

Article

Management Recommendations for Improving Decentralized Wastewater Treatment by the Food and Beverage Industries in Nigeria

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Abstract: The main aim of this study was to identify the enabling conditions that can lead to better wastewater management by industries (non-oil and gas sector) in Nigeria. The relevant data and information's required for this study were obtained through semi-structured interviews with different stakeholders in the Nigerian environmental sector. The lack of financial capability, technical expertise, and environmental awareness was envisaged as the main reason for non-compliance. According to the results, the enabling conditions that can lead to better decentralized wastewater management are government support, improved legal and regulatory framework, increased capacity, and skills of the regulators and financial arrangements for implementing environmental policies and treatment technologies in polluting facilities.

Keywords: wastewater pollution; decentralized wastewater management; enabling environment; regulated facilities; improvement options

1. Introduction

1.1. Current Situation in Nigeria

Rapid population growth in Nigeria, as well as in many other developing countries, has resulted in an equally rapid increase in urbanization and these are generators of increased domestic and industrial wastewater. In addition to the already prevalent natural scarcity of freshwater in many such regions, the quality of the available water is also quickly deteriorating due to pollution [1–4]. Industrial discharges into rivers are one of the causes of irreversible degradation occurring in surface water systems and improper wastewater management has a very direct impact on the biological diversity of aquatic ecosystems and disrupts the integrity of the systems which support a wide range of sectors, from urban development to food production and industry. The Pan-American Health Organization (PAHO) has stated that less than 10% of municipalities in developing countries treat sewage adequately before emptying it into natural water courses and that wastewater treatment for industrial effluent are often non-existent [5]. In Nigeria, apart from very few areas in the federal capital city, Abuja, and some parts of Lagos, there are no central sewage systems in any other city in Nigeria; thus, the onus of wastewater management is on individual citizens or businesses through the decentralized wastewater management system. Therefore, water pollution is one of the most evident forms of pollution in the country. Even though waterways can absorb substantial quantities of toxic substances, local pollutants have already exceeded this level [6,7]. Thus, it is evident that the concentrations of pollutants are high in different water environments and a proper environmental management and monitoring program is urgently required.

Industries and other regulated private or commercial facilities such as hotels and hospitals in Nigeria are required by law to treat their wastewater to stipulated quality before discharge, but wastewater treatment before discharge or re-use by these facilities is usually inappropriately done or completely non-existent. Most industries in Nigeria lack efficient effluent treatment plants and therefore discharge their effluents into water bodies without adequate treatment, often into the nearest water bodies [8–11]. Past studies have indicated fourteen major contributors to industrial waste pollution in Nigeria. These include slaughterhouses, breweries, cement industries, chemicals and paint manufacturers, and fertilizer companies. Others are textile industries, pharmaceuticals, tanneries, oil refineries, and steel and metal fabrication [12]. In all these industrial operations, large amounts of fresh water are required for various unit operations and production processes, as well as for the disposal of generated wastes [13–15].

Hence, this has resulted in serious externalities, such as environmental degradation and health problems in many areas of the country. Improper wastewater management in Nigeria has resulted in reduced surface and groundwater quality, health problems, and degraded land and vegetation [11]. For instance, industrial waste from the Lagos metropolis that are discharged daily into the Lagos lagoon has adversely affected marine life, navigation, and aesthetics of the city. The lagoon has shown marked variations and non-uniform distribution of different persisting pollutants, from one season to another, and it is continuously under the threat of pollution. These and other related factors have made the water unsuitable for domestic and recreational uses [16,17]. Industrial water pollution has serious economic and social consequences as well. Indiscriminate discharge of untreated wastewater affects receiving soil and vegetation and is known to cause land degradation. Most of the river basins in Nigeria experience severe water shortage and this water demand is alleviated by rapid industrialization, population growth, urban development and shortage of annual rainfall. Moreover, there is knowledge gap in determining suitable ways of enhancing the water re-use efficiency, resource recovery from wastewater, and even complying with existing Nigerian wastewater discharge standards. The introduction of toxic substances in wastewater into water bodies causes undesirable stress, or even death of fish and other aquatic organisms [18], and affects the livelihood of people who depend on these water bodies to earn a living [15].

Adequate wastewater management will prevent dangers, such as contamination of water bodies (water supplies) by chemical and biological agents, destruction of fish and other aquatic life forms, reduction of the quality of receiving waters due to excessive addition of nutrients, impairment of the beneficial use of fresh water, and land degradation. Importantly, it will also enhance community growth and development in the places where the regulated facilities are situated. Very often, industrial water pollution generates externalities, as polluters pass most of the costs associated with their activity onto other entities, such as communities located close to a waterway. Individuals that may be affected by these include fishermen who may lose their source of livelihood [15].

1.2. Nigeria's Existing Environmental Regulations and Framework

Over the years steps, have been taken by the Nigerian government to establish institutions for environmental protection and conservation. The National Water Resources Institute (NWRI) and the River Basin Development Authorities (RBDA) were established in 1976 and Federal Ministry of Water Resources (FMWR) was created in 1977 [12]. While the FMWR is in charge of policy formulation and advising, the NWRI is responsible for research and manpower training. The RBDAs, on the other hand, are responsible for making water available to communities for agricultural, domestic, and industrial purposes. In the same vein, in 1988, the government established the Federal Environmental Protection Agency (FEPA) through decree 58 of December 1988 [19]. The major aim of FEPA was to formulate national environmental guidelines, standards, and criteria, specifically in the domain of water quality, effluent discharge, and air and atmospheric quality. This institution was transformed into the Federal Ministry of Environment (FMENV) in 1999 [20]. Even with the creation of the FMENV, a lacuna existed in the effective enforcement of environmental laws, standards and regulations in the country and in order to address this problem, the federal government established the National Environmental Standards and Regulations Enforcement Agency (NESREA).

1.3. National Environmental Standards and Regulations Enforcement Agency (NESREA) as the Main Environmental Regulator in Nigeria

The creation of NESREA in 2007 is the most recent and one of the most important developments in the introduction of environmental regulatory institutions in Nigeria. The agency is responsible for protection and development of the environment, conservation of biodiversity, and sustainable development of Nigeria's natural resources in general and environmental technology. The Act by which the agency was established empowers it to be responsible for enforcing all environmental laws, guidelines, policies, standards, and regulations in Nigeria, as well as enforcing compliance with provisions of international agreements, protocols, conventions, and treaties on the environment to which Nigeria is a signatory [21]. The functional strategies and policy thrust of this agency can be summarized as follows:

- i. developing and maintaining strategies for effective environmental compliance monitoring and enforcement;
- ii. carrying out environmental compliance monitoring and enforcement programs to ensure sustainable use of Nigeria's natural resources, to protect the citizens' well-being and to control air, land and water pollution;
- iii. establishing a robust environmental information management system;
- iv. increasing the level of environmental awareness and creating partnerships with relevant stakeholders at both national and global levels; and
- v. coordinating and promoting research and studies, in collaboration with public and private agencies, institutions and organizations, on various aspects of environmental degradation and pollution including technological transfer.

An abridged organizational structure of the NESREA is presented in Figure 1. Currently, the agency has six zonal offices in the six geopolitical zones of the country and 23 field offices. One of the mandates of NESREA is to develop effluent limitation standards for wastewater dischargers. The agency has developed 24 environmental regulations for different sectors. The regulations advocate the use of pollution prevention, and waste minimization procedures and facilities are mandated to report any non-compliance event that may endanger human health or the environment. Some of the national regulations that have guidelines on wastewater management in regulated facilities are:

- i. National Environmental (Sanitation and Waste Control) Regulations, 2009 [21];
- ii. National Environmental (Food, Beverages, And Tobacco Sector) Regulations, 2009 [21];
- iii. National Environmental (Textile/Wearing Apparel, Footwear, and Leather Industries) Regulations, 2009 [21];
- iv. National Environmental (Chemical, Pharmaceuticals, Soap, and Detergent Industries) Regulations, 2009 [21];
- v. National Environmental (Domestic and Industrial Plastic, Foam, and Rubber Industries) Regulations, 2011 [21];
- vi. National Environmental (Surface and Ground Water Quality Control) Regulations, 2011 [21].

NESREA still follows the traditional "command and control" policies of industrial pollution control and it specifies the specific type of "end-of-pipe" treatment technologies that must be used by the industrial establishments. It makes use of regulations which recommend that no wastewater should be discharged from any facility without treatment, and specifies effluent discharge standards that must be complied with by the regulated facilities based on the best available technologies. The regulations mandate facilities to install pollution abatement equipment or make adequate provision(s) for effluent treatment and to take responsibility for all generated wastewater until final discharge. Penalties stipulated for non-compliance range from payment of fines to imprisonment of the personnel responsible, payment for any externalities, and sealing up of the facilities. However, the stipulated

effluent standards seem to have been designed to correspond to a high level of wastewater treatment technology compared to other developing and developed nations (Table 1), even when the Nigerian economy is not buoyant enough for most facilities to satisfy high wastewater treatment demand.

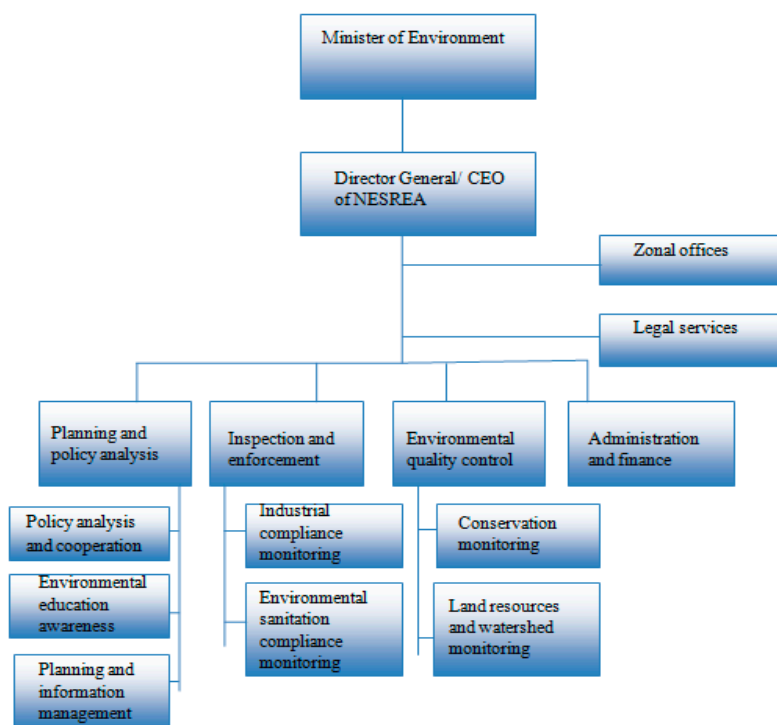


Figure 1. Organizational structure of the National Environmental Standards and Regulations Enforcement Agency (NESREA) (www.nesrea.gov.ng). CEO: Chief Executive Officer.

The implication is that the standards have become mere theoretical regulatory instruments without effective implementation or enforcement. The regulations exist on paper but their enforcement is still generally regarded as weak. Even with these directives in gazettes and despite the fact that the Nigerian environmental agency also carries out routine monitoring of regulated facilities, compliance has been widely reported as very low. According to the literature, environmental laws in Nigeria are hardly enforced, corruptly enforced, or oftentimes enforced with a revenue collection motive [20,22]. A recent report has also mentioned that the efforts taken by various administrations to mitigate the incidence and impact of water pollution through the establishment of laws and, in many instances, decrees, have not been successful due to political and various other reasons [15]. This political interference, lack of coordination among responsible agencies, and lack of environmental quality monitoring laboratories/institutions, and others, are some of the reasons that have been constantly cited for the lack of effectiveness of the institutions set up for the protection of the environment.

The main objective of this study was to examine the enabling conditions that can be improved upon to ensure that wastewater from industries in Nigeria are treated sufficiently, with a special focus on the food and beverage sector, to prevent the adverse environmental, health, and social impacts associated with improper management. The specific objectives are: (i) to identify the challenges faced by regulated facilities with respect to wastewater management in the food and beverage sectors; (ii) to assess the effectiveness of the institutional framework by Nigerian environmental protection agencies to prevent wastewater pollution; and (iii) to suggest possible enabling conditions for improvement.

Table 1. Comparison of effluent discharge limits for various water quality parameters in Africa and Asia.

Parameter	Unit	Effluent Discharge Standards						
		Africa				Asia		
		Nigeria	Tanzania	Ghana	Uganda	Thailand	Malaysia	India
Temperature	°C	40	-na-	-na-	35	40	40	-na-
pH	-	6–9	6.5–8.5	6–9	6–8	5.5–9	5.5–9.0	6.5–8.5
BOD	mg O ₂ /L	30–50	30	50	50	20–60	50	30
COD	mg O ₂ /L	60–90	60	250	100	120–400	100	250
Oil and grease	mg/L	10	5	5	10	5–15	10	10
DS	mg/L	200	3000	1000	1200	3000	-na-	-na-
SS	mg/L	25	100	50	100	50	100	50–100
Total N	mg/L	10	10	-na-	10	-na-	-na-	10
Total P	mg/L	2	6	2	-na-	-na-	-na-	5
Free chlorine	mg/L	0.5	-na-	-na-	1.0	1	2	1
Sulphide	mg/L	0.2	-na-	1.5	1.0	1	0.5	2
Phenol	mg/L	0.5	0.2	2	0.2	1	1.0	1
Cadmium	mg/L	1.0	0.1	0.1	0.1	0.03	0.02	2
Cr(VI)	mg/L	0.05	0.1	0.1	0.05	0.25	0.05	0.1
Total Cr	mg/L	1.0	1	0.5	-na-	-na-	-na-	2
Ammonia N	mg/L	1.0	-na-	1.0	10	-na-	-na-	-na-
Lead	mg/L	0.05	0.1	0.1	0.1	0.2	0.5	0.1
Copper	mg/L	0.5	1	5	1	2	1.0	3
Manganese	mg/L	0.2	-na-	-na-	1	5	1.0	2
Nickel	mg/L	0.05	0.5	0.5	1	1	1.0	3
Zinc	mg/L	2.0	1	10	5	5	1.0	5
Coliforms in 100 mL	MPN	400	-na-	400	-na-	-na-	-na-	-na-

Note: -na-: not available; -: pH units; BOD: biochemical oxygen demand; COD: chemical oxygen demand; DS: dissolved solids; SS: suspended solids; MPN: most probable number; Cr(VI): hexavalent chromium; data sources: [23–29].

2. Materials and Methods

2.1. Data Collection

The study was conducted as a case-based research with questionnaire analysis that was examined and supported by findings from relevant literature. Appendices A–C, provided in the supplemental file present the questionnaires used in the interviews. In addition, published articles, journals, online and government-published data, guidelines, regulations, and reports were reviewed. Some of the data used was collected from personal “on-the-job” observations made in the course of working with Nigerian environmental regulatory agency; secondary data was collected whenever required. Semi-formal interviews were also conducted with stakeholders in the environmental sector of Nigeria.

2.2. Description of the Study Area

Nigeria is located between latitudes 4°16' N and 13°52' N and between longitudes 2°49' E and 14°37' E and it borders Cameroon and the Republic of Chad to the east, the Republic of Niger to the north, and the Republic of Benin to the west, respectively [29]. The country is the twelfth largest country in Africa, with a total land area of 923,773 km² [7]. Nigeria has a population of about 194 million people [30]; moreover, it is richly endowed with abundant and diverse renewable and non-renewable resources. Some areas with relatively high concentrations of industrial establishments include Lagos and Ibadan in the South-West, Enugu and Port Harcourt in the South-East and South, respectively, and Kano in the northern region [31]. Industries in Nigeria are not the highest consumers of water; however, they have high contribution to pollution in Nigeria, as they introduce different polluting substances into their wastewater streams. For instance, the agricultural sector, the domestic household activities and the industrial sectors consume, approximately, 69%, 21%, and 10% of the water in Nigeria.

2.3. Interviews with Environmental Regulators

The regulators develop environmental standards and enforce them through compliance monitoring visits to regulated facilities, during which they also interact with officials from these facilities. The interviews with them were conducted to obtain pertinent information about their regulatory functions with respect to wastewater management in the regulated community and to ascertain the problems encountered with compliance monitoring, as well as the challenges faced by industries with regard to wastewater management. A semi-structured questionnaire (Appendix A) comprising mostly of closed-ended questions was prepared for this group of respondents. These were sent via email, filled in by the respondents, scanned and then returned by the same means. 58 staff with varying lengths of work experience with the NESREA in Nigeria filled the questionnaires. They are officers on salary grade levels 8 to 16 (in Nigeria, the maximum salary grade is 17, while the minimum is grade 1 for least paid staff) from the agency's national headquarters, 4 field offices and 2 zonal offices. 11 of the respondents have less than 2 years of work experience with the agency, 16 of the respondents have between 2 and 4 years of experience, while 31 of the respondents have more than 4 years of work experience. Ten government accredited environmental consultants from different geo-political zones of the country were interviewed. Their consultancy outfits ranged from small one-man managed companies to very large, commercial and well-known establishments. 1 person each was interviewed from the six industries across the country that range in size from small businesses (few workers) to large, public liability companies.

2.4. Interviews with Environmental Consultants

Environmental consultants in Nigeria are among the most important actors in environmental management. They serve as an interface between the regulators and the regulated facilities. They are responsible for conducting environmental impact assessments and audits for regulated facilities; therefore, they have close interactions with the facilities and thus know their challenges. Ten government-accredited environmental consultants from different geo-political zones of the country were interviewed. Their consultancy outfits ranged from small, one-man managed companies to very large establishments. The purpose of these interviews was to get to know their opinions about the effectiveness of the institutions set up by the government for environmental monitoring and regulation, the reasons for facility's non-compliance with stipulated wastewater management regulations and to receive feedback on the strategies for improvement. The consultants are listed in the directory of NESREA and they were contacted based on their areas of expertise. The interview questions were constructed as semi-structured, open-ended questions in order to get the complete perspective of the interviewees by allowing them to fully express themselves and thereby reduce bias (Appendix B).

2.5. Interviews with Industrialists

The food and beverage sector was selected because it is one of the largest industrial sectors in Nigeria. Hence, it uses a significantly high amount of water, has one of the highest numbers of employees, and has also been reported to be one of the highest polluters [7,32,33]. Although the sector comprises mainly small and medium scale enterprises with only a handful of large, indigenous, and multinational companies, the demand for their products has been estimated to be in excess of N500 billion (about US\$ 3 billion) per annum [34].

The interviews with industrialists from the food and beverages sector were conducted in order to obtain some information about their wastewater management practices, to understand their level of environmental awareness campaigns and commitments, their challenges in this area, as well as their perspectives on government regulations. One person was interviewed from each of the six industries that range in size from small businesses to large public liability companies (Appendix C).

2.6. Analysis of the Interview Results

The responses were reviewed and categorized into smaller sets of broad categories based on the interview objectives. Thereafter, the main responses that emerged were outlined and described. The responses from the regulators and industrialists were analyzed and presented by descriptive means, as well as with charts, percentages, and numbers. The structure of the questions for these two groups allowed for some degree of generalization of the results obtained.

3. Results and Discussion

3.1. Environmental Consultants

All ten consultants were of the opinion that the national wastewater discharge standards are reasonable for the country, but only two consultants thought they are realistic. 60% of the interviewees believed that the regulated facilities lack motivation to comply with the wastewater management regulations. The capital cost of constructing wastewater treatment systems, lack of environmental awareness, and lack of technical know-how on the parts of both the regulators and the regulated are the most prominent reasons given for non-compliance by the facilities.

On average, the consultants rated the effectiveness of government's environmental regulatory institution as fair. Some of the reasons given for ineffectiveness of the existing framework can be stated in brief as lack of adequate funding, lack of basic monitoring equipment for regulatory agencies, multiplicity and clash of regulatory mandates and duties (and therefore, multiplicity of taxations and fines), as well as corruption. About 50% of the interviewees believed that wastewater management in facilities can be enhanced if these facilities receive technical support and incentives from the relevant government authorities, while the remaining 50% were not aware of any technical support and improvement options.

3.2. Environmental Regulators

The 58 respondents from the NESREA differed in their answers to several questions and some ignorance of the Agency's workings could be deduced from some of the responses of the staff members. The interview showed that the regulatory agency does not have shortage of personnel; however, it was quite apparent that the available workforce has not received adequate training. 51% of the respondents did not know whether the baseline tests had been carried out before the national wastewater discharge limits were fixed; on the other hand, 41% were of the opinion that these tests were conducted, while 8% believed that no baseline tests were run.

A majority of the respondents who believed that baseline tests had been conducted were not able to elaborate more on the different tests that were carried out. The others that mentioned some tests gave answers that were divergent and ranged from the study of water bodies, sediment tests, and effluent toxicity tests to chemical oxygen demand (COD), biochemical oxygen demand (BOD),

and pH tests. Extending the interview with the environmental regulators, it was observed that the most authoritative factors given as the regulatory agency's basis for fixing wastewater discharge limits for facilities were: impact on the receiving environment, facility type and activity, health implications of discharged wastewater, and international standards.

Concerning non-compliance by facilities, financial constraints, lack of environmental awareness, lack of technical knowledge, frustration as a result of multiple taxation, and limited land space were some of the reasons given by the respondents for non-compliance by facilities to stipulated guidelines and threshold discharge limits, in that order. Among the reasons given for the ineffectiveness of the regulatory framework are: lack of technical know-how by regulators (23%), lack of basic monitoring equipment (39%), and poor attitude and disposition of the facilities to environmental protection (38%). Some of these reasons are in close agreement with those cited by the environmental consultants.

Finally, the respondents highlighted some factors as potential enhancers of compliance to specified wastewater management guidelines by facilities. These include: improved sensitization of personnel in the regulated facilities on environmental protection and the provision of technical support on Best Applicable Techniques (BATs) for wastewater management in these facilities. Other recommendations include: more stringent penalties for defaulters (23%), commendation for compliant facilities (15%), provision of access to financial incentives such as soft loans (13%) and subsidies (10%), providing access to cheap treatment options (2%), technical support (25%), and improved enlightenment of facilities (31%).

3.3. Industrialists

One representative from each of the six facilities was interviewed. The amount of water consumed as stated by the interviewees range from 200 to 1,000,000 L/day and the amount of wastewater discharged per day range from 3 to 200,000 L. 50% of the interviewees declared that they discharge their wastewater into water bodies and the other half stated that they discharge it into septic tanks. Although all the interviewees claimed to know the adverse impacts of discharging untreated wastewater and 80% claimed to be conversant with the national environmental regulations, only two respondents said their institutions carry out wastewater treatment before the final discharge. Further, half of the interviewees did not indicate any willingness to invest in wastewater treatment technologies. Three respondents stressed the need for the government regulators to be better trained in order to give the facilities sound technical support.

3.4. Analysis of Interviewee's Responses

The findings from literature and the analysis of the responses from the regulators and accredited environmental consultants collectively indicate that the institutional framework set up by the government for environmental regulation and protection may not have been as effective as expected. There appears to be a significant gap in the pollution control standards and the regulations, as well as their enforcement. Most of the environmental regulations are merely theoretical. For instance, although it is mentioned in the national environmental regulations that the national standards "represent minimum standards and different effluent standards shall be required based on the condition of the receiving medium", in practice, this has not been the case, as the baseline studies had not been conducted to ascertain the condition of the receiving medium before the guideline standards were stipulated. Furthermore, even though the regulators believe that the effluent discharge limits are appropriate for Nigeria, in reality, the standards are considerably stringent. The comparative analysis of the Nigerian wastewater discharge standards with those from some developing countries showed that the discharge limits for Nigeria were higher than that in most of the other compared countries with respect to several parameters (Table 1). Further, the regulation stipulates that the polluter-pays-principle shall apply to every company that pollutes and they will also bear the cost of all externalities. However, the responses from the staff of regulatory agency revealed that the implementation of this rule in regulated facilities has not been firm. 30% of the staff had knowledge

about the implementation of polluters-pay-principle, while the remaining staff did not know about such principle or had only very little information. Moreover, environmental protection and the principle that the “polluter pays” are not mutually exclusive. The environmental regulation indicates that technical support will be given to the pollution control personnel, but in reality, this has not been the case because the regulatory officers are themselves untrained. The enforcement of standards and regulations is now perceived by many to be carried out by the regulatory agency with a revenue-generating motive and not necessarily for the protection of the environment. The regulatory agency has been known to seal non-compliant facilities without giving sufficient time and consideration for incremental improvements in compliance and these facilities are unsealed only after huge sums of money have been paid as environmental fines. Thereafter, the facilities continue to function as previously. Ironically, many industries are grappling with unpleasant economic conditions and that money could have been used to address all or a part of the problems such facilities were having with compliance. In addition, the responses obtained from interviewed facilities suggest that they seem to have noticed some of the lapses of the regulatory agency (untrained, incompetent staff, lack of on-the-spot monitoring equipment) and therefore some of them capitalize on these weaknesses to continue to disregard blatantly stipulated guidelines by discharging their untreated effluent indiscriminately.

3.5. Enabling Conditions for Improving Decentralized Wastewater Management in Nigeria

The results from the interviews clearly shows that the regulatory framework for preventing environmental problems of wastewater does not seem to have yielded the desired results for which they were originally created, thus calling for definite measures for improvement. These measures are the enabling conditions that will be discussed in this section. Table 2 summarizes the aspects related to—how these enabling conditions can affect the regulated community and bring about the desired change.

Table 2. Different elements of an enabling environment and its impact on the regulated community.

Element of an Enabling Environment	How Can It Affect the Regulated Community?	Expected Environmental/Health Benefits *
Government support	Feeling of inclusion in government’s sustainable development agenda Favorable business environment Compliance is noticed and or rewarded	Considerably less amount of untreated wastewater is received by the environment Reduced human health risks from wastewater pollution Decreased wastewater pollution of natural water bodies Reduced environmental degradation Improved aesthetics
Improved legal and regulatory framework	Achievable, incremental compliance with stipulated guidelines Fear of sanctions or penalty also enhances compliance	
Effective skills and capacity	Guidance from regulators on best available/achievable technologies enhances wastewater management Increased environmental awareness	
Financial arrangements	Access to subsidies, loans for implementing wastewater management plans	

Note: * Points (i–v) are applicable to all the elements of an enabling environment.

3.5.1. Governmental Support

The extent of support from the government, especially at the federal and state levels, to develop policies and strategies aimed at wastewater management is very important. Government support for pollution prevention through proper decentralized wastewater management must be clearly demonstrated through appropriate policies that promote affordable and accessible wastewater treatment systems and allow for improving participation of the regulated community in environmental protection activities and programs. Since environmental governance in Nigeria takes place at the three

levels of government (federal, state, and local), it is important that there is an improved cooperation between and among the relevant regulators at these three tiers. The existing policies need to be revisited and improved to clearly state the responsibilities of the key players in environmental protection. Further, recognizing and rewarding compliance is likely to encourage facilities towards proper wastewater management.

3.5.2. Sound Legal and Regulatory Framework

The effective and sustainable decentralized wastewater management by the regulated community requires an enabling regulatory framework. The regulatory framework is supposed to provide an overview of environmental laws and regulations used to protect human health and the environment from potential hazards of wastewater disposal. However, both the regulators and regulated do not appear to have been performing their obligations as demanded by the regulations. The existing standards need to be critically reviewed, and made more realistic and achievable by considering the prevailing economic and technical conditions, and with adequate considerations for the characteristics of the receiving local environment. The setting up and adequate enforcement of reasonable standards and regulations can go a long way in bringing about sustainable changes in current wastewater management practices in the regulated facilities. Since the traditional “command and control” policy/instrument of enforcing compliance has not yielded results, a better understanding of the challenges faced by regulated facilities and treating compliance matters on an industry-by-industry basis, rather than lumping all industries together can effect a significant change. Even though effluent limitation guidelines are developed for the entire sectors, the discharge limits can be written into permits issued to industrial facilities based on their individual situations [35]. Additionally, within the confines of the legal framework, appropriate sanctions should be meted out to defaulters without fear or favor.

3.5.3. Effective Skills and Capacity Development

The technical skills and knowledge of regulatory officials responsible for ensuring compliance with wastewater management regulations need to be improved through regular training and capacity building activities. They have to be capable of giving sound technical advice on wastewater management to the regulated community. Giving sufficient attention to training staff of environmental regulatory agencies, as well as sensitization of the regulated community on proper wastewater management holds some promise of improved compliance with wastewater management guidelines and their enforcement. In addition to regular staff training, equipping the agencies with the necessary equipment to carry out their regulatory functions will instill some level of confidence in the staff and send a message to regulated facilities that the agency is serious in its quest to protect the environment from the deleterious effects of untreated wastewater discharge. The regulated facilities also need to be better informed about the implications of indiscriminately discharging untreated wastewater into the environment and on proper management using the best available and economically sustainable technologies that suit local conditions.

3.5.4. Financial Arrangements

Financial commitment towards all the components of environmental regulations is necessary from the different tiers of government and environmental regulation should not be seen mainly as a platform for generating revenues. These funds are necessary for the implementation of environmental policies, staff training, procuring the necessary equipment necessary for environmental monitoring, and other monitoring logistics. The challenges faced by the industries also appear to be significantly financial based. Credit facilities should be set up mainly to assist industries towards compliance with wastewater management especially the small and medium enterprises (SMEs). Additionally, soft loans and subsidies from relevant financial institutions and local financing bodies set up to support industry may help in mobilizing funds necessary to design and implement proper wastewater treatment systems.

3.6. Policy Recommendations

In Nigeria, the common user is not aware of any regulations on wastewater management; wastewater infrastructure and water services are rather poor and, in many regions, they are completely non-existent. Some of the challenges that are faced during wastewater management include the following: (i) lack of proper regulation; (ii) lack of investment in infrastructures; (iii) use of inefficient technologies for wastewater treatment; (iv) improper sludge management; and (v) lack of monitoring and awareness of the pollution levels. The environmental costs of indiscriminately discharging untreated or improperly treated effluent into the environment will always be greater than the financial costs of installing simple decentralized wastewater treatment plants. Technology exists for all, even for those living in developing countries; however, clean technology-based wastewater management practices (e.g., high rate algal bioreactors, anaerobic digester), including resource recovery have not been implemented in many such countries because of a lack of knowledge about the economic benefits of wastewater management. Wastewater management involves a wide range of efforts that promote effective and responsible water use, treatment, and disposal. The problem of improper wastewater management in Nigeria is strongly connected with the failure of the institutional framework set up by the Nigerian government for environmental monitoring and regulation. Based on the knowledge gained from the semi-formal interviews and questionnaires from stakeholders, a few plausible recommendations could be derived from this study, summarized as follows:

- i. Concerning financial implications, the Nigerian government should provide an adequate funding for relevant agencies involved in environmental management and ensure a proper implementation of their programs and policies. These agencies should be institutionally well-developed in order to technically guide the regulated facilities and to better enforce regulations and standards; and this development should be a continuous process. Further, since the challenges faced by the industries also appear to be partly financial, credit facilities should be made available for the participating organizations.
- ii. While it may not be an easy task to reduce the present guideline limits for the industrial wastewater discharge in Nigeria, consideration could be given for facilities to effect incremental improvements in compliance with stipulated standards on an industry-to-industry basis [35]. This is because polluters will find it much easier to increase their compliance with step-wise investment over some time than to make large, and in many cases, unaffordable investments.
- iii. Effluent standards are the basis by which responsible authorities protect public health and the environment from the deleterious effects of wastewater based on the best treatment technology economically achievable. The current national discharge standards should be reviewed periodically and made compatible with existing realities in the country [35]. Elaborate monitoring studies and data collection about water quality, water use and reuse patterns, and dilution and assimilation capacity of the receiving water bodies should be carried out. This should serve as the basis for defining effluent limit values.
- iv. Pilot scale demonstration studies should be performed using low-cost, natural treatment systems, such as wetlands, to remove nutrients and other pollutants. The use of such systems will avoid the use of synthetic fertilizers, and also create a good habitat for animal species living in the vicinity [36].
- v. Recently, the use of multi-level contact oxidation process (MLCOP) to treat high strength wastewater has been practiced in many developing countries. Such innovative treatment systems should also be tested by Nigerian industries because they offer several advantages such as low operational costs, small footprints, less sludge generation, and high treatment efficiency [37].
- vi. The transfer of advanced or innovative wastewater treatment systems from industrialized nations should be done with extra care because this is a basic issue for failing wastewater technologies and policies in developing economies. According to a recent report by Garrone et al. [38], *“the adoption of advanced wastewater treatment technologies is made complex by the sunk nature of highly specific*

infrastructures, and the consequent exposure of utilities to political and institutional influences. In addition, it requires the involvement of various actors (utilities, suppliers, contractors), and is influenced by various stakeholders (communities, business users, citizens' associations) that generally have no aligned objectives".

- vii. For future research, one should use the Likert scale because it has the ability to capture specific respondent opinion and attitudes. Further, questions should be formulated for more than one stakeholder so that adequate comparison of the results and good interpretation of the results can be made from the responses.

3.7. Limitations of This Study

During the study period of 6 months, it was rather difficult to obtain information from all regulated facilities, and hence this study was limited to a small respondent population. Effluent discharge reports from industries in the food and beverages sector could not be obtained due to the fact that these industries rarely analyze the quality of their wastewater before discharge. Presumably, easy access to a few effluent reports would have given a clear insight into the problematic parameters in the discharge of these facilities and might have allowed for a better suggestion of "end-of-pipe" treatment technologies. Due to privacy concerns, the interests of the industries in energy generation and conservation, and the willingness of the facilities to share pertinent information on their existing treatment systems, were avoided in the questionnaire and the interview questions. Nevertheless, it is noteworthy to accept the fact that the lack of adequate industrial wastewater treatment facilities is common in developing countries due to scarce scientific knowledge and understanding on the potential human and ecosystem health risks posed by the release of wastes and hazardous chemicals, inadequate governmental support, and non-functioning policies and guidelines. In the future, focus should be placed on identifying and demonstrating pilot-scale environmentally sound technologies and management practices, primarily with an aim to prevent pollution and recover resources from waste, and applying the concepts of cleaner production.

4. Conclusions

The results from this study show that the poor management of industrial wastewater has resulted in environmental and health problems in Nigeria, and that the institutional and regulatory frameworks set up by the government to tackle these problems, for the most part, have always remained ineffective. This study also showed that the staff of the main environmental regulatory agency are not well-informed about the regulatory activities of their agency, and do not have the (pre)requisite technical knowledge to carry out their daily duties. Further, over 50% of the interviewed industries do not have adequate wastewater treatment facilities and only half of the respondents showed some willingness to invest in these technologies. Furthermore, based on the findings from the literature and the interviews, some enabling conditions that can lead to improvement in decentralized wastewater management in Nigeria were identified. They are, amongst others, constant support from the government sector, improved legal and regulatory framework(s), increased capacity and skills of the regulators, and adequate financial arrangements for both implementation of environmental policies and for amending appropriate treatment technologies.

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Appendix A. Interview Questions to Staff from the National Environmental Standards and Regulations Enforcement Agency (NESREA)

1. Regulatory instruments

- What were the main factors that were considered before the effluent guideline limits for various sectors were fixed by the Agency?
- Were any baseline tests carried out before the limits were fixed? (Yes/No/Don't know)
- What type of baseline tests were carried out by the Agency?
- Do you think the regulations are reasonable and realistic for the country? (Yes/No/Don't know)
- Do you think the regulation has considered all the appropriate parameters? (Yes/No/Don't know)
- Do you think the parameters have actual importance for the desired protection of the intended water uses, without being excessive or inadequate? (Yes/No/Don't know)
- Were stakeholders such as the manufacturers and representatives of other regulated facilities consulted and involved in the drafting of the regulations? (Yes/No/Don't know)
- Is there room for future adjustments of regulations/parameters?

2. Challenges of compliance monitoring

- Do you think your Agency is sufficiently staffed and/or equipped to carry out its regulatory functions?
- What are some of the challenges faced in monitoring compliance of regulated facilities to wastewater discharge guidelines? (Poor regulations (standards)/Lack of technical know-how/Lack of monitoring equipment (e.g., laboratories, field equipment)/Attitude of regulated facilities)
- Do you carry on-the-spot analysis of wastewater during facility inspections? (Yes/Sometimes/No)
- What limitations/challenges do you perceive to be responsible for non-compliance by regulated facilities? (Please mention at least three).
- Is the polluter-pays-principle being implemented by your agency? (Yes/Partially/No/Don't know)

3. Enabling environment

- What can motivate regulated facilities to comply with stipulated wastewater guidelines? (e.g., technological assistance, financial incentives, more stringent penalties for non-compliance, etc.)
- What assistance does your agency currently render to regulated facilities to help them comply with stipulated wastewater discharge standards?
- What can be improved upon to increase enforcement/compliance? (Please mention at least three).

Appendix B. Interview Questions for Accredited Environmental Consultants

1. Institutional framework/regulatory instruments

- Do you think the wastewater discharge regulations are reasonable/suitable/realistic for the country?
- What are the limitations of these regulations?
- Do you think there is sufficient motivation for compliance to wastewater discharge standards by the regulated facilities?

- What is your assessment of the effectiveness of the regulatory agencies, with respect to regulatory instruments, equipment, technical knowledge, etc.?
- What are the hindrances to compliance by the regulated community?
- What are the hindrances to effective regulation and monitoring by responsible agencies?
- Do you think corruption is a contributing factor to unsuccessful enforcement by the regulators or non-compliance by the regulated facilities?

2. Enabling environment

- What should be improved on (from the governments side) to enhance wastewater management in regulated facilities in terms of the following key aspects, (a) frequency of inspections, (b) more stringent penalties for defaulters, (c) technical support to facilities, and (d) financial incentives such as tax rebate, etc.?

Appendix C. Interview Questions for Regulated Facilities

- How much water is consumed per day or per production batch in your facility?
- How much wastewater is being discharged?
- Is there mixing of wastewater with storm water?
- What is your wastewater discharge channel?
- What is the discharge pattern (continuous or intermittent; duration and frequency)?
- Where is the final discharge destination (water body, adjacent land, soak away)?
- Do you have wastewater treatment facilities? If yes, when was it built?
- What type of treatment(s) do you presently carry out?
- Are you concerned about the efficient operation of your treatment system(s)?
- Do you ensure regular operations and maintenance?
- Do you analyze the quality of your wastewater before final discharge?
- What is the average budget on wastewater management per month/quarter?
- Are you aware of the adverse impacts of improper wastewater management?
- How much do you know about National regulatory limits? Does your company have a copy of these standards, their limits?
- What is your perception about the regulatory instruments (such as standards, compliance monitoring, etc.)?
- How willing are you to comply with stipulated discharge limits?
- Have you received any complaints from neighbors or other residents in your community about nuisance resulting from your wastewater discharge?
- What are the major challenges of your facility with regard to compliance with stipulated wastewater discharge standards (if any)?
- In what area(s) do you need help for improving wastewater management?
- What is your opinion on government regulations/enforcement process? Provide some suggestions for improvement.
- Would you be willing to invest in wastewater management technologies in the presence of adequate technical guidance/support?

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