Reinventing Effluent Management in the Sugar Industry in the Nyando Basin, Kenya: From End-of-Pipe to Integrated Approaches

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Abstract
The industrial pollution discharge into the river basins of Lake Victoria in Kenya has been a major environmental management issue. Much of this discharge comes from the sugar mills and molasses distilleries in the Nyando River Basin. Voluntary approaches to pollution prevention have been on spotlight in the recent years as a viable option for enabling industries to meet, even surpass, statutory effluent discharge standards. Central to these approaches is use of cleaner production technologies and practices which have been experimented with in the Nyando River Basin since 2009. However, the potential of this voluntary ecological transformation tool to deliver economic and ecological advantages in a Kenyan perspective has not been examined. Using the case of the sugar industry in the Nyando Basin in Western Kenya, this article explores the benefits to firms of integrating cleaner production with end-of-pipe approaches in effluent management. The theoretical underpinning of the analysis is the Ecological Modernisation paradigm, owing to its emphasis on voluntarism and integrated approaches to pollution management that portend double-dividends of reduced expenses and pollution loads. The results indicate that companies integrating cleaner production with end-of-pipe treatment are likely to reduce pollution loads, register high water productivity and enhance compliance with effluent discharge standards. In addition to these improved environmental performance, they are likely to record financial rewards. It is concluded that cleaner production is a potential tool to promote pollution prevention. However, its current implementation framework based on time-bound donor-funded projects falls short of inducing a transformational culture towards a preventative pollution regime.
Keywords: Industrial effluent, pollution prevention, cleaner production, ecological modernisation

1.0 Introduction

Water pollution from industrial effluent has been a growing environmental problem in Kenya. The effect of industrial pollution on surface water sources, including the Nyando Basin of Lake Victoria, has been expressed in a variety of studies (Odata *et al*, 200; 4; Oketch, 2005; World Bank, 2012; KNCPC, 2013). The World Bank (2012) notes that industrial effluent is of great concern, particularly in relation to the local inshore area pollution affecting domestic water supply, fishing and navigation activities. The World Bank (2002) estimated that the average annual organic industrial pollution loads entering Lake Victoria by 2002 was 1,467 tons of Biological Oxygen Demand (BOD_5). More recently, the BOD_5 of 1,580 tons per year was estimated (KNCPC, 2013), with about 70% of this coming from the sugar firms.

The concern about this phenomenon is exacerbated by the increasing water scarcity situation in the country. In 1990, the Water Stress Index for Kenya was 635 and is projected to reduce to 141 by 2050 under the prevailing rapid industrialisation, population growth and urbanisation rates (Engelman & LeRoy, 1995, cited in World Resources Institute *et al*., 1996). Under these circumstances, efficient industrial water use and adequate effluent management is poised to remain a challenge to sustainable development in the event emerging innovative approaches are not integrated into the industrial pollution reduction strategies. While data on industrial effluent pollution for Kenya is largely anecdotal, its effective management is recognised as pivotal to socio-economic progress of the country (GoK, 2008, 2010), and needs to be embraced as a critical subject for national policy and legislative responses (GoK, 2013).

The sugar industry in the Nyando Basin in Kenya, comprising three sugar mills and two sugar-based molasses distilleries, presents an important starting point for this journey for various reasons. First, it is a major contributor to the total volume of industrial discharges into the water bodies in the Basin (World Bank, 2012). Second, the industry directly supporting 200,000 small-scale farmers who supply over 80% of the cane milled by the sugar companies, is an important employer and source of livelihood for most households in Western Kenya (KSB, 2010).

Finally, the sugar industry is built upon highly obsolete technologies with its production processes susceptible to inefficient water use and generation of pollution. The industry is earmarked for transformation under Kenya's Vision 2030 to make it competitive to operate in a liberalized trade regime after the Common Market for Eastern and Southern Africa (COMESA) safeguard measures lapse. The industry will have to enhance its competitiveness along the entire value chain and reduce production costs by at least 39% to be in line with East African Community (EAC) member countries and COMESA sugar producing countries (KSB, 2010). In view of this, it is necessary that the industry steps up its investment in ecological transformations such as efficient water use and wastewater management innovations as the broad dichotomy of effluent prevention to enhance its competitiveness as well as meet environmental regulations. Against the backdrop of this requirement, the sugar industry needs to adopt innovative environmental strategies that can deliver both financial and environmental benefits.

The conventional approach is to install end-of-pipe treatment technologies to treat effluent to comply with discharge standards. However, the persistence of industrial pollution in the Nyando Basin in the face of these efforts suggests that relying only on these technological fixes falls short of presenting a plausible roadmap for reduction of industrial effluent pollution. To this end, a more attractive proposition has been for Ecological Modernisation, a green industrial restructuring in which there is radical reform of production, consumption, state practices, and political discourses along eco-innovative pathways (Mol, 1995; Hajer, 1995). This theory suggests that a shift from end-of-pipe approaches to voluntary eco-innovative practices will lead to reduced pollution and cost savings. Cleaner production has been fronted as a key eco-innovative tool for successful ecological modernisation. It is characterised by source reduction of waste, recycling, resource recovery from waste and use of renewable resources.

Cleaner production is being championed in Lake Victoria by non-state actors, notably the World Bank and SIDA. A most notable intervention to this end is the joint implementation of the Lake Victoria Environmental Management Project II (LVEMPII) regional project from 2009. The project provides for voluntary integration of cleaner production into current industry end-of-pipe practices (World Bank, 2008) through the Kenya National Cleaner Production Centre (KNCPC). Under this project, the sugar mills and distilleries are expected to adopt this tool to transform their production processes to prevent pollution and enhance business competitiveness as posited by scholars such as Porter and van der Linde (1995a, 1995b) and Revell (2007).

This article is based on the findings of a study conducted in three sugar mills and one distillery in the Nyando Basin. The goal of the study was to examine the potential for integration of cleaner production opportunities with end-of-pipe treatment technologies. The study focused on the eco-innovative practices used by these sugar industries to prevent effluent pollution. This was conducted through observations, reviewing of company documents and interviewing key personnel from production, engineering and environmental departments of the firms. The article covers the results of the study on sugar mills A, B and C, and distillery D that participated in the LVEMPII project. Distillery E was closed at the time of the study and was, thus, not included in the target sample.

2.0 Innovations for water use efficiency and effluent management

From the precautionary premise of environmental policy paradigms upon which EMT is founded, the cleaner production practices include innovations that espouse process innovations for water efficiency that reduce the volume of effluent; and the novel practices that aim to reduce effluent recontamination before treatment. Innovations focusing on the production processes entail technology change or modification and fine-tuning to optimise water use, re-use and recycling. Other innovations are mainly good housekeeping that is closely linked to preventive maintenance and behavioural changes. Both these have been found to bring about significant reduction in effluent discharges from industries (UNEP, 2001; van Berkel, 2010). Thus, the extent of uptake of these technologies and techniques, and resultant outcomes should form the basis for transition to a preventive industrial effluent pollution regime.

2.1 Innovations for water use efficiency

The primary technological innovations in focus were those that enable water recycling as well as good housekeeping retrofits to prevent and minimize liquid loss. Others were those geared to monitoring performance and quantities of raw water abstracted.The range of recycling innovations adopted by the industries to achieve efficient water use were as presented in Table 1.

Table 1 Water recycling technological options by the sugar mills

Recycling option	Sugar milling firm applying
Barometric cooling waters recycling	A, B & C
Recycling condensate from first stage of evaporation pans	A, B & C
Condensate recovery from later stage evaporation pans	A, B & C
Recycling condensate from crystallization pans	A, B & C
The recycling of turbo machinery cooling waters	A, B & C
Re-using sweet water condensate	A & C only

The water recycling technologies by the sugar mills are mostly geared towards optimising use of condensates. They include; recycling waters from first stage evaporation and crystallisation pans for boiler feed water, re-using sweet water condensate in the centrifugals, filters and cleaning. Higher water recovery levels were noted in company A owing to its use of surface condensers for recycling of barometric cooling waters which are much more efficient compared to the classical contact barometric condensers technology used in other factories. Use of Surface condensers instead of direct contact barometric condensers allows total evaporated water to be condensed without contamination with condensing water and condensate diverted to process use. Barometric cooling water is the largest water use in a sugar factory, comprising 60% of the water balance (FAO, 2003). The other water efficiency measures employed by the factories was reducing raw water abstracted through retiring the number of supply pumps as observed in sugar mills A and C.

The water recycling measures put in place by the distillery are as presented in Table 2. The bulk of water recycling and recovery from processes in distillery D, targets those streams from the body jacket water in blowers, coolers, condensers and fermenter plate heat exchangers for applications like cooling water makeup. Other process such as maintenance of cooling tower, re-using non-process water and efficient steam utilization were not practiced.

Table 2 Distillery water conservation technological options by distillery, D

Recycling cooling water from the water jackets of coolers, blowers, condensers, fermenter plate heat and exchanger	Applied
Regular maintenance of the cooling tower	Not applied
Reuse of non-process water for cleaning	Not applied
Increasing the efficiency of steam use in distillation and boilers	Not applied

In addition to recycling technologies, good housekeeping cleaner production measures were found to be used by the sugar mills and the distillery to reduce the amount of water used through various techniques (Table 3).

Table 3 Good housekeeping options applied by firms

Good housekeeping option(s)	Number of options applied				
	A	B	C	D	Total
Spill and leakage prevention through maintenance of pumps, taps, steam pipes, mill rollers, storage tanks, and process tanks	7	1	4	0	**12**
Installation of auto cut-off nozzles on cleaning hoses and taps	2	0	3	0	**5**
Increased frequency of dry cleaning as opposed to frequent wet cleaning of equipment and floors	2	0	1	0	**3**
Routine plant inspection	1	0	0	0	**1**
Supervision of staff at various departments	1	0	1	0	**2**
Traps to intercept oils and greases	1	0	0	0	**1**
Total	**14**	**1**	**9**	**0**	**24**

Table 3 shows that the sugar mills A, B and C employed various techniques to avoid leakages and spillages that lead to water and product loss, thus, creating more pollution. Other measures taken for the same objective included use of minimal amount of water for washing equipment and auxiliaries, inspection, supervision and segregation of oily streams.

2.2 Innovations for effluent management

Specific effluent management options applied by the sugar mills were as presented in Table 4.

Table 4: Effluent reduction options by the sugar industries, 2010-2013

Effluent reduction option	Sugar mill applying
Maintenance of closed circuit for water applied for cooling bearings	A only
Flue gas scrubbing water recycling	None
Factory wastewaters recycling	A only
Use of treated effluent for cleaning and construction	A only

The first option was decreasing further contamination of wastewater by using and maintaining a closed circuit for water applied in cooling bearings of mill rollers, mill turbines, turbo-alternator bearings and cooling of final molasses. This was applied in company A but not in the other two mills. None of the sugar mills was found to recover flue-gas scrubber water from the bagasse combustion chimney. However, it is only in sugar mill A where the factory's wastewater is treated and recycled for non-sensitive processes such as cleaning and construction.

On the other hand, the distillery recovered biogas from the agro-industrial effluent through an anaerobic biogas digester as the primary wastewater treatment strategy. Generation of this for production of steam was found necessary to make the company economically viable and to reduce effluent treatment costs. Technological innovations taking place in the distillery effluent digester were mainly process-oriented to enhance bioconversion. These include: introduction of new mixers within the reactor; top new membrane to optimise separation of methane from other contaminating gases; and patching of internal lining of the reactor to prevent leakages.

Effluent treatment technologies used by industries are as presented in Table 5.They majorly relied on stabilisation ponds. The distillery was found to rely on the biogas digester integrated with six stabilisation ponds before discharge to the Nyando River. In sugar mills B and C, multiple stabilisation pond systems are exclusively used. The ponds were expansive, and numbered twelve and nine for sugar mills B and C respectively. In contrast, company A discontinued the use of a single stabilisation pond in 2009 in favour of a modified activated sludge system integrated with sand filters and a reverse osmosis plant.

Table 5 Effluent treatment technologies used by firms

Type of technology	Firm applying
Stabilisation ponds	B, C & D
Activated sludge	A only
Anaerobic digester	D only
Sand filters	A only
Reverse osmosis	A only

In sugar mill A, these effluent treatment innovations were adopted when the company increased daily cane crushing from 1650 tons to 2200 tons. The single treatment pond could no longer handle the increased effluent to comply with national effluent discharge standards. In addition, frequent downstream overflows ignited complaints from the neighbouring community prompting NEMA to issue improvement orders. With land scarcity, the firm opted for a system of effluent treatment comprising a modified activated sludge integrated with sand filters and a reverse osmosis plant that is more effective and enables treating effluent to re-usable levels.

2.3 Effects of innovations on performance of the sugar industries

An analysis was undertaken to establish the effects of water use efficiency and effluent management initiatives on environmental performance of the firms from three dimensions: effect of innovations on water productivity (the volume of water used per unit product); effluent characteristics (effluent volume generated, ex-factory BOD_5 and COD pollution loads); and compliance with national effluent discharge standards by NEMA and WRMA for the two parameters, BOD_5 and COD.

2.3.1 Effects of the innovations on water use

Table 6 shows the specific water use per ton of sugar made covering both process and non-process activities, and specific water per kilolitre (kL) of alcohol produced for the distillery covering only process water.

Table 6: Water productivity by the sugar mills and the distillery, 2010-2013

	2010	2011	2012	2013
Distillery D (kL water/kL alcohol)	0.029	0.044	0.039	0.041
Sugar mill A (m^3 water/ton sugar)	4.300	1.900	0. 810	1.200
Sugar mill B (m^3water/ton sugar)	*	*	*	*
Sugar mill C (m^3 water/ton sugar)	*	*	36.367**	27.464

* Data not available **Average for 4 months, September-December 2012

Source: Computed from records of respective industries, 2010-2013

The variations in specific water consumption for process operations were lowest for distillery D, ranging from 0.029 to 0.041 m^3/kL alcohol. On the contrary, a remarkable reduction in specific water consumption was noted in sugar mill A, from 4.3 m^3 water/ton sugar in 2010 to 1.2 m^3 water/ton sugar in 2013 (72% water productivity improvement in a span of four years). In sugar mill C, a gradual improvement of water productivity from 36 m^3 to 26 m^3 of water per ton of sugar was noted from September 2012 to 2013 although this figure is still too high, indicative of how inefficient the firm is. Sugar mill B had not installed raw water abstraction metre and therefore there was no data available. Thus, the pattern of change in its water productivity could not be determined as this statistic was not available. In the case of sugar mill A, the effluent quality improved to re-usable levels without the use of the reverse osmosis plant upon instituting the cleaner production options in 2010. This remarkable improvement caused the company to discontinue the use of the reverse osmosis plant.

To examine the outcomes of uptake of the eco-innovations by the firms, the various innovations were examined against data on water productivity in Table 6 for the 2010-2013 period. Table 7 presents a summary of the statistical tests of association between the number of good housekeeping practices adopted by firms and water productivity from 2010 through to 2013.

Table 7 Association between eco-innovations and water productivity, 2010-2013

Total good housekeeping practices applied	Association with water productivity (α=0.01)			
	χ^2	df	p -value	Remark
2010	2	1	0.157	Strong association
2011	2	1	0.157	Strong association
2012	*	*	*	*
2013	6	4	0.199	weak association

As table 7 shows, the two variables -total good housekeeping practices applied and water productivity-were found to be statistically significant for the two years (2010 and 2011) for which data on water productivity was available (p=0.157, df=1, α=0.01). The weak association between the two variables corresponding to the year 2013 is likely to have been caused by the high levels of water consumption by sugar mill C compared to the other firms. However, computations for the water recycling technological options applied versus water productivity could not be similarly computed because only data for sugar mill A was available for 2010 and 2011, and the total water productivity counts for 2012 and 2013 were constant.

2.3.2 Effects of the innovations on effluent characteristics

To determine the effects of innovations by the firms on the industrial effluent characteristics, these attributes were examined against data on volume of wastewater generated as well the ex-factory BOD_5 and COD pollution loads for the period 2010-2013. The pattern for volume of wastewater generated by the industries is as presented in table 8.

Table 8 Volume of wastewater generated by the sugar industries, 2010-2013

Industry*	Wastewater volume generated			
	2010	2011	2012	2013
Distillery D (m^3 wastewater/kL alcohol)	0.031	0.019	0.018	0.020
Sugar mill A (m^3 wastewater/ton sugar)	0.644	0.275	0.295	0.296
Sugar mill B (m^3 wastewater/ton sugar)	0.146	0.072	0.220	0.533
Sugar mill C(m^3 wastewater/ton sugar)	**	**	13.256	9.118

*Measurement units for the industry wastewater volume presented in the corresponding parentheses.
**Data not available kL - kilolitre m^3 - cubic metre

The values presented in table 8 depict a declining trend in effluent generation by sugar mill A. Its effluent generation dropped from 0.644m^3/ton in 2010 to 0.296m^3/ton in 2013 (54%) of sugar made. In distillery D, the pattern of reduction in wastewater volume was rather modest. Sugar mill C had the highest effluent generation that stood at 13.256 m^3/ton sugar in 2012 and falling to 9m^3/ton sugar in 2013 after the introduction of cleaner production. Similar trend was noted for water consumption. Sugar mill B recorded a reduction in its wastewater volume from 0.146 m^3/ton of sugar made in 2010 to 0.072 m^3/ton of sugar made in 2011 following the introduction of cleaner production in its operations but this ecological gain was compromised in the years that followed when the firm experienced long periods of closure due to liquidity problems. This inconsistency in the lowering of wastewater volume at sugar mill B was also likely attributed to weak support for the cleaner production program from the firm's top management.

To establish the effects of innovations by firms on the volume of wastewater generated by industry, the wastewater volume values for the 2010 through to 2013 were examined against the variable on water recycling technological options adopted by firms, and with the variable on number of good housekeeping practices embraced by industries. In the process, the Chi-square statistical tests were run to reveal the related strength of associations. The results of tests of statistical significance were as presented in table 9.

Table 9 Association between firm innovations and wastewater volume generated

Wastewater volume generated in	Association with					
	No. of recycling technological options applied (α=0.01)			No. of good housekeeping practices (α=0.01)		
	χ^2	Df	P	χ^2	df	p
2010	2	1	0.157	6	4	0.199
2011	2	1	0.157	6	4	0.199
2012	3	2	0.223	12	9	0.213
2013	3	2	0.223	12	9	0.213

From table 9, it can be deduced that the number of recycling technological options applied, and number of good housekeeping practices and volume of wastewater generated are statistically significant. This indicates that the uptake of firm eco-innovations is likely to be strongly associated with the volume of wastewater generated.

Similarly, the eco-innovations were examined against the ex-factory effluent BOD_5 and COD pollution loads with a view to determining the effects of their outcomes on firm environmental performance. Table 10 presents the ex-factory effluent BOD_5 and COD pollution loads of wastewater from the industries for the 2010-2013 period. Table 10 shows that from 2010 to 2013, sugar mill A decreased its BOD_5 intensity from 2.042 kg/ton sugar to 0.650kg/ton sugar (by 68%), and distillery D reduced its BOD_5 from 1.043kg/kL of alcohol to 0.774 kg/kL alcohol of organic pollution reduction (by 26%). But on this attribute, the changes for sugar mill B were relatively inconsistent.

Table 10 Ex-factory BOD and COD pollution load of wastewater, 2010-2013

Industry	Ex-factory BOD_5 pollution load				Ex-factory COD pollution load			
	2010	2011	2012	2013	2010	2011	2012	2013
Distillery D*	1.043	0.752	0.619	0.774	1.704	1.543	1.330	1.558
Sugar mill A**	2.042	0.905	0.821	0.650	3.059	1.632	1.510	1.547
Sugar mill B	0.295	0.014	0.051	0.227	0.767	0.081	0.110	0.657
Sugar mill C	***	***	2.78	6.25	***	***	***	33.000

*Corresponding pollution load measurement unit is kg/L alcohol
**Corresponding pollution load measurement unit is kg/ton sugar ***Data for the industry missing

Further, table 10 shows a decreasing trend in pollution intensity with respect to COD for sugar mill A from 3.059 kg/ton to 1.547 kg/ton of sugar in the period 2010 to 2013 (by 49%). Sugar mill B registered a reduction from 0.767 kg/ton sugar to 0.057kg/ton sugar (by 14%) and that of distillery D remained constant in the same period. The results of tests of statistical significance between these attributes and the innovations applied in the firms were as presented in table 11. As depicted by the statistics therein, a strong association between innovations applied and ex-factory BOD_5 and COD was found to permeate the sugar industries.

Table 11 Association between firm innovations and ex-factory BOD_5 and COD pollution loads

Ex-factory BOD_5, COD pollution load	Association with					
	Number of recycling technological options applied (α=0.01)			Number of good housekeeping practices (α=0.01)		
	χ^2	df	p	χ^2	df	p
2010	2	1	0.157	6	4	0.199
2011	2	1	0.157	6	4	0.199
2012	3	2	0.223	12	9	0.213
2013	3	2	0.223	12	9	0.123

2.3.3 Effects of eco-innovations on compliance with effluent discharge standards

The third examination of the effect of innovations on firm environmental performance was done by relating these innovations to compliance with the industrial effluent discharge standards established by NEMA and WRMA. To this end, the data required were the final effluent BOD_5 and COD quality for the four firms in the 2010-2013 period. These are as presented in table 12a and table 12b.

Table 12a: Final industrial effluent BOD_5 in 2010-2013 against NEMA and WRMA standards for discharge to surface water

Year	Industry				NEMA standard	WRMA standard
	ACFC mg/l	Kibos mg/l	Chemelil mg/l	Muhoroni mg/l	mg/l	mg/l
2010	2,092	31	42	*	30	30
2011	3,500	23	36	*	30	30
2012	2,593	37	57	29	30	30
2013	1,711	12	96	100	30	30

Source: Laboratory reports from Government Chemist and Kenya Bureau of Standards
*Data for industry not available.

Table 4.112b: Final industrial effluent COD in 2010-2013 against NEMA standards

Year	Industry				NEMA standard	WRMA standard
	Distillery D mg/l	Sugar mill A mg/l	Sugar mill B mg/l	Sugar mill C mg/l	mg/l	mg/l
2010	10,303	49	124	*	50	100
2011	17,444	53	70	348	50	100
2012	12,689	109**	118	51	50	100
2013	11,104	32	133	34	50	100

*data for industry not provided ** Company closed for major cleaning works
Source: Laboratory reports from Government Chemist and Kenya Bureau of Standards

Table 12a and 12b show that data on final effluent quality was unavailable for all firms in 2010-2013 period. Even where data were available, it was not on a quarterly basis. The tables also indicate that the effluent discharge standards for NEMA and WRMA differ with respect to COD, being 50 mg/l and 100 mg/l respectively, thereby making it difficult for firms to determine which of the two levels of compliance they should strive to meet or even surpass.

Over-compliance with the BOD_5 and COD NEMA standard was achieved by sugar mill A in 2011 and

2013, but it went up in 2012 due to major end-year cleaning works. Sugar mill C over-complied only in COD in 2013. On the other hand, distillery D was discharging highly polluted effluent into the Nyando River (BOD_5 of 1,711-3,500 mg/l, and COD of 10,303-17,444 mg/l) against the NEMA and WRMA effluent discharge standards. The expansive stabilisation ponds in distillery D, sugar mill B and sugar mill C could not consistently deliver a compliant effluent. To draw a statistically founded conclusion on the strength of association between the eco-innovations by the sugar industries and their chances of complying with the regulatory effluent standards, four more variables were computed from the data presented in table 12a and table 12b. The definition of these variables and their corresponding values were as presented in table 13.

Table 13: Frequency of compliance with final effluent standards, 2010-2013

Variable definition	Sugar mill A	Sugar mill B	Sugar mill C	Distillery D
Number of times industry complied with NEMA BOD_5 standard	3	0	1	0
Number of times industry complied with NEMA COD standard	3	0	2	0
Number of times industry complied with WRMA BOD_5 standard	3	0	1	0
Number of times industry complied with WRMA COD standard	4	1	2	0

*Assumption: Absence of corresponding final effluent values in table 4.13a and table 4.13b implies non-compliance

The variables presented in table 13 were subsequently associated with the number of recycling technological options adopted by the industries and good housekeeping practices in place in the respective industries, and the strength of associations tested with the aid of the Chi-square statistic. The results were as presented in table 14. From the statistics in table 14, uptake of good housekeeping innovative options and application of recycling technological options are likely to elevate the chances of complying with the final effluent standards established by the two regulatory institutions in Kenya, and even surpass them.

Table 14 Association between firm innovations and compliance with effluent standards

	Association with					
	Number of recycling technological options applied (α=0.01)			Number of good housekeeping practices (α=0.01)		
Compliance with	χ^2	df	p	χ^2	df	p
NEMA BOD_5 standard	3	2	0.223	8	6	0.238
NEMA COD standard	3	2	0.223	8	6	0.238
WRMA BOD_5 standard	3	2	0.223	8	6	0.238
WRMA COD standard	3	2	0.223	12	9	0.213

2.4 Financial returns on investment on innovations in effluent pollution prevention

Besides unravelling the ecological gains for the sugar industries associated with uptake of innovations for effluent pollution prevention, potential financial returns for the industries were also delved into. It emerged that the cost of investment in water efficiency and wastewater innovative techniques and practices for sugar mill A was US$ 9, 825, and had resulted in annual savings amounting to US$ 5,575, thereby producing a payback period of 21 months. Implementation of improvements in biogas digester by distillery D had cost this company a total of US$ 129,142butequally made it save US$ 3,011,765 per annum, mainly from displacing diesel with biogas and effluent treatment costs with a payback of 15 days.

The study demonstrated that a mix of source reduction and end-of-pipe treatment technological innovations are in use by the sugar industries for effluent management. Source reduction pollution measures include a range of cleaner production technologies and techniques (mainly good housekeeping) that enhance water efficiency thereby preventing the generation of effluent in the first place. End-of-pipe technologies for effluent treatment are predominantly stabilisation ponds, except for the sugar mill A that uses a modified activated sludge system. The common water efficiency measures employed by the sugar mills included recycling of non-process water from cooling and condensation; re-using sweet water condensate; treating and recycling factory wastewater. There are also good housekeeping options ("low hanging fruits") that comprise spill and leakage prevention, installation of auto-cut-off nozzles on cleaning hoses and pipes, reducing frequency of wet cleaning in favour of dry cleaning, segregation of wastewater streams, supervision and inspection.

Uptake of these cleaner production technologies and techniques led to reduction in water consumption and pollution in firms where they had occurred. This finding is in harmony with those of Jänicke *et al*. (1989) and Hager (1995) that water productivity indicator improves and pollution reduces as a firm adopts more water use reduction measures. A strong association between eco-innovations and water productivity was noted in the firms.

Sugar mill A in particular, that had undertaken greater integration of end-of-pipe treatment with cleaner production realised its specific water consumption go down from 4.3 m^3 water/ton sugar to 1.2 m^3 water/ton sugar in the period 2010 to 2013, a water productivity improvement of over 72%.

Wastewater volumes and pollution loading in terms of BOD_5 and COD are key parameters that indicate the degree of pollution and the levels of effort required to clean the effluent. In line with the postulates of ecological modernisation paradigm, companies that had introduced cleaner production as part of their ecological modernisation saw a reduction in both wastewater volume and strength of pollution level. In sugar mill A, the wastewater dropped by 54% from 0.644m^3 to 0.296m^3/ton of made sugar between 2010 and 2013. There was a substantive reduction for sugar mill C from 13 m^3 in 2012 to 9 m^3/ton sugar made in 2013 when effluent flow metering begun after the introduction of cleaner production. These results are supported by the Chi-square values of statistical test of significance; to the degree a number of water recycling technological options and good housekeeping practices were strongly associated with reduced pollution effluent volume.

Similarly, these innovations were strongly associated with reduced levels of BOD_5 and COD pollution indicators. Sugar mill A for example, reduced its BOD_5 by 68% from 2.042 kg/ton sugar to 0.650kg/ton sugarin the period 2010-2013. In the same period its COD was reduced from 3.059 kg/ton to 1.547 kg/ton of sugar (by 49%). Distillery D on the other hand, although facing serious technological challenges in distillery effluent management, reduced BOD_5 from 1.043kg/kL of alcohol to 0.774 kg/kL alcohol, representing 26% of organic pollution reduction due to innovations at the biogas digester.

Uptake of the innovations was found to enhance the chances of a firm complying with the effluent discharge standards. However, compliance levels to NEMA and WRMA effluent discharge standards to surface water could not be consistently met by those industries relying predominantly on stabilisation ponds, in particular, sugar mill B, distillery D and sugar mill C. However, industries often get confused whether to comply with NEMA or WRMA standards. Whereas these two standards have same limits of 30mg/l for BOD_5, it is different for COD being 50 mg/l and 100 mg/l for NEMA and WRMA respectively.

In the distillery, biogas is recovered from the ex-factory effluent for use in steam generation. However, its prospect of achieving compliance given the technological capacity in place was a big concern. The company consistently failed to attain both NEMA and WRMA effluent discharge standards in the period 2010-2013 with a final effluent BOD_5 being 1,711-3,500 mg/l and COD of 10,303-17,444 mg/l. In countries like India, distilleries are required by law to achieve zero discharge into inland surface watercourses by voluntarily choosing a suitable effluent management options after biological treatment. This can either be dilution of effluent and using it for irrigation or bio-composting it with sugarcane press mud to make organic fertilizer (AIDA, 2007 cited in Tewari *et al*., 2007). In other situations, the effluent can undergo aeration and clarification followed by reverse osmosis (RO) for re-use thereby reducing freshwater consumption by 50%. It can also be treated in a wetland and used for irrigation.

The study found that besides optimized water use, better effluent quality and lower volumes, the eco-innovations also translated into economic savings of USD 129,142/year for sugar mill A and USD 3,022,765/year in renewable energy recovery from the effluent by distillery D. This finding supports the EMT principle that adoption of cleaner production leads to improvement of eco-efficiency indicators as well as cost savings thus, providing a cost-effective platform for a fundamental shift of industrial production practices as well as environmental governance.

3.0 Conclusion and recommendations

The results presented in this chapter showed that cleaner production technologies are beginning to emerge for effluent pollution prevention with majority of the innovations being end-of-pipe stabilisation ponds. The cleaner production innovations were instrumental in reducing amounts of water consumed in the production processes as well as pollution levels. Using the Chi-square statistic, strong associations were witnessed between the numbers of cleaner production innovations with water productivity, effluent volume and pollution levels as measured by BOD_5 and COD. This was more pronounced in sugar mill A that had significantly integrated cleaner production with end-of-pipe. Its specific water consumption had reduced from 4.3 m^3 to 1.2 m^3 water per ton of sugar in the period 2010 to 2013, wastewater by 54% from 0.644m^3 to 0.296m^3/ton of made sugar, BOD_5 by 68% from 2.042 kg/ton sugar to 0.650kg/ton sugar and COD by 49% from 3.059kg/ton sugar to 1.547kg/ton sugar.

Innovations also had impact on compliance levels; the Chi-square statistic revealed a strong association between the eco-innovations and the likelihood of compliance to the effluent discharge standards. Those companies such as distillery D, sugar mills C and B, relying predominantly on end-of-pipe stabilisation ponds failed to consistently reduce pollution to a level compliant with either NEMA or WRMA effluent discharge standards. Sugar mill A, on the other hand, with significant integration of cleaner production and end-of-pipe approach managed to surpass NEMA effluent discharge standards in 2011 and 2013. The results of this article indicate that implementation of eco-innovations such as cleaner production leads to high water productivity and reduced pollution levels therefore offering a pathway to a preventive industrial effluent management regime by the sugar industry.

Arising from these scenarios two critical directions for action towards enabling transition from end-of-pipe to integrated approaches to effluent management in the sugar industry in the Kenyan setting suffices. One, it is necessary that effluent discharge standards are met by the sugar firms. However, this cannot be achieved through application of end-of-pipe technological changes alone. Thus, although cleaner production is not legislated in key legal instruments on industrial effluent management, it has proved to be beneficial to industry. Therefore, it should be implemented as part of compliance and enforcement strategy. This does not only promise to relieve pressure on the effluent treatment plants but also reduce costs associated with treatment and enhanced compliance. The resulting effluent can be treated to recyclable levels for application in other purposes, and to this end, compliance should begin with driving a sense of metering by industries of key performance indicators such as water use and effluent generation.

Second, cleaner production in Lake Victoria implementation in industry is mainly being driven by external partners, SIDA and the World Bank rather than Government. The invisibility of the Government in it is a potential explanatory factor for the lacklustre commitment levels of some of the sugar industries. To engender the momentum for switchover to preventive effluent pollution management approaches in the industry, greater Government engagement in cleaner production is necessary.

Finally, cleaner Production can be introduced in stages, with those industries already ahead acting as institutional entrepreneurs. For distilleries, this should be accompanied with different effluent management guidelines and standards as the current technological regime is incapable of delivering a voluntary-based effluent prevention pathway.

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