CASE

A public-private partnership linking wastewater treatment and aquaculture (Ghana)

Philip Amoah, Ashley Muspratt, Pay Drechsel and Miriam Otoo

Supporting case for Business Model 18	
Location:	Kumasi, Ghana
Waste input type:	Municipal wastewater
Value offer:	African catfish, treated water
Organization type:	Public-private partnership (PPP)
Status of organization:	Operational 2010–2012 (later transformed into a research project)
Scale of businesses:	Small-medium
Major partners:	Waste Enterprisers Ltd. (now: Waste Enterprisers Holding) Kumasi Metropolitan Assembly (KMA), Ghana Kwame Nkrumah University of Science and Technology (KNUST), Department of Fisheries and Watershed Management, Kumasi International Water Management Institute (IWMI), Accra

Executive summary

In Kumasi, Ghana, a public-private partnership was established between the Kumasi Metropolitan Assembly (KMA) and the private company Waste Enterprisers Ltd. (WE) to use aquaculture as a source of revenue for sustaining the sanitation services. As part of the agreement, WE is allowed to stock catfish in the final maturation pond(s) of governmental owned wastewater treatment plants, while in return WE uses half of its fish-sale profit to facilitate regular plant maintenance. This arrangement helps WE to access water and infrastructure for fish farming without related capital expenditures, while KMA gets its treatment plants well maintained which was so far more than challenging.

The business was co-funded by both parties without external support. Further beneficiaries are the low-income households charged for maintenance of the Waste Stabilization Ponds (WSP) and the maintenance subcontractor who is entitled of collecting the household fees.

Selling smoked catfish which is in high demand can make already the management of one treatment plant viable. For (unsmoked) fresh fish, with optimized production, break-even can be achieved from two managed plants upwards although only from three systems up the economic indicators

will be positive. With full compliance with safety regulations and policy support, the model is easily transferable to other locations, as pond based treatment systems are very common in the tropics.

The case is an example of an innovative pro-poor PPP that helps to ensure the sustainability of a wastewater facility whilst providing benefits to the community. During its engagement in Kumasi, WE rehabilitated two WSP, built rearing infrastructure for its fingerlings, and increased stock survival rates from less than 10% to 80% over the course of four cultivations. This case attracted international donor funding for accompanying research.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land use:	230–266m^2 (per fish pond); about 1 ha (total WSP)					
Water use:	225m^3 /day					
Capital investments:	Limited to fish hedging as ponds were in place. From a PPP perspective, less than 30% borne by WE and over 70% by KMA					
Labor	2 staff (part-time), 2 workers					
O&M costs	USD 3,429 /year/WSP (for 5 WSP systems), to USD 11,440 /year/WSP (for 1 WSP)					
Output:	Per hectare (water): 40 tons/year of fish; Per actual area: 2 tons/year from two ponds					
Potential social and/or environmental impact:	Reduction in public sanitation and health expenditures, improvement in food supply and job creation; poor households exempted from treatment plant maintenance fees					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR:	45%	Gross margin:	N.A.

Context and background

Kumasi is the capital of Ghana's Ashanti region and the second largest city in the country with a 2013 population of over 2 million and an annual growth rate of about 4–4.5%. The increasing population is challenging urban water and sanitation services. Like across Ghana, also the wastewater treatment facilities in the Kumasi metropolis are not or only partially functioning due to constrained institutional and financial resources (Murray and Drechsel, 2011). The resulting pollution of water bodies remains unchallenged as the enforcement of environmental regulations is especially weak for governmental infrastructure. Innovative partnerships and financing mechanisms are needed for sustainable wastewater management.

Waste Enterprisers (WE) is a non-profit organization, which focuses on building business models that incentivize waste collection and treatment services without further burden for poor households (tariff-independency). WE was set up with the goal to create demand for value-added waste products whilst providing an avenue for investing a portion of profits back into the sanitation sector, generating cycles of local investment, sustainable sanitation and healthier communities (Murray and Buckley, 2010).

In early 2010, WE approached KMA with its PPP proposal. The business locations of WE in Kumasi were the Ahinsan and Chirapatre housing estates and their wastewater treatment systems. Both were built in the late 1970s by the now-defunct State Housing Corporation of Ghana. Over 200 houses in each community (with ca. 1,500 inhabitants in Ahinsan and ca. 1,800 in Chirapatre) are connected to a communal sewerage network, which, along with storm-water runoff, is channelled to the respective WSP for treatment (Tenkorang et al., 2012). Like most sanitation facilities in Ghana, both WSP systems have chronically lacked reliable maintenance. In theory, a KMA subcontractor is responsible for raising the necessary fees from the served households for undertaking the maintenance of the plant. However, as households are poor and consider this a task of the municipality, the effort of collecting the fees erases any incentive to do the job and ponds were hardly maintained over years (Tenkorang et al., 2012).

The aquaculture production by WE was accompanied by an extensive testing of fish quality and safety. Studies targeted pathogenic contamination, heavy metals and pharmaceutical residues (Amoah and Yeboah-Agyepong, 2015a; Asem-Hiablie et al., 2013). Also the cultivated species, African Catfish (*Clarias gariepinus*), was chosen for safety reasons as in the study region it is normally smoked and not consumed fresh, but cooked.

Market environment

Traditionally, fish is the preferred and cheapest source of animal protein in Ghana with about 75% of total annual production being consumed locally. Tilapia constitutes about 80% of aquaculture production, while catfish accounts for the remaining 20%. According to Cobbina and Eiriksdottir (2010), fish trading is an important occupation in Ghana with an estimated 10% of the population engaged in it, on a full time or part time basis, both in rural and urban communities. Commercial farms mostly deal with wholesale buyers who buy the bulk of the harvested product and go on to sell to retailers or fish processors while fish harvested by the non-commercial farmers is mostly retailed by themselves or their spouses. Only a few non-commercial farmers sell their product to wholesale buyers. Unsold fish is either frozen or processed via smoking, salting and/or fermentation. Fish availability and marketing is most common in the southern and the middle zone of Ghana (GLSS, 2014). Ghana's Ashanti region is currently the leading region in pond-based fish farming in Ghana, with about 1,205 fish ponds, involving over 500 fish farmers. Available water surface area in Ashanti for fisheries development is about 151 ha producing about 585 metric tons of fish annually. Ashanti also leads in the production, supply and export of catfish in Ghana (Rurangwa et al., 2015).

In Kumasi, the majority of people consume catfish at home and in street restaurants which offer traditional stews. About 68% of the interviewees indicated to eat fish eight times per month or all three to four days (Amoah et al. 2015b). The 2014 Ghana Living Standard Survey recorded an annual food budget share of 15.8% for fish and seafood, which is nationwide the second most important food consumption subgroup, after cereals (e.g. rice and bread) (17.7%), and twice as high as meat (GLSS, 2014). Product attributes that influence consumers' decisions prior to purchasing fish are price, size and quality of the fish. Source of fish is among the least important product attributes influencing consumers' decision. In surveys which explained the wastewater use, consumers in Kumasi reconfirmed that they are more likely to choose fish farmed in treated wastewater if it was less expensive and larger than fish from other sources (Amoah and Yeboah-Agyepong, 2015b), which mirrors consumers' behaviour in view of wastewater irrigated vegetables (Keraita and Drechsel, 2015). An indicator of demand and tolerance of the source of water is the frequent theft of fish directly from the wastewater treatment ponds.

Macro-economic environment

Ghana's total annual fish requirement has been estimated to be 880,000 t while the nation's annual fish production average is 420,000 t, leaving a significant deficit. This deficit is partly made up for through fish imports which were estimated at 213,000 t in the year 2007 and valued at USD 262 million (Cobbina and Eiriksdottir, 2010). However, import of farmed fish is not allowed so as to ensure good prices for local fish farmers. However, illegal import, especially of Tilapia, is a growing concern. The deficit between fish demand and production has been a main driving force for pushing the agenda of developing aquaculture (Awity, 2005). Studies conducted by Asmah (2008) reported a 16% mean annual growth rate in the number of aquaculture farms since the year 2000. Fish production in ponds range from about 35 kg to over 35t/ha/year (Asmah, 2008), with less than 10% of commercial farmers exceeding production levels of 20t/ha/year. Common production cycles range between seven and 12 months (Asmah, 2008).

Business model

The partnership arrangement between the WE and KMA offers an interlinked double value proposition: maintaining the treatment capacity financed through waste valorization via fish production (Figure 225). The model ensures that WE gets nutrient rich water at no cost and KMA derives benefits from cost savings, as a more reliable WSP maintenance will lead to lower public health expenditures

FIGURE 225. BUSINESS MODEL CANVAS – FROM THE WE PERSPECTIVE

KEY PARTNERS

- Kumasi Metropolitan Assembly (KMA)
- Kwame Nkrumah University of Science and Technology (KNUST)
- International Water Management Institute (IWMI)
- Fingerling and feed supplier

KEY ACTIVITIES

- Maintain wastewater treatment functions
- Production of fingerlings and fish
- Fish marketing, sale and trust building
- Research and development

KEY RESOURCES

- Wastewater, land, treatment ponds
- Labor, capital
- Fingerlings, extra feed
- Expertise, laboratory access

VALUE PROPOSITIONS

- Improved wastewater treatment at no cost for the authority through resource recovery for fish (protein) farming

CUSTOMER RELATIONSHIPS

- Personal contact with wholesalers of harvest times
- Personal (on-site) contact with WSP maintenance sub-contractor

CHANNELS

- Direct sales to wholesalers
- Direct contracting of maintenance staff (if not done by KMA)

CUSTOMER SEGMENTS

- Wholesalers/ fish smokers
- Maintenance sub-contractor

COST STRUCTURE

- Capital investment (max. 30 %)
- Regular fingerling purchase
- Pond O&M (sub-contracted)
- Fish harvest, marketing, sales
- Fish farming research and development cost
- Debt repay

REVENUE STREAMS

- Fish sale

SOCIAL & ENVIRONMENTAL COSTS

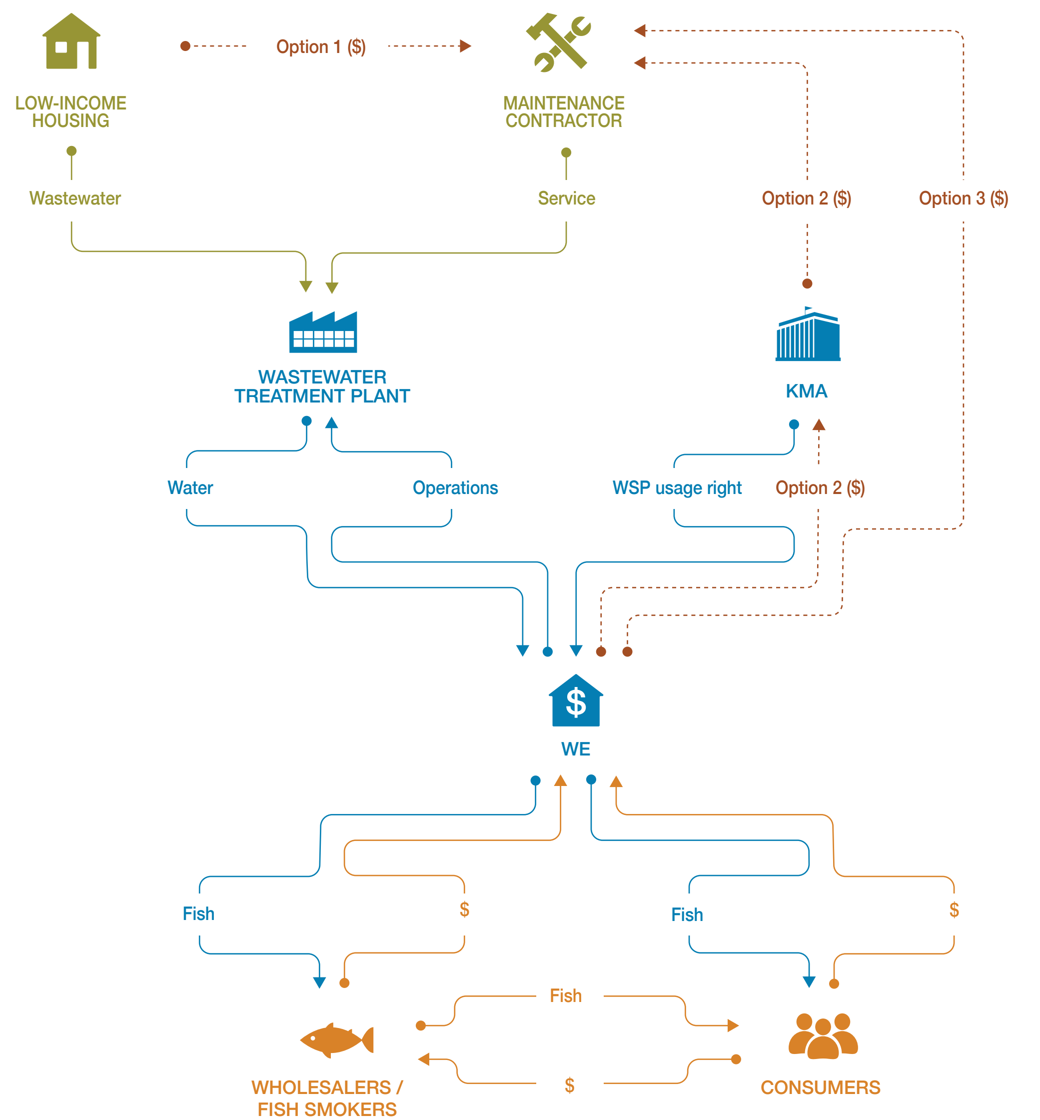
- Potential health risks of plant workers and through fish consumption if monitoring and the HACCP system fail
- Potential risk to biodiversity if fish escapes

SOCIAL & ENVIRONMENTAL BENEFITS

- Improved wastewater treatment and public health
- Reduced food miles and increased protein supply
- Poor households exempted from maintenance fees

from insufficiently treated wastewater entering the environment. Other beneficiaries are (i) the WSP-connected households which were so far asked to pay the maintenance contractor (see Figure 226, option 1); and (ii) the contractor who faced significant opportunity costs trying to collect the household fees. While KMA provides the land and pond system, WE cultivates the fish under strict safety monitoring standards. KMA as public partner is not paying the WE for the expected service; in contrary, any profit WE achieves is shared 1:1 with the public utility allowing it to improve sanitation services, like to fully pay for pond maintenance (see Figure 226, option 1)[1], i.e. without need for the subcontractor to collect fees from the served households which appeared difficult as both estates were set up for low-income groups.

FIGURE 226. BUSINESS PROCESS FLOW OF WASTE ENTERPRISERS



So far, WE and its operational 'successors'[2] sold the produced catfish very easily to wholesalers who smoke the fish or sell it to fish smokers. Wholesalers are typically contacted and notified of harvest times. WE sold initially their product at a competitive price (USD 3/kg) equivalent to local market prices but could achieve far higher revenue by smoking its fish before sale, which would also help to control pathogenic health risks. One of the key strengths of the aquaculture business model is that once the WSP is in place, the additional start-up costs are low, and the operating costs (in particular staff salaries) become bearable with more than two WSP to manage. However, the fish production needs a pre-run to optimize fish stocking, feeding and survival (Amoah and Yeboah-Agyepong, 2015b). The key elements of the business model canvas are presented above.

Value chain and position

The fish produce is up to 80% directly supplied to wholesale/fish smokers, while 20% goes to consumers who roast or smoke the fish before it gets cooked (Figure 226). Up till now, demand for catfish remains higher than supply, and all fish brought offered gets also sold. Parts of the revenues from fish sale are used to maintain the treatment quality of the WSPs, without charging the low-income neighborhood. Although the "source of fish" is so far among the least important product attributes influencing consumers' purchasing decisions, a potential threat to the viability of the business could be that despite safety controls, traders or consumers start rejecting the fish.

Institutional environment

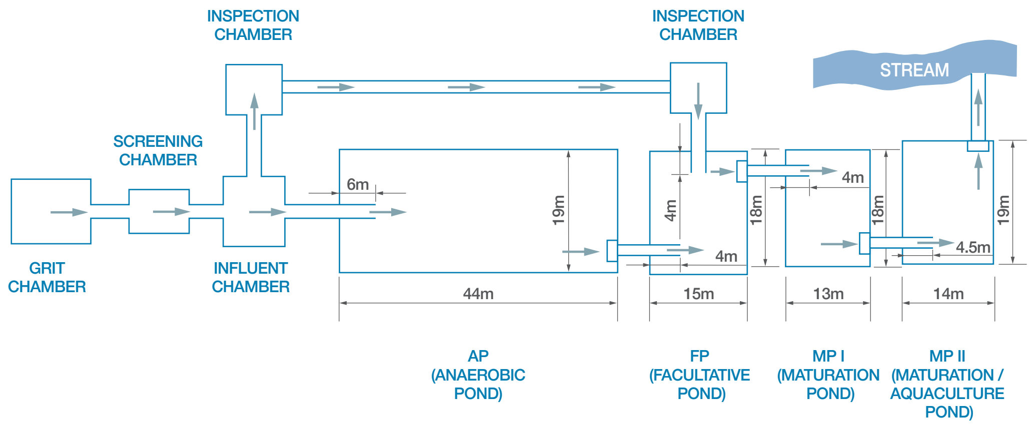
This is a public-private partnership business between WE and the city of Kumasi (KMA), where WE controls the operation and management of the WSP and KMA supplies the land with its treatment infrastructure and wastewater. While there are no legislations in Ghana that explicitly promote or ban the use of wastewater for aquaculture, an environmental impact assessment is required for commercial aquaculture[3]. With the permit from the Ghana Environmental Protection Agency (EPA) and a permit for (fresh) water usage from the Water Resources Commission (Act 522, 1996) the Fisheries Commission will approve the business. The WE-KMA public private partnership did not fit into the common scheme and was authorized through the agreement of the city to enter into contract with WE to support environmental sanitation in the city. Since then, the National Aquaculture Development Plan of 2012 was developed, which calls among others for more attention to fish health, and the 2013 established Ministry of Fisheries and Aquaculture Development published in 2014 through the Fisheries Commission, "National Aquaculture Guidelines and Code of Practice" to set minimum standards for operators in the aquaculture value chain and also prevent any possible negative impact of aquaculture on the environment in line with the Fisheries Regulations 2010 (L.I. 1968) and Fisheries Act, 2002 (Act 625).

WE's business was from 2011-on accompanied by research, e.g. on feeding, stocking and food safety by the Department of Fisheries and Watershed Management, Kwame Nkrumah University of Science and Technology (KNUST) and the International Water Management institute (IWMI). This was supported by a grant from the African Water Facility to Ghana's Water Resources Commission.

Technology and processes

In both project locations, the WSPs were overgrown and dysfunctional when WE arrived. The setup of the WSP systems is shown in Figure 227 on the example of Ahinsan. The system is made up of five sludge chambers: a grit, screening, influent, two inspection chambers and four treatment ponds, which were overgrown before WE took the WSP over. The four treatment ponds are: anaerobic pond (AP), facultative pond (FP), and first and second maturation ponds (MP I, MP II). Given the fixed number of connected households, the series of ponds make up an effective and low-cost means of treating wastewater, if well maintained. The last pond (MP II) or depending on water quality also MP I

FIGURE 227. TREATMENT PROCESSES OF THE WSP SYSTEM AT AHINSAN, KUMASI, GHANA



and MP II are used to cultivate catfish, which has a relatively high tolerance for low levels of dissolved oxygen. Phosphorus and nitrogen provided with the wastewater are essential to facilitate production of natural microscopic plants and plankton which are food for the fish. There are two growing seasons per year and three fingerlings per m^2 are stocked in both maturation ponds per season, targeting an average annual production of about one ton per pond or 2t of fish per treatment plant with a survival rate of about 80%[4]. WE holds no inventory of fish at harvest and sells its product easily to wholesalers to be resold in the local markets to consumers and fish smokers for processing. Wholesalers are typically contacted and notified of harvest times.

Funding and financial outlook

Aquaculture, in general, appears to be a good business option in Ghana. A feasibility study by the Ministry of Food and Agriculture (MoFA) for Tilapia, indicated a positive Net Present Value (NPV) and Internal Rate of Return (IRR) of 32%, a Benefit Cost Ratio (BCR) of 1.18, and a payback period which is slightly longer than four years (Cobbina and Eiriksdottir, 2010). Aside labor and management costs, the cost of feed forms the bulk of the variable cost. Sensitivity analysis showed that the cost of feed, the fish survival rate as well as the farm gate price of fish are the main factors affecting profitability, while the most constraining factor for commercial aquaculture are the high start-up cost of which about 68% are fixed costs.

In the presented business case of WE, the possibility to use existing infrastructure, provided a huge cost saving (covering nearly all fixed cost except rearing infrastructure for fingerlings). Although wastewater was expected to support the development of a significant amount of feed for the fish, the experience of WE showed that this is not sufficient (or sufficiently balanced) and feeding remains recommended. This feeding pays off as catfish grown with wastewater eventually grew much larger than fish in freshwater control ponds (Amoah and Yeboah-Agyepong, 2015b).

Table 53 presents financial projection based on WE data for the management of one to five WSP systems, using a ten-year planning horizon. Data show that although with two systems, the business can break even, with three or more WSPs, staff costs are most efficiently used, resulting in a viable business with NPV and IRR positive.

TABLE 53. INCOME STATEMENT OF WASTE ENTERPRISES

NUMBER OF WSP SYSTEMS				1	2	3	4	5
COST ITEMS								
A) Capital investment			GHC	4,495	8,990	13,485	17,980	22,475
B) Production Costs								
	Cost/ stocking	Stocking/ year						
Fingerlings	225	2	GHC	450	900	1,350	1,800	2,250
Fish Feed	70	2	GHC	140	280	420	560	700
Pond/Tank Maintenance	Cost/ stocking	Stocking/ year						
Patching Cement	10	2	GHC	20	40	60	80	100
Chlorine	10	2	GHC	20	40	60	80	100
Pond Liming	120	2	GHC	240	480	720	960	1,200
Hand Sanitizer	25	2	GHC	50	100	150	200	250
Total production costs			GHC	920	1,840	2,760	3,680	4,600
C) Administrative Costs								
Employees	Annual Salary							
Manager	GHC	15,000	GHC	15,000	15,000	15,000	15,000	15,000
Grounds Keeper	GHC	1,200	GHC	1,200	2,400	3,600	4,800	6,000
National Health Plan	GHC	20	GHC	40	60	80	100	120
Total Administration Costs			GHC	16,240	17,460	18,680	19,900	21,120
D) Total Operating Costs			GHC	17,160	19,300	21,440	23,580	25,720
Operating cost/system			GHC	17,160	9,650	7,147	5,895	5,144
REVENUE ITEMS								
E) Total revenue per number of systems			GHC	9,720	19,440	29,160	38,880	48,600
Administrative Cost as percentage of Total Revenues				167.0%	89.8%	64.0%	51.1%	43.4%

Production cost as percentage of Total Revenues		9.5%	9.5%	9.5%	9.5%	9.5%
Total Cost as percentage of Total Revenues		176.5%	99.3%	73.5%	60.6%	52.9%
PROFIT ITEMS						
F) Total Profits	GHC	(7,440)	140	7,720	15,300	22,880
Interest Income/ (Expense)	GHC	–	–	–	–	–
Taxes	GHC	–	–	–	–	–
Total profits before Interest & Taxes	GHC	(7,440)	140	7,720	15,300	22,880
G) Net Profits	GHC	(7,440)	140	7,720	15,300	22,880
Net profits as percentage of Total Revenues		–76.5%	0.7%	26.5%	39.4%	47.1%
Net Present Value (calculated over a 10-year period)	GHC	(36,516)	(5,118)	25,030	55,178	85,325
Internal Rate of Return (calculated over a 10-year period)	negative net cash flows over 10 years		–17%	82.0%	119%	141%
Break-even year (calculated over a 10-year period)	not in ten years		year 1	year 1	year 1	year 1

Source: Waste Enterprises; updated.

1 Reported financials for Year 1 of business with two annual harvests of two 250m² ponds per system. 20% mortality rate. Fish sold fresh.
2 Aquaculture business has tax exemption for the first 5 years and thereafter an income tax of 10% is assumed. Capital costs after depreciation over 10 years.
3 Inflation rate assumed at 8% as in 2011/12; Exchange rate in mid-2011: USD 1.0 = GHC (GHS) 1.50.

Another option to make already a one-WSP system viable is to sell fish **smoked** and not fresh which allows a much higher sales price and return. For such a case, WE internal projections estimated for catfish an IRR of up to 45% (at 20% discount rate). With an estimated profitability index of 2.1, and a BCR of 1.13, a payback period of three years was estimated under favorable stocking and sales conditions (Amoah et al., 2015b).

As experience in wastewater aquaculture had first to be gained, time was lost with optimizing production on both WE sites, and after two years, revenues hardly covered daily operations. As indicated in the sensitivity analysis the profitability improved with increased fish survival, which was supported by the accompanying research. For the research, WE in association with IWMI and Ghana's Water Resources Commission attracted external funding from the African Water Facility. After its successful proof of concept, Waste Enterprisers planned initially to expand its aquaculture business across Africa with a Technical Director in charge of fish-farming, but then received funding to engage in another resource recovery challenge and discontinued fish farming (IWMI, 2012) while the accompanying research continued at the WSP sites until 2015.

Socio-economic, health and environmental impact

At the aggregate level, the business will help with the reduction in public health expenditures through avoided cost of diseases associated with untreated or only partially treated sewage entering surface water bodies, thereby leading to their improvements. On the other hand, health risks of workers at the WSPs, fish traders and consumers have to be assessed, monitored and minimized. This objective was supported through studies addressing pathogenic contamination, as well as the accumulation of heavy metals and pharmaceutical residues (Amoah and Yeboah-Agyepong, 2015a; Asem-Hiablie et al., 2013). Also the type of fish (African Catfish; *Clarias gariepinus*) was chosen for safety reason as in the study region it is normally smoked and cooked before consumption. As the Fisheries Act does not address fish health, quality assurance or product safety, a WHO recommended Hazard Analysis and Critical Control Point (HACCP) system was developed which allows to monitor a number of critical control points where compliance with safety procedures interventions is required to reduce or eliminate potential health risks (Yeboah-Agyepong et al. 2017).

In view of environmental impacts, the WSP rehabilitation and maintenance will improve the environmental situation. As wastewater aquaculture is so far not addressed in any legislation, the Ghana Environmental Protection Agency (EPA) became member of the steering committee of the business accompanying research.

Although fish meat analysis did so far not point at actual risks, in the Ahinsan or Chirapatre system, critical control-points are the smoking of the fish directly after harvest as well its well-cooked consumption to remove pathogens from fish surface. An additional safety option would be to purify the fish in a fresh water pond after harvest and prior to sale, i.e. to clean as far as possible also the fish's digestive tract. Smoking of fish on-site, would also increase its market value, i.e. sales price.

Scalability and replicability considerations

In general, the investment climate for aquaculture is across and beyond Africa very positive. To promote and encourage new aquaculture enterprises in Ghana, they are granted for example a five-year tax free period (Cobbina and Eiriksdottir, 2010).

The use of (treated) wastewater for fish farming is more challenging. It has a long tradition, especially in Asia, and although it is supported by WHO (2006) with an own set of guidelines, many authorities might not agree with the idea especially where risk monitoring is weak. On the other hand, pond-based treatment systems are very common in many tropical countries, supporting housing estates, towns, military camps, universities, boarding schools, etc. Moreover, the majority of these systems are on a similar trajectory to failure as observed in Kumasi (Murray and Drechsel, 2011). Thus, the general drivers for the success of the business are:

- Supportive (or at least non-restrictive) regulations and policies, and positive perceptions.
- High local demand for catfish, allowing to share profits.
- Win-win public-private partnership resulting in low capital cost investment by the private partner.
- Research partnership to monitor and optimize system safety and productivity.

The implemented model has a significant potential for replication and scaling up if compliance with national or international safety guidelines such as WHO (2006) can be assured. The accompanying research in Kumasi resulted in fish farming manual and implementation plan summarizing the lessons learnt from wastewater aquaculture (Amoah et al., 2015a; Amoah and Yeboah-Agyepong, 2015b). But even with full compliance, market demand remains also a function of risk awareness and consumer perceptions, which has to be considered in local feasibility studies. Where wastewater treatment systems are to be newly set up for aquaculture, land requirements for pond-based systems have to be considered. The maintenance of the ponds can eventually be outsourced, or become part of the business.

Summary assessment – SWOT analysis

The model WE developed was intended to inspire opportunities that exist for using the resource value of human waste to the economic benefit of the sanitation sector. The aquaculture business supports via the productive use of treated wastewater the maintenance of otherwise dysfunctional wastewater treatment plants without charging poor households. With fish being nation-wide the second most important food consumption subgroup, market demand, especially for catfish is high. The strength of the business (Figure 228) is its ability to negotiate for the supply of free wastewater and land, which helps reduce fixed cost by 70%. The benefits are equally important for the municipality which is lacking funds to maintain environmental and human health. The HACCP system, fish smoking and boiling minimizes risks, and make the fish acceptable to traders. However, changing public perception remains a potential threat. Day to day challenges were more of technical nature, like optimizing fish survival and feeding.

FIGURE 228. SWOT ANALYSIS OF WASTE ENTERPRISERS AQUACULTURE BUSINESS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Continuous free water supply ▪ Low investment costs ▪ Contractual agreement with the authority ▪ Direct contact with wholesalers ▪ Safety monitoring ▪ Economies of scale in the long-run due to low average cost and gained expertise ▪ Savings for authority and no charge to poor households	**WEAKNESSES** ▪ Requires space for pond based treatment plants ▪ Requires uncovered demand for cultivated fish species ▪ Needs efficient systems to handle possible on- and off-site health risks (e.g. high risk where fish is eaten uncooked) ▪ Requires aquaculture expertise (feeding, survival, predator and duckweed control, etc.)
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Easily replicable ▪ Significant market demand for fish ▪ Missing regulations and supportive investment climate	**THREATS** ▪ With city growth, more compact treatment plants appear ▪ Competition in alternative fish production may cause fish price to decrease ▪ Health risks reduction and monitoring costs for fish consumption may be high for the business ▪ Changing regulation and/or consumer perception of wastewater-reared fish

Contributors

George K. Danso, Government of Alberta
Michael Kropac, CEWAS
Mark Yeboah-Agyepong, KNUST, Kumasi
Nelson Agbo, KNUST, Kumasi

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See also: www.flickr.com/photos/waste-enterprisers/sets/72157627841508651/.

Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2014/16. As business operations are dynamic data can be subject to change.

Notes

1 After a test period the arrangement was changed to accelerate the maintenance process, and WE organized directly full-time plant maintenance, i.e. without need for KMA to organize this (see Figure 226, option 3).

2 The pond systems were till 2015 maintained by the local university (KNUST) and IWMI for research purposes. One of the ponds is currently (2017) used as a fish hatchery.

3 So far, mostly commercial private sector operators undertook environmental impact assessment, but not small-scale operators (Awity, 2005).

4 High survival rates were achieved with longer feeding periods (rearing fingerlings to at least 20g) and after successful removal of a large numbers of predators (snakes) from the ponds.