulates a minimum depth for all waste injection wells in the petroleum industry at 1067 meters (EGASPIN Appendix VIII-C3 Part2.2.2(i)), and for NORM, " far below the deepest underground source of drinking water" (Appendix VIII-C3 Part 3.2.4.3), DUI merely states that the disposal formation "should be below the deepest underground source of drinking water" (DUI, Section 4.1(c)). The problem here is: what would be the quality of water in the so called deepest underground source of drinking water? What are the parameters to be used in the determination of the quality of water contained therein? In the United States Underground Injection Control program for example, an upper protection limit of 10,000 mg/l TDS is set for potential underground sources of drinking water that deep well injection regulations seek to protect. The depth of injection wells is a crucial factor in the economics of waste injection and precision in the regulations is of paramount importance.
- Section 4.1g (iii) of the DUI states in part that *"mechanical integrity for disposal or storage wells drilled or converted to disposal wells must be demonstrated by the operator"*. This provision lumps two important procedures together. The first is the storage of wastes or some other material in a well bore. The second is the conversion of existing wells drilled for some other purpose into waste injection wells. EGASPIN explicitly makes provisions for what is described as encapsulation of wastes in a deep well separately from injection into a receiving formation (Part VIII, section C, Appendix VIII – C3). Detailed guidance is provided therein for the encapsulation procedure. Encapsulation is emphasized here because it could be a practicable method of isolating extremely hazardous wastes from the biosphere. Oil and gas storage wells are also important enough to be given special guidance. With respect to the conversion of one type of well to the other detailed guidance on any conversion procedure should be specific and each case should be reviewed individually.
- Clause 4.1 (h) of the DUI which states that *"A permittee of an Oil or Gas well shall not dispose of fluid wastes in the annular space between strings of casing. The Ministry may grant a temporary exception to the prohibition if the Ministry (sic) that annular disposal will not damage underground freshwater, oil, gas or other minerals"* is dangerous as well as unnecessary. The concession in this clause which allows waste disposal "temporarily" in the annular space of a hazardous waste disposal well cannot be technically justified.
- With respect to waste disposal in waste pits, landfills, land treatment and associated monitoring requirements, the FEPA Guidelines and EGASPIN specify single natural or artificial liners and very loose requirements for monitoring wells. As in waste injection wells, facility design specifications are also left to the interpretation of project proponent or facility owner. Lee and Jones-Lee (2011) have shown that single liner systems may not be relied upon to contain leachates over time. This much has been confirmed at the Oviamughe sanitary landfill in Delta State where Mosunmolu (2005) used ground penetrating radar to show that the single liner used in the facility had been thoroughly compromised. Furthermore, widely spaced monitor wells can also not be expected to detect leaked leachates close to a land fill facility (Cherry 1990; Haitjema 1991). The location of monitor wells associated with landfills should thus be reviewed.

URBAN RUNOFF (STORM WATER) INJECTION

It would appear from the foregoing review that storm water injection and associated wells are not explicitly addressed by existing regulations. Because of the nature of evolution and development of Nigerian cities there are no sewerage systems, neither are there formal operational urban runoff control systems. The open and usually disgustingly filthy and stagnant drains (gutters) that characterize most cities are typically choked with garbage such that the drains constitute a source of continuous recharge to and pollution of near surface aquifer horizons. Storm

water management and associated floods is thus a major challenge for municipalities, local governments, states and the federal government. Injection of storm water into underground reservoirs is thus an attractive and pragmatic option. Injection is typically into near surface aquifers that are exploited by homeowners nationwide with dug wells and shallow (< 30m deep) drilled wells for water supply purposes in the absence of adequate public water supply systems. Akpoborie et al. (2000) and Ejechi et al. (2007) among many others have shown that dug well water from several parts of the western Niger Delta is unfit for drinking purposes without prior treatment due to bacteriological contamination. Akujieze and Oteze (2007) have established that the quality of water from even the deeper (> 100m) public water agency owned municipal water supply wells in Benin City is being compromised over time, while Omozeje's (2011) analyses of storm water quality from the Benin City injection programme indicates that it can potentially contaminate the aquifer into which it is being injected. Clearly, regulations and guidelines for storm water management through wells in Nigeria are needed.

ENFORCEMENT ISSUES

There are those enforcement problems that are associated with two seemingly parallel laws, which are enforced by two independent agencies. This problem comes to the fore when environmental impact assessments (EIA) for proposed projects are either being prepared or reviewed by independent reviewers. The consultants who normally undertake this function for project proponents would opt for the easier to follow DUI set of regulations and specifications while the reviewers of the EIA report, usually also independent consultants employed by the regulatory agency could recommend non approval of the project on the basis of non compliance with reasonable and legitimate stipulations in EGASPIN that are absent from the DUI. Such a recommendation could be costly for project proponents as it would negatively affect project realization timelines.

Another example is the Ozoro, Delta State waste injection facility that has resulted in conflict and subsequent litigation between the operator of the facility, the two regulatory agencies on the one hand and the Ozoro community on the other. The injection well has been forcibly abandoned because of this action. There is no post closure monitoring, such that when wastes backed up and erupted from the capped well on at least one occasion, technicians were flown to the site under armed police guards to shut in the well. Akpoborie (2004) and Akpoborie and Diwanbor (2006) discuss this problem in detail and report that DPR has claimed ignorance of the existence of the facility, while the operator has insisted they have approval from the FMEnv. Presently, DPR seems to be playing a more subdued role in environmental management in the petroleum industry while FMEnv is on the ascendancy. That is to say, it is the less than adequate set of DUI regulations that now guide and regulate underground waste disposal practice in the petroleum industry.

Furthermore and with respect to the mandatory EIA and EER reports that are a requirement for all waste disposal and management projects as part of the permitting and approval process, Akpoborie(2010) has observed that the Environmental Management Plans (EMP) which are a part of every EIA report have a fundamental flaw as currently interpreted and operated. In the typical EMP template a portion of which is shown in Table 1, the project proponent is required to monitor the EMP and send reports to the regulatory agency.

Table 1. Typical EMP Template

Environmental Components (To be monitored)	Indicator parameters	Frequency	Responsible Party
Air quality	NOx, CO_2, CH_4,SPM	Yearly.	PROPONENT
Surface Water Quality	Dissolved Oxygen , Nutrient Content, pH, Biological Oxygen Demand, (BOD)	One per season (dry and wet)	PROPONENT

This is the same situation with injection well integrity testing mentioned earlier where the regulator has to rely on reports submitted by the operator. It is suggested that this situation be reviewed to allow for joint evaluations by the regulatory agency and the proponent/operator of any underground waste disposal facility. At a minimum, independent consultants could be employed to undertake the monitoring during the construction and operation of the project.

This not as trivial an issue as it might seem because it has crucial implications for environmental management. Figure 1 for example is a photograph of

an ongoing land application of spilled crude oil on the north bank of the Forcados River. At the time this photograph was taken during an inventory of polluted sites in the area (Richdrill 2009), the regulator had not been to the site, was probably unaware of the spill and could never have approved such a remediation method if they were on hand to oversee the process.

Fig. 1: Crude oil spill "clean up" operations at Yokri, Delta

Another important and related issue is the complete absence of recognition and specification of roles for resident communities in environmental policing (Akpoborie 2010) in the existing laws. The Yokri site shown Figure 1 could not have been detected without the assistance of the local community who are powerless in monitoring project related environmental degradation.

DISCUSSION AND CONCLUSIONS

The major sedimentary basins in Nigeria namely, Anambra Basin, Benue Trough, Nupe Basin, Chad Basin, the Dahomey Basin and Niger Delta Basin all possess potential geological reservoirs that can be utilized for municipal waste, industrial waste, and storm water disposal. Many of the reservoirs are also aquifers which are the source of fresh ground water that forms a most important component of Nigeria's water resources. Delta State for example, relies entirely on ground water for its water supplies. In addition, rivers and other surface water sources are usually in hydraulic continuity with ground water which accounts for 100 percent of all dry weather flows. It is important that these aquifers be isolated and protected. Incompetent design and completion of underground waste disposal facilities immediately place these ground water reserves in jeopardy.

Before the relevant geological and hydrologic concepts associated with deep well injection of wastes were clearly understood, there was the tendency to treat them as ordinary boreholes, which led Piper (1969) to remark that *"injection underground would put them (wastes) out of sight, but in a responsible society, not out of mind"*. In appreciation of this warning, and a spate of reported occurrences of ground water contamination related to underground injection of wastes, the United States enacted the Safe Drinking Water Act in 1974 that stipulated the establishment of a specific underground waste injection control program. Under this programme, the USEPA is continuously evaluating the status of the practice through constant reviews (USEPA, 1985; 2001), the consistent funding of research (Smith 1996), and publication and update of guidance documents on virtually every aspect of the practice. Brown (1986) for example, describes several cases of ground water and air pollution resulting from injection wells in the United States and concluded that the regulations as they existed then were not firm enough to prevent adverse interactions between wastes and the receiving formation; lacked adequate monitoring requirements and requirements for financial responsibility after closure and well abandonment. A review of the literature since that study shows that firm steps have been taken to address these issues in the United States (U.S.EPA 2001), and that monitoring and research is a continuous process that can further confirm the efficiency of operational injection wells (Maliva, Guo, Missimar 2007; Warner DL, Davis SN, Syed T 1986; USEPA 1990).

In the Nigerian case, while there are no recorded cases of pollution resulting from injection wells to rely on, the foregoing review of existing regulations show inadequacies that need to be addressed in order to manage and(or) forestall the occurrence of such incidents. Indeed, the fact that there are no records does not mean that such incidents have not occurred or that they are not occurring. An assessment of waste injection in the Niger Delta petroleum province where the practice has been in use for more than half a century is overdue. Major structural reform of regulatory mechanisms for underground waste disposal are a needed if aquifers are to be adequately protected should underground waste disposal gain universal acceptance and applicability in Nigeria's emerging waste management industry. The successful use of injection wells for management of urban floods by the government of Edo State without regulations or oversight for example portends dire consequences for the Benin Formation one of the richest and most productive regional aquifers in Nigeria. Should other states emulate this practice

without appropriate regulations, ground water reserves will be threatened nationwide.

Finally, while sedimentary basins that might contain suitable reservoirs for underground injection exist in Nigeria, specific formations within the basins that meet injection criteria need to be identified. Outside the petroleum industry, there is a virtual complete lack of knowledge in underground waste injection technology in Nigeria. Research should and must be encouraged and funded by government and industry to generate the relevant data on geological formations, their characteristics and the classification of wastes that can be disposed of by underground injection. Industry must also collaborate with the regulatory agencies and research institutions to identify those waste categories that should be excluded from deep-well injection because of their extreme toxicity and stability. FMWR which by virtue of the Water Resources Act is the custodian of the nation's water resources should be the major driver of this process.

REFERENCES

Akpoborie IA, Egboh SHO, Akporhonor E, Etobro AAI (2005). The Potential of Deep Geological Reservoirs for Industrial Waste Disposal in Nigeria. Proceedings of the 28th International Conf. of the Chem. Soc. of Nigeria, Maiduguri, pp 641-651.

Akpoborie IA (1998). Environmental Impact Assessment for proposed Egbelekwu permanent Landfill: A Review, prepared for Delta State Environmental Protection Agency, Asaba.

Akpoborie IA, Ekakite OA, Adaikpoh EO (2000). The Quality of Groundwater from Dug Wells in Parts of the Western Niger Delta. Knowledge Review 2(5): 72-75.

Akpoborie IA (2005). Deep-well injection of Industrial and Hazardous Wastes in Nigeria: Prospects, Federal Regulations and the Ozoro Waste Injection Facility, Proceedings of the 29th Annual SPE International Technical Conference, Abuja, Paper No. 98804, pp 1-8.

Akpoborie IA (2010). Framework for the formulation and implementation of Standards and Guidelines for environmental management in Delta state, Presented at the UNDP/DSENV Environmental Standards and Guidelines W/shop, Royal Courtyard Hotel, Agbor, 29-30 Nov.

Akpoborie IA, Diwanbor GU (2006). Do Environmental Laws in Nigeria Encourage Conflict? A Case Study of the Ozoro Waste Injection Facility, in: G. Omotor et al. (eds.) Readings in Conflict Management and Peace Building in Africa Vol. 2. Delta State University Press, Abraka, Nigeria.

Alao T (2011). Lagos adopts waste water policy, woos investors in N76b projects. The Guardian Newspaper, March 14, p.49.

Akujieze CN, Oteze GE (2007). Deteriorating quality of groundwater in Benin City, Edo State, Nigeria. Water Resources 17: 17-23.

Brown M (1986). The Lower Depths: Underground Injection of Hazardous Wastes. *The Amicus Journal* (Winter).

Cherry J (1990). Groundwater Monitoring: Some Deficiencies and Opportunities, In: Hazardous Waste Site Investigations: Towards Better Decisions, Proc. 10th ORNL Life Sciences Symposium, Gatlinburg, TN, Lewis Publishers.

Department of Petroleum Resources (2003). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria, DPR, Lagos.

Ejechi BO, Olobaniyi SB, Ogban FE, Ugbe FC (2007). Physical and Sanitary Quality of Hand Dug Well Water from Oil producing area of Nigeria. Environ Monit Asses 128:495-501.

Egboh, SHO, E. Nwajei E, Adaikpoh EO (2000). Selected Heavy Metals in Sediments from major Roads and Gutters in Warri, Delta State, Nigeria, Nig Jnl. of Science and Environment 2: 105-111.

Federal Government of Nigeria (1993). Decree 101. Supplement to Gazette Extraordinary No. 27, Vol.80, Sept.1. Abuja.

Federal Ministry of Environment (1999). National Guidelines on Waste Disposal through Underground Injection, FMEnv, Abuja.

Federal Environmental Protection Agency (1991a). Guidelines and Standards for Environmental Pollution Control in Nigeria, FMEnv, Abuja.

Federal Environmental Protection Agency (1991b). *S.I.8* National Environmental Protection (Effluent Limitation) Regulations, FMEnv, Abuja.

Federal Environmental Protection Agency (1991c). *S.I.9* National Environmental Protection (Pollution Abatement in Industries and Facilities Generating Wastes) Regulations, FMEnv, Abuja.

Federal Environmental Protection Agency (1991d). S.I.15 National Environmental Protection: Management of Solid and Hazardous Wastes Regulations, FMEnv, Abuja.

Geraghty & Miller Inc. and Booz, Allen & Hamilton Inc. (1982) Injection Well Construction Practices and Technology (U.S.EPA Contract Report No. 68-01-5971).

Lee GF, Jones-Lee A. (2011). Deficiencies in Subtitle D Landfill Liner Failure and Groundwater Pollution Monitoring, http://members.aol.com/gfredlee/gfl.htm, Accessed on April 13, 2011

Maliva, RG, Guo W, Missimer T (2007). Vertical migration of municipal wastewater in deep injection well systems, South Florida, USA. Hydrogeology Journal 15: 1387–1396

Mosunmolu Limited (2005) Subsurface Investigation of soil and underground water contamination at Ughelli West Engineered Dumpsite, Warri. Project Report prepared for The Shell Petroleum Development Company, Warri.

Ojo GU (2010). Opening Remarks. Technical Meeting on Livelihood Issues: Legislative Reform of Environmental Laws, Nigerian Institute of Advanced Legal Studies, Lagos, 13-14 December.

Onisarotu AW (2011). Hazardous Waste Regulation, Treatment and Disposal in Lagos State . www.gooledocs.com . Accessed on March 15,2011.

Piper AM (1969). Disposal of Liquid Wastes by Injection Underground – Neither Myth Nor Millennium, *U.S.G.S. Circular 631*.

Richdrill Nigeria Ltd. 2009. Study of Major Oil Impacted Sites in Forcados Area, Delta State. Final Report prepared for the Federal Ministry of Niger Delta Affairs, Abuja.

Smith RE (1996). EPA Mission Research in Support of Hazardous Waste Injection 1986-1994, in: Apps JA, Chin-Fu Tsang (eds.) Deep Injection of Hazardous and Industrial Waste: Scientific and Engineering Aspects (Academic Press).

The Presidency (1999). The National Policy on the Environment, Federal Ministry of Environment, Abuja.

U.S. Environmental Protection Agency (1989). Requirements for Hazardous Waste Landfill Design, Construction and Closure (EPA/625/4-89/022).

U.S. Environmental Protection Agency (1990). Assessing the Geo-chemical Fate of Deep-Well-Injected Hazardous Waste: A Reference Guide (EPA/625/6-89/025a).

U.S. Environmental Protection Agency (1985). Report to Congress on Injection of Hazardous Waste (EPA 570/9-85-003. 3rd Printing).

U.S. Environmental Protection Agency (2007). Underground Injection Control (UIC) Program (http://www.usepa.gov).

U.S. Environmental Protection Agency (1999). The Class V Underground Injection Control Study Volume 3: Storm Water Drainage Wells (EPA/816-R-99-014c)

Warner DL, Lehr JH (1977). An Introduction to the Technology of Subsurface Waste Water Injection (EPA. 600/2-77-240).

Warner DL, Davis SN, Syed T (1986) . Evaluation of Confining Layers for Containment of Injected Waste Water, in: Proceedings of the Int. Symposium on Subsurface Injection of Liquid Wastes, New Orleans, pp.417-446 (NWWA, Dublin, Ohio).