The Developing Economies, XXXIX-4 (December 2001): 395–431

TECHNOLOGY INVESTMENT IN POLLUTION CONTROL IN SUB-SAHARAN AFRICA: EVIDENCE FROM NIGERIAN MANUFACTURING

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I. INTRODUCTION

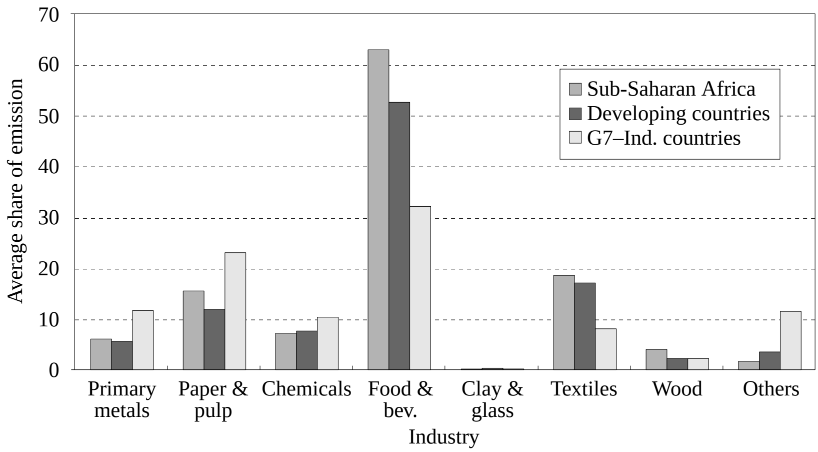
Investigations on the impact of environmental regulation in developing countries are often devoted to regulatory achievement (or otherwise) of emission reduction.[1] However, the underlying technological impact that determines the efficiency and nature of emission reduction has not been emphasized. Departing from this trend, this paper focuses on the technological impact of environmental policy in a sub-Saharan African country. Sub-Saharan Africa represents one of the regions where environmental regulation is an emerging phenomenon. In the case of industry, Nigeria is one of the developing countries where some regulatory measures have been implemented to promote the environmental performance of firms. Water pollution control has been identified as a top priority area in environmental protection, and it is a domain where countries usually develop initial capabilities for environmental regulation (Dasgupta, Lucas, and Wheeler 1998, p. 3; Hettige et al. 2000, p. 455). In this regard, we have selected two water pollution–intensive Nigerian manufacturing sectors; viz., food & beverages and textiles. As Figure 1 demonstrates, the two sectors are representative of industrial organic water pollution–intensive sectors in all countries, irrespective of the level of development. For developing countries in particular, the two sectors are relatively more notorious generators of industrial wastewater.

The challenge of industrialization remains daunting in many developing coun-

I wish to gratefully acknowledge the financial support of the African Economic Research Consortium (AERC), Nairobi, Kenya for the research reported in this paper. I thank René Kemp, Lynn Mytelka, Anthony Arundel, and Robin Cowan for their comments/suggestions on the initial draft. I am grateful to two anonymous referees for their comments and suggestions. I also thank Banji Oyeyinka and G. O. A. Laditan of the Nigerian Institute of Social and Economic Research (NISER), Ibadan, Nigeria for their kind support during the fieldwork aspect of the research from which this paper is drawn. The views expressed in the article are those of the author and neither the United Nations University, Institute for New Technologies (UNU/INTECH) nor the AERC bears responsibility for them.

[1] For example, see Hettige et al. (1996); Aden, Ahn, and Rock (1999); and Afsah, Blackman, and Ratunanda (2000).

Fig. 1. Industry Shares of Emissions of Organic Water Pollutants, 1993



Source: Based on data from World Bank (1998).

tries, especially in Africa. Though the experiences of some newly industrializing countries of Southeast Asia have demonstrated that there are opportunities (Perez and Soete 1988) for catching-up that may not take the conventional path of traditional industry, development essentially remains a process with the industry, particularly traditional manufacturing enterprises, at its core. Accordingly, for countries of sub-Saharan Africa, traditional manufacturing remains a major focus in the development strategy. Moreover, the apparent relatively low level of physical and human capital makes the leap into advanced manufacturing activities and production of high technology goods difficult. Thus, there is ample evidence that the manufacturing industry in these countries focuses on relatively low-technology industrial production activities (Stewart, Lall, and Wangwe 1992; Jalilian, Tribe, and Weiss 2000). Among the manufacturing sectors in this category, the food & beverage and textile sectors are prominent. To illustrate this aspect for some selected sub-Saharan African countries for which data are available, except for South Africa, the two sectors generally accounted for more than 40 per cent of manufacturing value added in 1995 (see Table I). Thus, while it can be argued that sub-Saharan Africa has experienced "deindustrialization" in recent decades (Lall 1999; Jalilian and Weiss 2000), the contribution of these two sectors to environmentally unsustainable industrialization may be quite significant if appropriate technical change to mitigate or prevent pollution is not adequately encouraged. Figure 2 depicts the relative importance of the two selected organic water pollution–intensive sectors in Nigerian manufacturing.

In the following section, we give a brief overview of the environmental regulatory framework for industrial water pollution control in Nigeria. Section III pre-

TABLE I

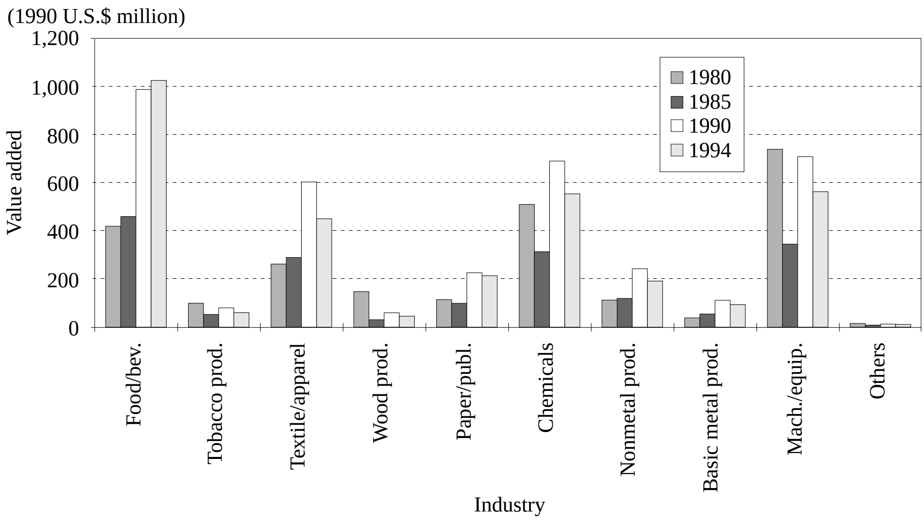
MANUFACTURING VALUE ADDED OF FOOD & BEVERAGE AND TEXTILE SECTORS OF SELECTED SUB-SAHARAN AFRICAN COUNTRIES IN 1995

(U.S.$ Million)

Country	Manufacturing Sector			Total Manuf.	Share of VA in Total VA (%)		
	F&B[a]	Textile	F&B+Textile		F&B[a]	Textile	F&B+Textile
Cameroon	159	90	249	539	29.5	16.7	46.2
Côte D'Ivoire	306	152	458	1,395	21.9	10.9	32.8
Kenya	336	47	383	814	41.3	5.8	47.1
Nigeria	2,595	823	3,418	7,884	32.9	10.4	43.4
South Africa	4,688	923	5,611	29,071	16.1	3.2	19.3
Zambia	163	44	207	450	36.2	9.8	46.0
Zimbabwe	589	136	725	1,670	35.3	8.1	43.4

Source: Extracted from data in UNIDO (1997).
[a] Food & beverage sector.

Fig. 2. Structure of Nigerian Manufacturing Value Added, 1980–94



Source: Based on data in UNIDO (1996).

sents our main hypothesis and a graphical description of important issues in the underlying theoretical framework. Section IV describes the nature and source of our data. In order to emphasize the importance of the two water pollution–intensive sectors in Nigerian manufacturing, detailed current characteristics of the two sectors are given in Section V. This is expected to show that in spite of the recent claims of "deindustrialization" in sub-Saharan Africa, the two sectors have been active in Nigeria and pose a significant challenge to policies aimed at stimulating firms' technology investment in pollution control. It is important to emphasize that technology adoption is used in this paper as a proxy for technology investment. The current trends in the adoption of environmentally benign technologies for industrial water pollution control are presented in Section VI and the final section concludes the paper.

II. ENVIRONMENTAL REGULATORY FRAMEWORK FOR INDUSTRIAL WATER POLLUTION CONTROL IN NIGERIA

Environmental regulation related to industrial waste management and pollution control did not attract adequate attention until the establishment of the Federal Environmental Protection Agency (FEPA) in 1988 as a result of the discovery of 3,888 tons of toxic wastes of Italian origin in the Nigerian harbor of Koko (Nigeria, FEPA 1991b). The agency became the Federal Ministry of Environment (FME) with a full cabinet minister in January 2000. The FME is responsible for determining permissible industrial effluent standards, and accordingly, for formulating regulatory laws, which the National Assembly[2] subsequently examines, and passes into law. In addition, the FME is responsible for monitoring firms' compliance with the regulatory standards, while at the same time assisting in the building of capacity for environmental regulation at the level of state environmental protection agencies (SEPAs).[3] The SEPAs are directly responsible for compliance monitoring of industrial firms located within their respective states.

The instrument for industrial water pollution control in Nigeria is essentially "command and control (CAC)" in nature. It specifies technology[4] adoption for firms' compliance with statutorily permissible levels of wastewater effluent parameters. The basic law is the 1991 composite law designated as National Effluent Limitation Regulation (S.I.8 of 1991), and Pollution Abatement and Facilities Generating Wastes Regulation (S.I.9 of 1991). This law makes it mandatory for Nigerian manufacturing firms to install pollution abatement equipment or make provision for effluent treatment, and prescribes maximum limits of effluent parameters (Nigeria, FEPA 1991a, 1995; Laditan 1998). Penalties attached to noncompliance range from fine

[2] As in 1988, Nigeria was under the rule of a military government, a committee of the ruling junta called Armed Forces Representative Council symbolically represented the National Assembly.

[3] Nigeria is a federation consisting of thirty-six states and a federal capital territory (FCT). There is a national FEPA, which at the end of 1999 became the Federal Ministry of Environment (FME). Each state and FCT have a state environmental protection agency (SEPA). While FME enacts laws and is the most important agency of industrial pollution control in Nigeria with respect to the establishment of pollution control laws and compliance monitoring, the SEPAs are in charge of direct compliance monitoring at the state or local levels.

[4] In the usual tradition of technology forcing standards under a CAC regulatory regime, the Nigerian industrial water pollution control law stipulates the "best available technology (BAT), or best practicable technology (BPT), or technology that limits emissions to the uniform effluent standards (UES)" for adoption by the manufacturing enterprises.

to imprisonment of liable persons and closure of contravening industrial plants. Though the S.I.8/S.I.9 law became effective in August 1991 when it was enacted, companies were however granted a three-year moratorium (which expired in December 1994) to implement necessary technical change that would enable compliance.[5]

III. THEORETICAL FRAMEWORK

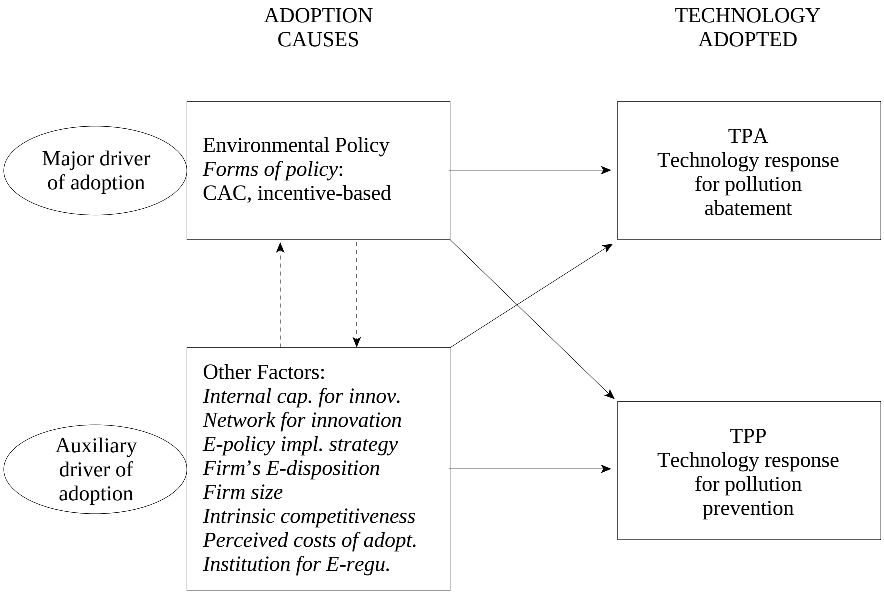
Traditional economic theory affirms that, because of the trade-off between private costs and social benefit of a firm's environmental investments, firms will not implement technical change to prevent or control pollution unless compelled to do so (Baumol and Oates 1988; Palmer, Oates, and Portney 1995). Though this mainstream economic concept has been disputed in recent times by the so-called win-win notions on the compatibility of environmental performance and competitiveness of firms (Porter and Linde 1995; Bonifant, Arnold, and Long 1995), we nonetheless postulate that environmental policy is the *major driver* of the adoption of environmentally benign technologies by firms. This is because the new divergent views have never denied the important role of environmental policy in stimulating technology adoption for pollution control. Besides, it also appears that much empirical justification is still needed for the point of divergence (Jaffe et al. 1995; Repetto 1995). As Figure 3 shows, we however recognize that other factors,[6] which we have designated as *auxiliary drivers* could also play important roles in stimulating technology adoption that reduces external diseconomy of manufacturing firms.

As shown in Figure 3, we have classified environmentally benign technologies (EBTs) into two groups; viz., firm's technology response for pollution abatement (TPA) and firm's technology response for pollution prevention (TPP). TPA represents the conventional end-of-pipe technologies. In industrial water pollution–intensive sectors, for the TPA, industrial wastewater treatment plants are generally employed (UNEP 1993; UNIDO and MITI 1995; Bartzokas and Yarime 1997; TEP 1999). Wastewater treatment plants are classified into three main categories: plants for primary wastewater treatment, biological or secondary wastewater treatment, and advanced or tertiary wastewater treatment. The primary wastewater treatment facility is the minimum that guarantees some reduction in pollutant load of wastewater effluent. The biological system incorporates a secondary treatment that ensures more efficient reduction in the organic load of effluents, while the tertiary

[5] For more details on environmental regulation and policy in Nigeria, see Adeoti (1999) and Okorodudu-Fubara (1998).

[6] These other factors may include internal capability for innovation, external network for innovation, firm size, firm's environmental disposition, intrinsic competitiveness, perceived costs of adoption, institutional framework for environmental regulation, and the environmental policy implementation strategy.

Fig. 3. Framework for the Analysis of the Adoption of Environmentally Benign Technologies



system introduces advanced treatment techniques or chemical reactions that ensure the removal of substances, which the secondary treatment is not normally able to remove. TPP refers to process integrated techniques or measures aimed at reducing pollution at the source. This is in agreement with the concept of cleaner production, which requires that pollution be reduced at the source and, where possible, eliminated from industrial production processes (Skea 1994; UNEP 1997). In this paper, four types of TPP are considered; viz., water or/and wastewater recycling, raw material reuse or recycling, changes in raw material input(s), and integrated physical devices aimed at improving water use economy in the production line.

As already indicated in Section II, industrial waste management and control became entrenched in Nigeria with the establishment of the Federal Environmental Protection Agency (FEPA) as a national institution for determining and formulating effluent and regulatory standards for industrial pollution control. With respect to industrial water pollution, the National Effluent Limitation Regulation (S.I.8 of 1991) and Pollution Abatement and Facilities Generating Wastes Regulation (S.I.9 of 1991), which became law in August 1991, are the main regulatory instrument (Nigeria, FEPA 1991a; Laditan 1998). Based on the assertion that environmental policy is the major driver of adoption, the main hypothesis to be investigated in this paper could thus be stated as: *the introduction of the S.I.8/S.I.9 environmental regulatory law has led to the adoption of water pollution control technologies in the Nigerian manufacturing industry*. Technology adoption in this context will be limited to evident introduction of EBTs as part of a firm's strategy to control industrial wastewater pollution. By implication, an adopter firm has made actual technology investment in EBT(s). Furthermore, our analysis shall not include the examination of phases or stages of technology adoption such as those described by Rogers (1983, pp. 163–209), Biemans (1992, pp. 41–45), and Preece (1995). It is also important to state that this paper does not intend to test the strength or weakness of the Nigerian environmental regulatory regime. Neither do we intend to provide evidence on the effectiveness (or otherwise) of the environmental policy in achieving pollution load reduction. Our objective is to demonstrate whether or not the existing environmental policy instrument has exerted some technological impacts on water pollution control in the Nigerian industry. The following section describes the nature and source of our data sample.

IV. DATA SAMPLE

The data used in this paper were obtained from a recent survey[7] of firms in the Nigerian food & beverage and textile sectors using a structured questionnaire. Some detailed case study interviews[8] were also conducted to gain a deeper insight into the information obtained by the use of the structured questionnaire. The case study interviews involved twelve firms (ten food & beverage and two textile firms), and were carried out by the author himself. The key questions in the structured questionnaire are presented in an Appendix to this paper. The survey was part of a doctoral research project sponsored by the United Nations University, Institute for New Technologies (UNU/INTECH) and the African Economic Research Consortium (AERC). Within the resources available for the research, it was not possible for the researcher to travel to major industrial centers in the northern and eastern parts of Nigeria.[9] During the fieldwork, the researcher was based at the Nigerian Institute of Social and Economic Research (NISER), Ibadan, Western Nigeria. It should however be noted that most of the Nigerian manufacturing enterprises are located in Western Nigeria. Some estimates claim that 60–70 per cent of the Nigerian industries are located in Lagos State[10] alone (Lubeck 1992, p. 17; LASEPA 1999). The researcher and two trained assistants distributed and retrieved the questionnaires by hand in Western Nigeria, while several mailed questionnaires in addition to repeated telephone calls were used to collect data from firms in other parts of Nigeria.

7 The survey was carried out from November 1999 to April 2000 inclusive (see Adeoti [1999] for a detailed description of the survey procedure/activities).

8 See Adeoti (1999) for a detailed description of how the twelve case study firms were selected.

9 According to the kilometer chart for Nigerian cities presented in NISER (2000), Ibadan is located at a distance of 1,009km, 759km, and 863km, respectively from the Northern Nigerian industrial cities of Kano, Kaduna, and Jos, and 526km and 625km, respectively from the Eastern Nigerian industrial cities of Enugu and Port Harcourt.

10 Lagos State, located in Western Nigeria, is the Nigerian major industrial center.

The firms selected for the survey are those listed in the directory of Manufacturers Association of Nigeria (MAN),[11] and other formal-sector manufacturing firms that we located using address lists provided by State Environmental Protection Agencies. From preliminary fieldwork carried out in the month of January 1999, it was revealed that environmental regulatory activities in Nigeria are yet to target small-scale enterprises, especially in the informal sector of the economy. The focus of regulation and compliance monitoring was (and still is) on formal-sector manufacturing enterprises, particularly those in the medium- and large-scale enterprises categories, which is in agreement with the generally observed trend in developing countries. Environmental regulation related to industrial pollution control in developing countries focuses more on well-established formal-sector medium- and large-scale enterprises because they are assumed to have the capability and resources to technologically respond to demands for pollution abatement or prevention. Moreover, due to social welfare considerations arising from employment generation effects of small-scale industrial facilities, regulatory authorities either ignore them or are extremely lenient on them (Blackman and Bannister 1998; Dasgupta 2000; Adeoti 2000). Thus, the research from which this paper draws focused largely on Nigerian formal sector firms, particularly the medium- and large-scale manufacturing plants.

In the literature, firms have been classified into small-, medium- and large-scale enterprises, either based on sales turnover, capital outlay, or number of persons employed. In Africa, according to Lall et al. (1994) and Oyelaran-Oyeyinka (1997b), firms employing less than 10 persons are considered to be micro-enterprises. Firms employing 10 to 49 persons are usually considered to be small-scale, 50 to 199 medium-scale, and firms employing 200 or more persons are considered to be large-scale firms (Winston 1981; Liedholm 1992; Oyelaran-Oyeyinka 1997a). The Nigerian Federal Office of Statistics (Nigeria, FOS 1998)[12] gave detailed statistics of the firms employing 10 or more persons in Nigeria, in which 55 per cent of the firms employing 10 or more persons in the food processing industry belonged to the category employing between 10 and 19 persons. However, for the textile sector, only 18 per cent of the firms employing 10 or more persons belonged to the category employing between 10 and 19 persons. Moreover, based on the MAN directory (MAN 1994), hardly any firm employed less than 20 persons.[13] In view of our decision to target formal-sector manufacturing firms, we intuitively concluded that it is unlikely that any of our respondent firms would be employing less than 20

[11] Manufacturers Association of Nigeria (MAN) is the foremost association of industrial organizations in Nigeria. Membership comprises formal sector firms in all the manufacturing sectors of the Nigerian economy. The MAN directory (1994) contains names, addresses, factory locations, and possible contact persons (in some cases) of about 2,000 Nigerian firms.

[12] This recently published survey report of the Nigerian Federal Office of Statistics (FOS) contains relatively detailed information on the Nigerian manufacturing industries. However, the report covers only the years 1991 and 1992.

[13] Some of the firms listed in the MAN directory indicated the number of persons employed.

TABLE II

DISTRIBUTION OF FIRMS IN FOOD & BEVERAGE AND TEXTILE SECTORS IN 1992 ACCORDING THE NUMBER OF PERSONS EMPLOYED

Sector	20–49 Persons	50–199 Persons	200 and More Persons	Total	Total (MAN)[a]
Food & beverages	217	99	68	384	286
Textiles	18	20	47	85	67
Total	235	119	115	469	353

Sources: Extracted from data in Nigeria, FOS (1998, p. 10), MAN (1994).
[a] This total is based on the number of formal-sector firms listed in the 1994 MAN directory.

persons. For the purpose of this paper, we therefore defined small-scale firms as firms employing 20 to 49 persons; and following Winston (1981) and Liedholm (1992), we considered medium-scale firms to be those employing 50 to 199 people. Companies employing 200 or more people were considered to be large-scale enterprises. For the two sectors under investigation, Table II shows the distribution of the manufacturing firms in these categories.[14]

The MAN directory listed 286 food & beverage firms and 67 textile firms. Since the MAN directory was published in 1994 and the FOS statistics (Nigeria, FOS 1998) refer to the 1992 country-wide industrial survey, we did not anticipate that there would be much discrepancy in the figures from the two sources. However, as Table II shows, discrepancies should not be overlooked.[15] Our enquiries and discussions with MAN officials revealed that not all Nigerian formal sector manufacturing firms belonged to MAN because MAN is a voluntary association. Thus, the FOS survey could have captured other firms not listed in the MAN directory. Besides, the rate of firms abandoning and becoming engaged in manufacturing activities in the two sectors might have had a negative sum due to the uncertain economic conditions arising from the Nigerian 1993/94 political problems.[16] At any rate, the MAN directory was used as a guide, but without limiting the selection of firms to the directory. As previously indicated, regulatory agencies (FME and relevant SEPAs)

14 According to Nigeria, FOS (1998), in 1992 a total of 5,203 manufacturing firms employed ten or more persons in Nigeria, out of which 929 (18%) belonged to the food & beverage industry, and 115 (2.2%) to the textile industry. It should, however, be noted that whereas the food & beverage sector has a relatively large number of small and micro-enterprises, medium- and large-scale firms dominate the textile sector.

15 Like in most of the countries of sub-Saharan Africa, secondary statistical information is difficult to obtain in Nigeria; and when found, there could be significant discrepancies in information from different sources. Mosley (1992) and Thoburn (2000) also confirmed this fact.

16 There was a serious political problem starting from mid-1993 when the ruling military junta annulled a widely accepted election of a civilian president. The period 1993/94 thus corresponded to a period of high political instability in Nigeria.

were consulted for their working lists of firms, which we used as supplements to the MAN directory.

Since it was difficult to ascertain the actual number and distribution of existing firms, the survey was extended to all the firms in the two sectors, which deprived us of the benefit of a stratified sample that may follow a predetermined population distribution. We distributed questionnaires to a total of 337 firms and successfully retrieved 130 questionnaires, out of which 122 were found to be useful for our research.

In addition to the foregoing, a semi-structured questionnaire was also given to environmental regulators in order to obtain information that may complement the views expressed by firms so that we may gain a deeper and relatively fair understanding of firms' responses. We were able to retrieve forty-four useful questionnaires from environmental regulators distributed across FME and SEPAs.

Having described the nature and source of our data set, in the next section, our findings are presented with the characteristics of the two water pollution–intensive sectors under investigation.

V. CHARACTERISTICS OF THE MANUFACTURING SECTORS

The characteristics of the Nigerian food & beverage and textile sectors presented in this section are based on the findings of our field survey. The two sectors are among the oldest manufacturing sectors in Nigeria (Forrest 1994). We will consider industry characteristics such as firm size distribution, affiliation to multinational enterprises (MNE), age in production, human and physical capital, sources of technological knowledge, and environmental management.

A. *Firm Size Distribution*

Table III shows the size distribution of the 122 sample firms in the two sectors according to our classification of small-, medium-, and large-scale industries. As expected, the size distribution was skewed in favor of medium- and large-scale firms in the two sectors. The bias was more pronounced in the textile sector apparently because of the generally higher minimum efficient scale in this sector compared to most of the food processing industries.[17] For example, the smallest food & beverage plant in our sample employed 23 persons, whereas the smallest textile plant employed 154 persons, and only two textile plants in the sample employed less than 200 persons. It is also noteworthy that the number of food & beverage firms was almost four times that of the textile ones. Table II shows that the number

[17] In addition, it is widely acknowledged that the textile industry is relatively more labor-intensive than other industries (see Mytelka [1985]). Since our size classification was based on the number of persons employed, it is thus more likely that the tendency towards a large firm size could comparatively be skewed to the textile firms.

TABLE III

DISTRIBUTION OF SAMPLE FIRMS ACCORDING TO SIZE

Sector	No. of Firms Employing			Total
	20–49 Persons	50–199 Persons	200 and More Persons	
Food & beverages	15 (16%)	35 (37%)	45 (47%)	95 (78%)
Textiles	0	2 (7%)	25 (93%)	27 (22%)
Total	15 (12%)	37 (30%)	70 (58%)	122 (100%)

Source: Author's field survey.
Note: Parenthesis: percentage of total.

TABLE IV

MULTINATIONAL COMPANIES' INVOLVEMENT IN NIGERIAN MANUFACTURING

Sector	No. of Firms Employing			Total MNE Affiliate	Total No. of Firms
	20–49 Persons	50–199 Persons	200 or More Persons		
Food & beverages	1	5	19	25 (26%)	95
Textiles	0	0	6	6 (22%)	27
Total	1	5	25	31 (25%)	122

Source: Author's field survey.
Note: Parenthesis: percentage of multinational enterprise affiliates in total number of firms.

of food & beverage firms in the actual population of our selected category of firms may just be between four and five times that of the textile firms.[18]

B. *Affiliation to Multinational Enterprises*

The involvement of multinational companies in Nigerian manufacturing in the two sectors is indicated in Table IV. As the table shows, about one-quarter of our sample firms were affiliates of multinational companies, and more than two-thirds of these were large-scale industries. It is necessary to mention that hardly any of the multinational affiliates belonged to the small industry category. The only company in this category was a technology-intensive beverage plant[19] producing an important intermediate product for the Nigerian beverage industry. None of the other multinational affiliates employed less than 100 persons. Among the twenty-five

[18] Table II, based on the FOS data (Nigeria, FOS [1998]), indicated that the number of food & beverage firms was 4.5 times that of textiles; while 4.3 times, when based on the MAN directory listing.

[19] This plant is the only one of its type in West Africa. In the sub-Saharan African industrial contextual setting, it would actually be classified as a large-scale industry, especially if sales turnover is used as criterion.

TABLE V

Age Distribution of Sample Firms (Reference Year: 2000)

Sector and Firm Size	No. of Firms with Age			Total
	1–10 Years	11–20 Years	> 20 Years	
Food & beverages				
SSI	5	6	4	15
MSI	7	20	8	35
LSI	4	14	26	44
Subtotal	16 (17%)	40 (43%)	38 (40%)	94 (78%)
Textiles				
SSI	0	0	0	0
MSI	0	1	1	2
LSI	0	7	18	25
Subtotal	0	8 (30%)	19 (70%)	27 (22%)
Total	16 (13%)	48 (40%)	57 (47%)	121[a] (100%)

Source: Author's field survey.
Notes: 1. SSI = small-scale industry; MSI = medium-scale industry; LSI = large-scale industry.
2. Parenthesis: percentage of total.
[a] There is one missing value, hence the total number here is 121 firms.

food & beverage multinational affiliates, fifteen (60 per cent) had North American-based parent companies, while ten (40 per cent) were affiliates of Western European-based firms. All the textile firms with multinational affiliation had either India or China-based parent companies.

C. *Distribution of Age in Production*

Another interesting characteristic of the sample firms was the age distribution of the plants, with 2000[20] as the reference year. As Table V shows, nearly half of the sample firms were older than twenty years, with 40 per cent being between eleven and twenty years old, and just a little above one-tenth being ten years old or less.[21] It is however necessary to state that we excluded all the firms that were not established before 1994 from our sample because our objective was to determine the influence of the S.I.8/S.I.9 law (enforced from January 1995) on firms' technology responses for industrial water pollution control. The age distribution for the food & beverage firms was slightly different from that of total firms with a fewer proportion (40 per cent) in the older than twenty-year category, and a relatively higher

[20] The year when the survey was carried out.

[21] Age indicated by firms in the questionnaire refers to the years of first establishment. We did not bother to take into consideration incidences of temporary closure due to economic reasons. Cases of temporary plant closures or very low capacity utilization have not been uncommon since the mid-1980s, when the World Bank structural adjustment program was introduced (see Lall [1999]).

TABLE VI
AGE DISTRIBUTION OF MNE AFFILIATES VS. LOCAL FIRMS

Type of Firm	No. of Firms with Age			Total
	1–10 years	11–20 Years	> 20 Years	
MNE affiliates	2 (7%)	12 (40%)	16 (53%)	30 (25%)
Local firms	14 (15%)	36 (40%)	41 (45%)	91 (75%)
Total	16 (13%)	48 (40%)	57 (47%)	121[a](100%)

Source: Author's field survey.
Note: Parenthesis: percentage of total.
[a] There is one missing value in the MNE affiliates, hence the total number here is 121 firms.

proportion in the ages one–ten years (17 per cent) and eleven–twenty years (43 per cent). No plants more than ten years old were included in the textile sample, and 70 per cent of the firms were older than twenty years. This may be an indication that in the last decade, few or no new firms were established in the textile sector, whereas the food & beverage sector had new firm entrants. Overall, only two plants in the sample were older than forty years, indicating that industrial production activities in Nigeria are largely a post-independence experience.[22] In addition, it appears that the relatively older firms were the largest plants. This is not unexpected because older firms would normally have grown, and perhaps overcome the difficulties that would have led to their disappearance.

Furthermore, Table VI demonstrates that whereas more than half of the MNE affiliates were older than twenty years, most of the local firms[23] were below twenty years of age.[24] This could be an indication that MNE investment in Nigerian manufacturing had declined since the end of the oil boom years.[25] At any rate, the trend appears to confirm the findings of Lall et al. (1994) in which they reported in their study of Ghanaian industries under economic structural adjustment that newer firms were local firms.

D. *Human and Physical Capital*

For the food & beverage and textile firms in our sample, the smallest plants em-

22 Nigeria obtained her political independence from Britain on October 1, 1960. It is widely acknowledged that prior to independence, foreign merchant firms dominated the modern sector in Nigeria. Modern manufacturing activities became a notable feature of the Nigerian economy after independence (see Biersteker [1987]; Forrest [1994], and Bevan, Collier, and Gunning [1999]).

23 The term local firms should not imply that these firms do not have foreign capital or human resources. They are only "local" in the sense that they are not MNE affiliates; in fact, a large number of them have foreign technical partners.

24 In addition to the statistics in Table VI, note also that the median age of the firms was twenty years.

25 For Nigeria, the oil boom years approximately corresponded to the period from 1972 to 1981, when relatively large revenues were obtained through exports of crude oil.

TABLE VII

LOCAL AND FOREIGN SKILL INTENSITY RATIOS OF THE RESEARCH SAMPLE FIRMS

Factor and Statistics	Food & Beverages	Textiles	Pooled Sample
Local skill intensity ratio			
Mean	0.126	0.016	0.113
Median	0.098	0.014	0.086
Minimum	0.012	0.013	0.012
Maximum	0.714	0.135	0.714
Foreign skill intensity ratio			
Mean	0.008	0.068	0.010
Median	0.006	0.063	0.008
Minimum	0.000	0.002	0.000
Maximum	0.086	0.032	0.086

ployed 23 and 154 persons, respectively, while the largest plants employed 3,000 and 3,211 persons, respectively. Since engineering and scientific skills play a very important role in production, we calculated a skill intensity ratio for the sample firms in order to estimate the depth of the engineering and scientific skills involved in the firms. The skill intensity ratio is the ratio of the number of engineering and scientific staff members employed to the total number of persons employed by a firm. In this respect, we calculated the local skill intensity ratio based on the number of Nigerian engineers, technicians and scientists employed, and the foreign skill intensity ratio based on the number of foreign engineers, technicians and scientists employed.

As Table VII shows that the highest and lowest local skill intensity ratios of 0.714 and 0.012, respectively were recorded in the food & beverage sector. However, the highest local skill intensity ratio for the textile firms was only 0.135. For the two sectors pooled together, the mean local skill intensity ratio was 0.113, while the median was 0.086. Thus, whereas the mean for the textile sector (0.016) was lower than the pooled sample mean, the mean for the food & beverage sector (0.126) was higher than that of the pooled sample. This indicates that, though the lowest local skill intensity ratio may be found in the food & beverage sector, there may generally be a relatively lower local skill intensity in textile firms in Nigeria when compared to the food & beverage sector. However, in terms of the qualification for plant management, no appreciable difference between the two sectors was detected. Our field data revealed that over 80 per cent of the firms in the two sectors were run by managers with at least a university degree or higher education diploma.

As for the foreign skill intensity ratio, the minimum of zero was found in the food & beverage sector. In fact, 41 per cent of the plants in the food & beverage sector did not employ foreign (non-Nigerian) engineers or scientists. However, the highest foreign skill intensity ratio of 0.086 was also found in the food & beverage

TABLE VIII

MEAN PROPORTION OF WORKERS ACCORDING TO THEIR EDUCATIONAL QUALIFICATION

(%)

Workers with	Food & Beverages	Textiles	Pooled Sample
Higher education	29	23	27
Secondary education	54	64	57
Primary education	17	13	16

Source: Author's field survey.

(see Table VII). The mean and median for the food & beverage sector were nevertheless below the mean and median for the pooled sample. All the textile firms included foreign skill input in our sample; the foreign skill intensity ratio statistics were generally above the corresponding pooled statistics, except for the maximum skill intensity ratio, which did not exceed 0.032. Thus, while textile plants in our sample may generally display a higher foreign skill intensity than the food & beverage firms, the most foreign skill-intensive firms nevertheless belonged to the food & beverage sector. Since we had previously observed that food & beverage firms generally have a higher local skill intensity, this may be an indication that relatively less skill-intensive food & beverage firms have been able to successfully substitute local for foreign skills.

Generally speaking, we may deduce from the foregoing that whereas the food & beverage plants in our sample used relatively more local scientific and technical skills, the textile plants used relatively more foreign scientific and technical skills for their production activities. This may help to explain our findings in Table VIII, which indicates that the food & beverage firms have a relatively more educated Nigerian workforce than the textile firms. Besides, this is expected because the food processing industry requires strict hygienic control, which may perhaps necessitate a relatively highly educated and enlightened workforce. Such a workforce may however not necessarily include a substantial foreign element.

As for the physical capital in the two sectors, most of the sample firms sourced their main capital equipment from abroad (see Table IX). The situation was however more pronounced in the textile sector, which indicated that almost all the sample firms used exclusively imported foreign technology equipment for their main production. This is not surprising because the Nigerian capital-goods sector is known to be relatively underdeveloped (Oyelaran-Oyeyinka 1997a; Okejiri 2000). More than two-thirds (73 per cent) of the food & beverage and about two-thirds (67 per cent) of the textile firms indicated that the foreign equipment originated from Western Europe. However, in the food & beverage sector, some locally manufactured capital goods were used.

The present vintage years of the main physical production equipment in the food

TABLE IX

Source of Main Production Equipment

Source	Food & Beverages	Textiles	Pooled Sample
Locally fabricated	3 (3%)	0	3 (2%)
Combination of local and foreign equipment	28 (30%)	1 (4%)	29 (24%)
Exclusively foreign technology equipment	64 (67%)	26 (96%)	90 (74%)
Total	95 (100%)	27 (100%)	122 (100%)

Source: Author's field survey.
Note: Parenthesis: percentage of total.

& beverage sector ranged from a minimum of two to a maximum of thirty-six years with a mean of fifteen years. In the case of the textiles, they ranged from a minimum of five to a maximum of thirty-five years with a mean of nineteen years. The production technology was acquired in the open market in 91 per cent of the cases that responded. There were no joint ventures; only 5 per cent acquired technology through licensing,[26] all in the food & beverage sector.

The unweighted average current[27] capacity utilization in the pooled sample was 49.5 per cent (the minimum was 10 per cent and the maximum was 100 per cent). Though the mean appeared to be relatively low, it was however above the industry average which had never exceeded 40 per cent in recent years (Okejiri 2000; MAN 2000; Akinbinu 1997), indicating that our sample was skewed towards comparatively healthy firms in the Nigerian manufacturing sector. It should nevertheless be noted that the textile firms in the sample appeared to be relatively more active with an unweighted average capacity utilization of 55.2 per cent, whereas the unweighted average capacity utilization of the food & beverage sector was 47.9 per cent.

E. *Sources of Technological Knowledge*

Based on the results of the survey, it appeared that important sources of technological knowledge or innovation for most of the firms in the pooled sample included suppliers of the main production technology or equipment, firm's in-house R&D, and firm's foreign technical partners. The most important source of technological knowledge or innovation was represented by firm's in-house R&D. It should however be noted that, the detailed interviews in our case study confirmed the fact that R&D in the conventional sense was minimal in Nigerian manufacturing. What most of the firms indicated as R&D included only technical activities targeted at adapting and maintaining existing technology to suit local production conditions or

[26] Note that the balance of 4 per cent corresponds to missing values.
[27] At the time of the survey (i.e., November 1999 to April 2000).

requirements. It should also be noted that, when the textile sample was treated separately, the supplier of the main production technology was not an important source of technical knowledge. Regarding technical solutions to industrial water pollution problems, firm's in-house R&D appeared to be the most important source of technological knowledge for the food & beverage sample, while the textile sample indicated that foreign technical partners were the most important source. This may be related to the fact that the textile wastewater effluent is more difficult to handle compared to the food & beverage effluent;[28] and hence textile firms may be prone to consulting their foreign technical partners to solve wastewater effluent treatment problems.

F. *Environmental Management*

From the perspective of the sample firms, more than 70 per cent of the plant managers or their representatives rated current top management commitment to environmental management as high or top priority. Understandably, this rating might have been exaggerated. From our discussions with regulators, though firms had generally made considerable improvement in their commitment to environmental management, only the management of some MNE affiliates was considered to deserve such a high performance rating. In the case of MNE affiliates, 43 per cent claimed that the standard of their environmental management in Nigeria was lower than that of their parent company, 54 per cent claimed that it was the same, while 3 per cent claimed that it was higher.

As for the impact of the S.I.8/S.I.9 law, 83 per cent of the respondents stated that their commitment to environmental management before its enforcement in January 1995 ranged from very low to moderate, while 66 per cent claimed their commitment after January 1995 ranged from high to very high. Again, the commitment after January 1995 might have been exaggerated. We may only suggest that the responses indicated that the enforcement of the S.I.8/S.I.9 law had apparently raised the level of firms' commitment to environmental management.

Almost all the respondents claimed that they discussed technical solutions to pollution problems with the regulators, and more than three-quarters rated regulators' technical suggestions from useful to very useful. More than 80 per cent of the respondents stated that the attitude and disposition of the regulators to compliance monitoring were cooperative. About the same proportion also indicated that they never had any disagreement with the regulators about the most appropriate compliance technology or method of water pollution control. In addition, the regulators also disclosed that most of the firms cooperated in compliance monitoring and en-

[28] Whereas the food & beverage wastewater effluents contain largely organic load that can be treated with conventional biological methods, the textile effluent usually contains a substantial amount of chemical load that needs additional tertiary treatment.

forcement issues.[29] It is however necessary to add a caveat to these apparently favorable perceptions of regulator-industry relationship. From our discussions with plant managers and regulators, it appeared that the respondents were being extra-polite in their assessment of their relationship with the regulators. Generally speaking, plant managers considered that some regulators were antagonistic and not interested in the economic implications of their suggested technical solutions to water pollution problems. Thus, though the regulators also claimed to be friendly and normally adopted a persuasive approach to compliance enforcement, the situation may however not be as cooperative as depicted in the responses. Besides, 89 per cent of the respondents indicated that environmental regulation had led to substantial increases in their production costs in the last four years.

In the previous part of the paper, a fairly detailed descriptive analysis of the characteristics of the two selected Nigerian water pollution–intensive manufacturing sectors was given. On the whole, the features described indicated that the two sectors have been active in Nigeria despite recent experiences of "deindustrialization" in sub-Saharan Africa. The environmental performance of the firms in the two sectors could thus have significant implications for environmentally sustainable industrial development in Nigeria. In this regard, what has so far been achieved by these firms in terms of technical change in response to the imperatives of environmentally sustainable industrial development? The following section gives an overview of recently observed trends that may enable to answer this question, especially in terms of the technological impact of the S.I.8/S.I.9 law.

VI. TRENDS IN TECHNOLOGY INVESTMENT IN INDUSTRIAL WATER POLLUTION CONTROL

As expected, most of the respondents (81 per cent) in the survey acknowledged that the most important pollution issue in the two selected sectors was industrial wastewater. To confirm the validity of our hypothesis (presented in Section III), we analyzed the two possible categories of environmentally benign technical changes described in our theoretical framework.

[29] Our regulator survey showed that more than half of our respondents acknowledged that the attitude of most of the firms to compliance monitoring and enforcement was cooperative. More than two-thirds (73%) of the respondents also claimed that when disputes arose, the most important approach used for compliance was dialogue and persuasion, followed by issuance of warnings (17%), and court action/closure of plant (10%). Pecuniary penalty such as "fine" was not mentioned perhaps because it was not used. This may be due to the fact that the statutory specification in this respect is so small that it presently makes no sense. The S.I.8/S.I.9 law specifies a maximum fine of 500,000.00 naira (current U.S.$5,000.00) for a non-complying firm. This has never been reviewed to catch up with the trend in the gradual devaluation of the Nigerian currency.

A. *Technology Response for Pollution Abatement (TPA)*

In Section III we classified environmentally benign technologies into two categories: viz., TPA and TPP. TPA is the technology response for pollution abatement, while TPP is the technology response for pollution prevention. As previously explained, TPA with respect to water pollution control in the industry is represented by industrial wastewater treatment plants and 46 out of the 122 firms in our pooled sample claimed to have adopted TPA. As shown in Table X, 44 out of the 46 TPA adopters indicated the type of TPA used. Primary wastewater treatment accounted for about half of the TPA adoption, secondary wastewater treatment for 39 per cent, while advanced wastewater treatment for 13 per cent. Whereas about 60 per cent of TPA in the food & beverage sector consisted of primary wastewater treatment, only 16 per cent of TPA consisted of primary treatment for the textile sample. Only 3 per cent of TPA consisted of tertiary treatment in the food & beverage sector, while 42 per cent of TPA in the textile sector consisted of advanced wastewater treatment. Approximately 40 per cent of TPA in each sector consisted of secondary treatment. It thus appears that the trend in TPA adoption in the two sectors differed, in that most of the food & beverage firms were engaged in only primary treatment, whereas a relatively substantial number of textile firms was engaged in tertiary treatment. This might be related to the human capital factor and the sources of technological knowledge. As shown in Section V, the food & beverage firms relied more on local skills, and considered that in-house R&D was the most important source of technological knowledge for water pollution control. Primary wastewater treatment is not a sophisticated technology and can be carried out with local technical skills, which tend to prevail in the food & beverage sector. However, the relatively sophisticated tertiary wastewater technology, which is imported, has been more adopted in the textile sector. This might have been influ-

TABLE X

ADOPTION OF INDUSTRIAL WASTEWATER TREATMENT PLANTS IN NIGERIAN MANUFACTURING

Type of Industrial Wastewater Treatment Plant	Number Adopted		
	F&B[a]	Textiles	Total
Primary	19 (59%)	2 (16%)	21 (48%)
Secondary	12 (36%)	5 (42%)	17 (39%)
Advanced	1 (3%)	5 (42%)	6 (13%)
Total	32 (73%)	12 (27%)	44[b] (100%)

Source: Author's field survey.
Note: Parenthesis: percentage of total.
[a] Food & beverages.
[b] Out of forty-six TPA adopters only forty-four indicated the type of TPA adopted.

enced not only by the need for a more effective technology to handle textile effluents, but also by the fact that the firms in our textile sample considered that foreign technical partners were the most important source of technological knowledge for water pollution control.

Twenty (45 per cent) TPA adopters claimed to have adopted the technique before January 1995, while twenty-four (55 per cent) stated that they had adopted it after January 1995 (see Table XI). This gives the impression that the enforcement of the S.I.8/S.I.9 law in January 1995 might not have made a significant difference to firms' technology responses to mitigate industrial water pollution. However, the average period of TPA adoption in our pooled sample was seven years,[30] which indicates that TPA was mainly adopted after the enactment of the S.I.8/S.I.9 law in August 1991. By implication, it appears that the firms were prepared and anticipated that actual enforcement of the law would take place as planned at the end of the three-year moratorium given by the regulatory authority to the firms to undertake necessary technical changes for compliance. In the food & beverages sample, the mean period of TPA adoption was about eight and half years, the minimum one year and the maximum twenty-seven years, whereas for the textile sample, the mean period was three and half years, the minimum six months and the maximum eight years. It thus appears that TPA was implemented in the food & beverage industry before the enactment of the S.I.8/S.I.9 law, and the food & beverage industry responded faster than the textile firms in Nigeria in terms of TPA adoption. It is also apparent that TPA adoption did not occur in the textile sector until the enactment of the S.I.8/S.I.9 law. Furthermore, Table XI shows that most of the TPA types adopted before January 1995 consisted of primary wastewater treatment, while most of the TPA types adopted after January 1995 consisted of secondary and advanced wastewater treatment. This may be an indication that most of the TPA types adopted before January 1995 were preemptive, just to have something to show to the regulators when mandatory enforcement started. Adoption of more effective TPA types was largely a post–January 1995 impact of the S.I.8/S.I.9 law. The impact may however be more pronounced in the textile sample, as suggested by the relatively lower average period of TPA adoption of only three and half years. In fact, it may be inferred from Table XI that TPA adoption was limited in the textile sector before January 1995.

An interesting trend to note in TPA adoption is that, twenty-one (48 per cent) of the adopters were MNE affiliates (see Table XII), and the chi-square test showed that the association of TPA adoption with the affiliation to MNE was significant.[31] As expected, the same was true for TPA adoption's association with the firm size, according to our size distribution classification. It is also noteworthy that more than

[30] Here and subsequently, 2000 is taken as the reference year.
[31] Significant at 1 per cent level.

TABLE XI

NUMBER OF CASES OF TPA ADOPTION ACCORDING TO TIME AND SECTORAL DISTRIBUTION OF ADOPTION

Type of TPA	When Adopted				Total
	Before 1995		After 1995		
	F&B[a]	Textiles	F&B[a]	Textiles	
Primary wastewater treatment	11	2	8	0	21
Secondary wastewater treatment	5	1	7	4	17
Advanced wastewater treatment	1	0	0	5	6
Total	17	3	15	9	44[b]

Source: Author's field survey.
[a] Food & beverages.
[b] Out of forty-six TPA adopters only forty-four indicated the type of TPA adopted.

TABLE XII

TPA ADOPTION BY AFFILIATES OF MULTINATIONAL ENTERPRISES (MNE)

Type of TPA	No. of MNE Affiliate Adopters			No. of Total Adopters
	F&B[a]	Textiles	Total	
Primary	10	0	10	21
Secondary	7	1	8	17
Advanced	1	2	3	6
Total	18	3	21	44[b]

Source: Author's field survey.
[a] Food & beverages.
[b] Out of forty-six TPA adopters only forty-four indicated the type of TPA adopted.

60 per cent of TPA adoption by MNE affiliates[32] occurred after January 1995. However, the chi-square test showed that the association of the period of adoption with the affiliation to MNE was not significant. It is thus difficult to determine whether multinational affiliates adopted TPA relatively more before January 1995 than local firms. Furthermore, though the sample indicates a relatively higher adoption of secondary and advanced wastewater treatment by MNE affiliates, the association of the type of TPA adopted with the affiliation to MNE was not significant. It is thus also difficult to determine whether TPA adoption by MNE was significantly higher than that by local firms.

B. *Technology Response for Pollution Prevention (TPP)*

As previously mentioned in Section III, the TPP types considered in this paper

[32] Thirteen out of a total of twenty-one TPA adopters affiliated to MNE in our sample adopted TPA after January 1995.

TABLE XIII

NUMBER OF FIRMS ADOPTING TPP ACCORDING TO TIME AND SECTORAL DISTRIBUTION OF ADOPTION

Type of TPP	When Adopted				Total
	Before 1995		After 1995		
	F&B[a]	Textiles	F&B[a]	Textiles	
Water/wastewater recycling	11	0	19	1	31 (33%)
Raw material reuse/recycling	7	9	9	3	28 (29%)
Changes in raw material input(s)	4	7	2	1	14 (15%)
Integrated physical devices	8	1	12	1	22 (16%)
Total	30 (32%)	17 (18%)	42 (44%)	6 (6%)	95 (100%)

Source: Author's field survey.
Note: Parenthesis: percentage of the total number of firms adopting TPP.
[a] Food & beverages.

included water or/and wastewater recycling, raw material reuse or recycling, changes in raw material input(s), and integrated physical devices aimed at improving water use economy in the production line. Out of the 122 firms in our research sample, 60 claimed to have adopted TPP. The sectoral distribution of the type of TPP adopted depending on the time of adoption is shown in Table XIII. The total number of TPP types adopted was 95 because some firms adopted two or more types of TPP. Half of the TPP adoption in the sample took place before 1995. Most of the adoptions before and after January 1995 took place in the food & beverage sector. No strong conclusion can be directly drawn from this because our sample was biased in favor of the food & beverage sector. However, if we use a technology adoption quotient and define it as the proportion of adopters in a given sectoral sample, then, for the food & beverage sector, the pre– and post–January 1995 TPP adoption quotients would be 0.32 and 0.44 respectively. For the textile sector, the pre– and post–January 1995 TPP adoption quotients were 0.63 and 0.22 respectively.[33] Thus, whereas the TPP adoption quotients for the food & beverage sector increased slightly, those for the textile sector declined sharply. The underlying reason for this may be related to the trend in TPA adoption previously demonstrated, in which, the textile sector's TPA adoption occurred largely after January 1995. It appears that investment in TPA might have diverted the attention of the textile firms from more investment in TPP. In fact, while it appeared that the enforcement of the S.I.8/S.I.9 law had a positive impact on the stimulation of TPA adoption in the two sectors, the impact

[33] These TPP adoption quotients were calculated by dividing the total number of pre– and post–January 1995 TPP adoptions given in Table XIII by the size of each sectoral sample (i.e., 95 for the food & beverage sector, and twenty-seven for the textile sector).

was relatively less evident for TPP adoption. The impact on TPP adoption in the food & beverage sector appeared to be only marginal, while the impact appeared to be negative (i.e., decline in TPP adoption) in the textile sector.

The enhanced TPP adoption in the food & beverage industry may be partially ascribed to the relatively higher local skill intensity ratios in the food & beverage sector. The comparatively larger pool of local technical personnel in the food & beverage sector may enable a better and faster adoption and understanding of relevant TPP types. Moreover, as shown in Section V, the food & beverage firms in our sample considered that in-house R&D was the most important source of technological knowledge for water pollution control. This might imply that they would look more in-house for TPP opportunities. Furthermore, Table XIII indicates that water or wastewater reuse/recycling and integrated physical devices to improve water use economy were relatively common among the food & beverage plants. The integrated physical devices observed in the course of the fieldwork included improved bottle washing devices, metering devices/equipment, re-engineering of aspects of process lines which resulted in leakage prevention or minimization, improved CIP[34] procedure with introduction of pressurized nozzle points at strategic locations that enhanced the efficiency of water use during CIP, caustic soda recovery tanks/process, etc. The textile plants might not have availed themselves of some of these opportunities, but focused rather on end-of-pipe TPA processes that could mitigate the relatively more severe external diseconomy of the textile production.[35] This may explain the decline in TPP adoption in the textile industry. The option of change in raw material input(s) appeared to be relatively less common compared to other TPP types in food processing perhaps due to the strict public control of the food & beverages industry. In the case of the textiles, raw material reuse/recycling appeared to be relatively more common than other types of TPP perhaps due to the introduction of the wax recovery process in some textile plants. It was however observed during the fieldwork that this practice could be ascribed to economic reasons such as savings[36] resulting from repeated use of the same stream of wax rather than to environmental protection factors.

As shown in Table XIV, most of the TPP adopters affiliated to MNE belonged to the food & beverage sector. Chi-square test results showed that the association of TPP adoption with the affiliation to MNE in our sample was significant[37] for the food & beverage plants except for the case of changes in raw material input(s). The

34 "Clean-in-place" process for periodic cleaning/washing of process lines and equipment.

35 During the fieldwork, the most advanced TPA facility was found in the textile sector.

36 It was shown during the fieldwork that textile firms producing African wax prints presently import wax. The recovery of wax from wastewater effluent stream is a very dirty and difficult process. However, because of the foreign exchange implications of wax importation, textile plants are being compelled to introduce wax recovery processes.

37 Significant at 1 per cent level.

TABLE XIV

TPP Adoption by Affiliates of Multinational Enterprises

Type of TPP	No. of MNE Affiliate Adopters			No. of Total Adopters
	F&B[a]	Textiles	Total	
Water/wastewater recycling	14	0	14	31
Raw material reuse/recycling	9	4	13	28
Changes in raw material input(s)	3	2	5	14
Integrated physical devices	12	0	12	22
Total	38	6	44	95

Source: Author's field survey.
[a] Food & beverages.

results for the textile plants showed that the association was not significant for any of the TPP types. As expected, the chi-square test also showed that the association of TPP adoption with the firm size was significant for all the four TPP types.

Overall, according to nearly two-thirds (64 per cent) of our respondents, the most effective pollution control technology in terms of industrial water pollution control was TPA. This is understandable because TPP is generally perceived as being highly restricted in industry compared to the option of retrofitting with end-of-pipe TPA solution. Besides, TPA may derive sunk cost advantage from existing production facilities (Hartje and Lurie 1984; Rothwell 1992). The foregoing results nevertheless indicate that in Nigeria further efforts should be made to promote TPP adoption, especially among the textile firms. Moreover, most of the TPP adopters (82 per cent) indicated that the adoption resulted in net economic gain for their firms.

C. *Reasons for and Obstacles to Adoption*

It is pertinent to note that only 41.3 per cent of the TPA adopters considered that environmental policy was the most important reason for TPA adoption (see Table XV). Besides, while 91.3 per cent of the TPA adopters considered that the prevention of environmental incidents was an important reason for adoption, 78.3 per cent of the TPA adopters considered that environmental policy was an important adoption rationale. Other reasons deemed important for most of the TPA adopters included the improvement of firm's environmental image, alleviation of community pressure, and the international norm of parent company (applicable only to MNE affiliates). For TPP adoption, the results of our survey revealed that cost reduction factors were more responsible for the adoption observed. As shown in Table XVI, an average of 72 per cent of the TPP adopters considered that cost reduction was an adoption rationale when TPP was adopted, while only an average of 41 per cent of the TPP adopters considered that environmental regulation was an adoption ratio-

TABLE XV

REASONS FOR TPA ADOPTION

TPA Adoption Reasons	Percentage of Respondent Firms Considering Reasons for Adoption	
	Important	Most Important
Prevent environmental incidents	91.3	34.8
Nigerian environmental policy	78.3	41.3
International norm of parent company	51.6[a]	6.5
Improve environmental image	71.7	13.0
Product acceptance in intern. market	6.5	0
Pacify local community	54.3	4.3
Pacify NGOs	13.0	0
Other reasons	7.0	0
Total		100.0

Source: Author's field survey.

[a] This factor is applicable only to MNE affiliates (i.e., sixteen out of thirty-one MNE affiliates in the research sample).

TABLE XVI

MOTIVATION FOR TPP ADOPTION

TPP Type	Percentage of TPP Adoption due to		Total No. of TPP Adopters Responding
	Cost Reduction	Environmental Regulation	
Water/wastewater recycling	85	70	33
Raw material reuse/recycling	92	30	36
Changes in raw material input(s)	38	29	21
Integrated physical devices	71	33	24
Average	72	41	

Source: Author's field survey.

nale at the time of TPP adoption.[38] It is thus apparent from these results that, though the introduction of the Nigerian S.I.8/S.I.9 environmental regulatory law has been shown to have stimulated both TPA and TPP adoption, firms also acknowledged that many other factors had motivated the decision to adopt.

It is also important to note that out of the 122 firms in our research sample, only 46 had adopted TPA, while 60 had adopted TPP and 66 firms had adopted at least TPA or TPP. In fact, 56 firms had neither adopted TPA nor TPP. This raises the question of the effectiveness of the implementation of the S.I.8/S.I.9 law. There are

[38] Note that the sum of the percentage of TPP adopters exceeded 100 per cent because some TPP adopters claimed to have adopted a particular TPP type for both cost reduction and environmental regulation reasons.

TABLE XVII

OBSTACLES TO ADOPTION

Obstacles to Adoption	Percentage of Respondent Rirms Considering Reasons for Adoption		
	Important	Most Important	Second Most Important
Lack of information about EBTs	36.9	8.2	12.2
High cost of installing and operating TPA	83.6	51.6	19.1
Lack of technical capability to use TPA	13.1	0.8	0.9
High cost of TPP	61.5	0.8	26.1
Lack of capability to implement TPP	7.4	0	0.9
Low technical feasibility of TPP	7.4	0	1.7
Uncertain impact of EBTs on competitiveness	36.9	2.5	8.7
Lack of credit to invest in EBTs	45.5	6.6	15.7
Other obstacles	58.2	29.5	14.8
Total		100.0	100.0

Source: Author's field survey.

obstacles to firms' decisions to comply with the demands of the environmental policy. Table XVII revealed that more than half (51.6 per cent) of our sample firms indicated that the high cost of installing and operating TPA was the most important obstacle to adoption. As mentioned previously, 64 per cent of our research sample considered that industrial wastewater treatment was the most effective solution to the problem of industrial wastewater pollution. This underscores the importance of the high cost of TPA as an obstacle to adoption compared to the high cost of TPP. High cost of TPP is nonetheless an important obstacle as it ranked highest among the factors cited as second most important obstacle to adoption. Furthermore, information asymmetry between firms and regulators notwithstanding, the results of the regulators' survey using a semi-structured questionnaire confirmed the relative importance of the high cost of pollution control technologies as a hindrance to adoption. More than two-thirds (71 per cent) of the regulators considered that the high cost of water pollution control technologies was the major hindrance to firms' compliance with the Nigerian S.I.8/S.I.9 environmental regulatory law.

The results reported in Table XVII also indicate that most of the firms did not consider that reasons such as lack of information on water pollution control technologies, lack of technical capability to manage TPA or implement TPP, uncertainty about impact of EBTs on firm's competitiveness, and lack of credit to invest in EBTs were important hindrances to their technological responses for industrial wastewater pollution control. However, when the most important obstacles to adop-

TABLE XVIII

OBSTACLES TO ADOPTION

Obstacles to Adoption	No. of Respondent Firms in Sectors		Total No. of Respondent Firms
	Food & Beverages	Textiles	
Lack of information about EBTs	7	3	10
High cost of installing and operating TPA	44	19	63
Lack of technical capability to use TPA	1	0	1
High cost of TPP	1	0	1
Lack of capability to implement TPP	0	0	0
Low technical feasibility of TPP	0	0	0
Uncertain impact of EBTs on competitiveness	3	0	3
Lack of credit to invest in EBTs	3	5	8
Other obstacles	36	0	36
Total	95	27	122

Source: Author's field survey.

tion are considered based on their sectoral distribution (see Table XVIII), lack of credit to invest in EBTs and lack of information on water pollution control technologies became conspicuous for the textile sector. This may be ascribed to the more intricate nature of textile effluents. Textile effluents contain significant quantities of inorganic chemical pollutants, which are apparently more expensive to treat compared to the largely organic pollutants handled by wastewater treatment facilities in the food and beverage sector. The cost implications might have prompted the request for credits, while the more complex nature of the treatment process might have resulted in relatively less accessible information on appropriate treatment methods for the textile firms.

VII. CONCLUDING REMARKS

In this paper we have presented some of the salient features of the Nigerian manufacturing industry with a focus on the food & beverage and textile sectors. This enabled us to demonstrate that, recent claims of "deindustrialization" in sub-Saharan Africa notwithstanding, the two sectors investigated were active and significant sectors where our hypothesis on the technological impact of the Nigerian S.I.8/S.I.9 law could be verified. The descriptive analysis given has been based on a sample of 122 firms in the two sectors. However, because the sample was biased towards the medium- and large-scale enterprises, conclusions that may be drawn from the paper sidelined the small-scale industries which were considered to be a significant feature of manufacturing in sub-Saharan Africa (Lall et al. 1994; Stewart, Lall, and Wangne 1992; Lundvall and Battese 2000). An important characteristic of the two sectors is that they depend heavily on imported capital goods. However, it appears that some of the food processing equipment was manufactured locally. More research is needed to provide additional details on this aspect. If verified, such an area should be encouraged. Furthermore, we revealed that 41 per cent of the food & beverage plants in our sample did not employ foreign (non-Nigerian) engineers or scientists. The sector had an average local skill intensity ratio of 0.126 compared to an average ratio of 0.016 for the textile sector. Likewise, the highest local skill intensity ratio among the food & beverage firms was 0.714 compared to only 0.135 for the textile firms. However, while the average foreign skill intensity ratio was 0.068 for the textile sector, it was only 0.008 for the food & beverage sector. It appears that the food & beverage sector was able to source much of its technical and scientific skills locally compared to the textile sector, or had succeeded in substituting local for foreign skills.

The paper described the current trends in technology responses for water pollution control in the two sectors. Evidence was shown that Nigerian firms are actively involved in adopting both conventional end-of-pipe technologies such as industrial wastewater treatment plants, and process-related innovations that may reduce or eliminate the generation of wastewater at the source. Our findings revealed that most of the adoptions of secondary and advanced industrial wastewater treatment plants in the two sectors took place after the end of the moratorium period given to Nigerian firms to comply with the S.I.8/S.I.9 environmental regulatory law. This may imply that substantial adoption of relatively more effective pollution control technologies did not occur until serious enforcement activities were implemented. Likewise, the two sectors showed appreciable evidence of water or/and wastewater recycling, raw material reuse or recycling, changes in raw material input(s), and the use of integrated physical devices/equipment that enhance water use economy. There are indications that investments in these technologies were largely driven by the environmental regulatory regime in Nigeria. However, the environmental regulatory impact was more visible for the technology response for industrial wastewater pollution abatement, and it appeared that the environmental regulatory regime should be fine-tuned to enhance technology response for industrial wastewater pollution prevention, especially among the textile firms.

Though we observed that the association of affiliation to multinational enterprises (MNE) with the adoption of environmentally benign technologies (whether TPA or TPP) was significant, the association of affiliation to MNE with the time of TPA adoption was however not significant. It is thus difficult to determine whether the implementation of the S.I.8/S.I.9 law in January 1995 exerted a significant impact on the stimulation of more TPA adoption among MNE affiliates. This notwithstanding, it is important to point out that more than 60 per cent of the TPA adoption cases by MNE affiliates occurred after January 1995. In addition, irrespective of whether or not a firm was a multinational affiliate, evidence from our survey data revealed substantial improvement in technology adoption (TPA and TPP) for water pollution control after the enforcement of the S.I.8/S.I.9 environmental regulatory law. Due to the limitations of our data, it has not been possible to substantiate the actual effectiveness of the technologies adopted in reducing the pollution load generated by the Nigerian firms investigated. This is an important issue for further research. It is however important to demonstrate that environmental policy in a sub-Saharan African country was effective in stimulating technology investment in pollution control. The technological impact is certainly an indication of some measure (even if marginal) of success in pollution load reduction.

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APPENDIX

KEY QUESTIONS INCLUDED IN THE STRUCTURED QUESTIONNAIRE

Section 1: Basic Information on the Firm

1.1. Is your firm a subsidiary or an affiliate of a multinational enterprise? ☐ YES ☐ NO
If ***yes***, please give the country of your parent company: ……………………

1.2. Ownership structure of your firm:
My firm is ……% Nigerian owned. [*please, give the percentage of domestic equity in the firm*].

1.3. The highest educational qualification of the plant manager is: [***tick*** the most appropriate below]
☐ Degree or Higher diploma ☐ Professional technical certificate ☐ Secondary school certificate ☐ Others (*specify*) …………

1.4. Year firm was established: ………………

1.5. Current capacity utilisation: ………%

1.6. Total number of persons currently employed by your firm: ………………

1.7. Total number of ***Nigerian*** engineers/technicians and scientists (e.g., chemists, microbiologists, etc.) currently employed by your firm: ……………………

1.8. Total number of ***foreign*** (i.e., non-Nigerian) engineers/technicians and scientists (e.g., chemists, microbiologists, etc.) currently employed by your firm: ……………………

1.9. Please, give the proportion of your firm's employees with primary, secondary, and higher education:
Primary education: ……%; Secondary education: ……%; Higher education: ……%

Section 2: Technology Adoption for Water Pollution Control

2.1. Are the following pollution issues important to your firm?

	YES	NO
A. Wastewater	☐	☐
B. Air pollution (CO_2, SO_2, particulates, etc.)	☐	☐
C. Solid waste	☐	☐
D. Noise	☐	☐

Which is the most important? …………… [*fill in letter*]

2.2. Please, briefly mention the types of liquid waste produced by your firm. ……………………

2.3. Has your firm introduced any of the following measures or technologies to reduce water pollution before or after January, 1995? [*Please, **tick** all that apply*]

Water pollution control measure/method	***Adopted before Jan. 1995***	***Adopted after Jan. 1995***	***Not adopted***
A. Primary wastewater treatment	☐	☐	☐
B. Secondary or biological wastewater treatment	☐	☐	☐
C. Advanced wastewater treatment	☐	☐	☐
D. Water or/and wastewater re-use or recycling	☐	☐	☐
E. Raw material re-use or recycling	☐	☐	☐
F. Changes in one or more raw material inputs	☐	☐	☐
G. Integrated physical devices in the production line	☐	☐	☐
H. Others (*pls., specify*): …………………………	☐	☐	☐

From the experiences of your firm, which of the measures do you consider the most effective in achieving less water pollution? ……………… [*fill in letter*]

If your firm has never adopted any of the water pollution control measures mentioned in question 2.3, then go to question 3.1.

2.4. If your firm has adopted wastewater treatment, where is the source of the wastewater treatment technology mentioned in question 2.3? [*Please, **tick** only the option that apply*]

Locally built or fabricated equipment	☐
Combination of locally built and foreign equipment	☐
Completely foreign technology equipment	☐

Please, state the country of origin of the foreign equipment component: ………………
Give the year in which the wastewater treatment plant was built or adopted by your firm: ……

2.5. Did your firm invest in wastewater treatment technology for any of the following reasons?

	YES	NO
A. To pacify non-governmental organisations complaining about pollution	☐	☐
B. To pacify the local community around your production plant	☐	☐
C. To prevent environmental incidents	☐	☐

D. To comply with Nigerian (FEPA) environmental regulation	☐	☐
E. To comply with the international norm of your parent company	☐	☐
F. To improve the environmental image of your company	☐	☐
G. To make your products acceptable in international market	☐	☐
H. Other reasons (*pls., specify*):	☐	☐

Which of the reasons above do you consider the most important reason? ……… [*fill in letter*]

2.6. Was the adoption of the wastewater treatment expected to reduce total production costs, perhaps through savings on environmental regulation–related expenses?
☐ YES ☐ NO ☐ I can't say

2.7. Why did your firm adopt the wastewater reduction measures/methods given in the table below? [*Please, **tick** all that apply*]

Measures for achieving wastewater reduction	***Environmental regulation motivated***	***Cost reduction motivated***	***Not adopted***
A. Water or/and wastewater re-use or recycling	☐	☐	☐
B. Raw material re-use or recycling	☐	☐	☐
C. Changes in one or more raw material inputs	☐	☐	☐
D. Integrated physical devices in the production line	☐	☐	☐
E. Others (*pls., specify*): …………………………	☐	☐	☐

Has the effect of the adoption of wastewater reduction measures led to a net economic gain for your firm? ☐ YES ☐ NO ☐ I can't say

2.8. Which of the following sources are used by your firm to solve technical problems with your wastewater treatment system or wastewater reduction measures? [***Tick** all that apply*]

A. The technology supplier	☐
B. Your firm's in-house technical staff	☐
C. Your firm's foreign technical partners	☐
D. Your firm's parent company	☐
E. Nigerian engineering maintenance firms	☐

Which of these five sources of technical support is the most important to your firm? …………… [*fill in letter*]

2.9. How successful do you consider your firm's technical capability to operate or use wastewater treatment technology or the wastewater reduction measure that your firm has adopted?

	Very low	Low	Moderate	High	Very High
Wastewater treatment technology	☐	☐	☐	☐	☐
Wastewater reduction measure	☐	☐	☐	☐	☐

2.10. Overall, have the effects of the adoption of water pollution control measures led to a net economic gain for your firm? ☐ YES ☐ NO ☐ I can't say

Section 3: Obstacles to Adopting Water Pollution Control Technology

3.1. ***Before adopting*** technologies or measures that could reduce water pollution by your firm, was any of the following factors an important obstacle to your adoption? ***Alternatively***, in case your firm has not adopted any water pollution control measure or technology, is any of the following factors an important obstacle to your adopting measures that could help your firm in reducing water pollution?

	YES	NO
A. Lack of information about water pollution control technologies	☐	☐
B. High cost of installing and operating wastewater treatment plant	☐	☐
C. Lack of technical capability to use wastewater treatment plant in my firm	☐	☐
D. High cost of process integrated techniques that reduce wastewater generation	☐	☐
E. Lack of capability to carry out process integrated technical innovations in my firm	☐	☐
F. Poor technical feasibility of process integrated innovation that reduces wastewater	☐	☐
G. Uncertain impact of water pollution control technologies on firm's competitiveness	☐	☐
H. Lack of credit to invest in water pollution control technologies	☐	☐
I. Other obstacles	☐	☐

Which of the obstacles do you consider the ***most important***? …………… [*fill in letter*]
Which of the obstacles do you consider the ***second most important***? …………… [*fill in letter*]

Section 4: Production Process

4.1. Where is the source of the main production equipment currently used by your firm?

Locally fabricated equipment	☐
Combination of local and foreign equipment	☐
Completely foreign technology equipment	☐

Please state the ***main country*** of origin of the foreign equipment component: ………………
Mode of foreign equipment (technology) acquisition: ☐ Licensing ☐ Open market

4.2. How old is the main production equipment? …………………………

4.3. Are you using any of the following organisations or institutions as source(s) of general technological knowledge or innovation?

	YES	NO
A. Supplier(s) of the main production technology	☐	☐
B. Supplier(s) of environmental technology	☐	☐
C. Local research institute(s) in Nigeria	☐	☐
D. International research institute(s)	☐	☐
E. Nigerian higher institutions (universities, polytechnics, etc.).	☐	☐

F. Your firm's in-house R&D	☐	☐
G. Your firm's parent company	☐	☐
H. Your firm's foreign technical partners	☐	☐
I. Other firm(s) in your manufacturing industry	☐	☐

Which is the most important source of technological knowledge or innovation? …………… [*fill in letter*]
Which is the most important source of technical solutions to water pollution problems? …………

Section 5: Environmental Regulation and Management

5.1. Which of the following best describes the current attitude of your firm's top management to environmental issues? [*Please,* ***tick*** *only one option*]

No commitment or environmental management is seen to be unnecessary	☐
Somewhat committed or environmental concerns should only be addressed when necessary	☐
Fairly actively involved, environmental management is regarded as useful	☐
Environmental concerns are important	☐
Environmental concerns are a top priority	☐

5.2. FEPA's national effluent limitation regulation came into effect in January, 1995. How would you rate the commitment of your firm to environmental management before and after January, 1995?

	Very low	Low	Moderate	High	Very High
Before Jan. 1995	☐	☐	☐	☐	☐
After Jan. 1995	☐	☐	☐	☐	☐

5.3. If your firm is a subsidiary or an affiliate of a multinational, how do you view the standard of environmental management in your firm in comparison to that of the parent company?
The standard of environmental management in my firm is:

lower than that of the parent company.	☐
same as that of the parent company.	☐
higher than that of the parent company.	☐

5.4. Do you discuss technical options for solving identified pollution problems with the government compliance monitoring officials? ☐ YES ☐ NO.
If ***yes***, how useful are the technical suggestions of the government compliance monitoring officials?

Very useful	☐
Useful	☐
Sometimes useful	☐
Not useful	☐
Usually they have no technical suggestion, they are only interested in forcing compliance	☐

5.5. Is the attitude of the government compliance monitoring officials co-operative or confrontational to your firm? ☐ co-operative ☐ confrontational

5.6. Was there ever a disagreement between your company and the environmental authority about the most appropriate compliance technology or method for water pollution control?
☐ YES ☐ NO
If ***yes***, was your firm forced to invest in the technology or measure favoured by the environmental authority? ☐ YES ☐ NO