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Biogas digester types installed in South Africa: A review

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ABSTRACT

This narrative review paper begins with a brief history of biogas digesters in South Africa followed by a listing of the biogas digesters that have been installed in the country then the critical analyses of the different types of small scale biogas digesters since the introduction of the biogas technology into the country in the year 1957. The analysis is done on a basis of conducted studies and observations of the strengths and limitations of each small scale digester design installed. It is the aim of the review to help stakeholders in the selection of the most appropriate digester type well suited to their environmental conditions and to fill the knowledge gap existing in the biogas technology and hence making it easier to map of a way forward into the design of improved anaerobic digesters. In this review, the in-situ cast concrete digester has been analyzed to be the most suitable design for installation in the South African context though stakeholders can still do their own selection based on the analyses of the other designs. Some recommendations of aspects to consider in the introduction of a new design are also given.

1. Introduction

A biogas digester is an airtight enclosed container designed to enhance the anaerobic digestion of biodegradable waste such as animal manure, domestic wastes, black water or sludge and the collection of the produced biogas [1]. In terms of operational mode, biogas digesters can be divided into three categories: passive systems where biogas recovery is added to an existing waste treatment facility and there is little control of the anaerobic digestion process, low rate systems where the manure waste flowing through (into and out of) the digester is the main source of methane-forming microorganisms and it only leaves the digester when the designed retention time lapses i.e. the solids retention time (SRT) is equal to the hydraulic retention time (HRT) and high rate systems where the methane-forming microorganisms are trapped and retained in the digester to increase biogas production efficiency in the biodegradable material being fed into the digester [2]. In terms of scale, biogas digesters are classified as domestic/residential digesters which have a power supply capacity less than 25 kW and are meant to supply energy for cooking, lighting or sanitation in rural residential areas, small-scale and medium commercial digesters with a capacity between 25 and 250 kW and meant for heating or electricity generation and large-scale installations with a capacity greater than 250 kW [3].

2. History of biogas digesters in South Africa

There are about 700 digester installations done in South Africa since the introduction of the biogas technology in the country in 1957 by John Fry [4]. The first biogas digester in South Africa was installed in 1957 by John Fry on a pig farm [5]. The substrate being used was pig manure. In 1958, electricity was generated from the produced biogas to power pumps on the farm. Since then, South Africa has experienced limited market penetration for biogas [6]. The reasons for this limitation include the cheap cost electricity from other sources such as fossil fuels, limited grants or government incentives to support the biogas technology and unavailability of local biogas technology providers [7].

In 1998 the Ceres fruit farm digester was built in Veolia followed by the Cape flats biogas digester for dewatering sludge in 2003. In the same year, the installation of a 1 MW digester was commenced in Mariahill in Durban. This was later on completed in 2010. In 2009, Mark Tiepelt founded BiogasSA after failing to find a local company that could install a biogas digester a smallholding in Johannesburg [7]. The company initially focused on domestic scale digester installations but expanded its operations over the years into the commercial sector and commissioned its first large scale 0.4 MW anaerobic digester in 2016. Being an agent for other international biogas equipment suppliers, BiogasSA plays a big role in bringing quality products and

Abbreviations: C/N, carbon to nitrogen ratio; CSTR, continuous stirrer tank reactor; HRT, hydraulic retention time; MW, megawatt; PVC, polyvinylchloride; SA, South Africa; SRT, solids retention time; UASB, up-flow anaerobic sludge blanket; UV, ultra violet; DIY, do it yourself; EC, eastern cape; WC, western cape; KZN, kwazula natal

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expertise into the country. It has two basic small scale digester designs namely the in-situ cast concrete Puxin and the DIY biobag digesters.

Due to the introduction of a regulatory framework promoting renewable energy, appropriation of green funding and incentives, unreliable grid supply and ever increasing tariffs, availability of unused feedstock sources e.g. biomass and landfill sites that are fast reaching their capacity, the need to treat wastewater at a lower cost and the government's commitment to cleaner energy sources, the Central Energy Fund (CEF) sought to develop a bio-energy programme for South Africa in 2005 [7]. More digesters were then introduced in the years that followed. These include the biogas digesters installed in the South African breweries such as Alrode in 2005, Newlands in 2007, and digesters installed on industrial and municipal wastewater treatment facilities such as PetroSA in 2008 and Joburg northern works facility in 2013. Some digesters were installed in landfills which include the Chloorkop and Ekhurleni landfill gas projects in 2010. Institutions such as the University of Fort Hare and the University of Kwazulu Natal also gave a hand in the installation of small scale/domestic digesters in 2013 [6]. More digesters were introduced into the country between the years 2005 and 2017. Following is a list of the recorded medium and large scale biogas digesters installed. Several hundreds of small domestic scale digesters have also been installed but there is no individual record of their number that has been published as yet.

3. Biogas digesters installed in South Africa

3.1. Domestic/residential digesters

Table 1 shows the list of biogas digesters installed in different parts of South Africa by different developers. The substrates used and power output are stated wherever the information was available. These power output values give a close estimation of the biogas yield achieved by a given digester since 1 m^3 of biogas generally produces 6 kW h energy [8].

The domestic/residential scale digesters installed are currently involved in three projects: Melani village biogas expansion, Illembe

Table 1
Location, developer name, substrate input and power out of biogas digesters installed in South Africa.

Area	Developer	Substrate input	Power output
Alice, Eastern cape	CAE / University of Fort Hare	4000 m^3 of dairy and piggery manure	2 × 132 kVa electricity generators
	Alrode brewery		
Athlone Industria	Farm Secure Energy, Wastemart, CEA/New Horizon waste to energy	400 t of organic waste per day	
Bela-bela Limpopo	CAE Humphries Boerdery piggery		
Belville		Waste water treatment plant	
Bonnievale	FarmSecure Carbon	> 5 t bovine manure	
Bredasdorp	iBert	4 t abattoir waste per day	100 kW
Cavalter	iBert	20 t abattoir waste per day	500 kW
	EnviroServ/ Chloorkop LFG		
	Cullinan		190 kW
Darling Uilenkraal	CAE/Uilenkraal dairy farm	Bovine manure	600 kW
Darling GrootPost	FarmSecure manure	Bovine manure	
Durban	Bisasar road LFG	3500–5000 refuse per day	6 MW
Durban	Marrianhill LFG	550–850 t per day	1.5 MW
	Ekhurleni LFG		
Grabouw	Elgin Fruit and juices	> 5 t of fruit waste per day	500 kW
	Ibhayi brewery		
Jan Kempdorp	iBert	5.5 t abattoir waste per day	135 kW
	Jacobsdale		150 kW
Johannesburg	WEC/Northern Waste Water Treatment Works	Sewage sludge	1.2 MW
Johannesburg	Robinson Deep		19 MW
Klipheuwel	Reliance Composting	700 t organic waste per day	
Klipheuwel (Zandam)	Farmsecure	> 5 t of manure per day	600–700 kW
Mossel Bay	Biotherm SA, Mossel Bay PetroSA	Refinery waste water	4.2 MW
Newlands	SAB Miller	4500 m^3 of wastewater per day	10% of the plant's energy demand
Paarl	Drakenstein municipality		14 MW
Pretoria	Bio2watt / Bronkhorst-Spruit Biogas plant	Manure	4.6 MW
	Prospection brewery		
Queenstown	iBert	42 t mixed waste from a piggery per day	
Riverdale	iBert	4 t abattoir waste per day	100 kW
	Robertson		150 kW
	Rosslyn brewery		
Springs	BiogasSA / Morgan Springs Abatrtoir	Slaughter waste and organic waste	0.4 MW
Stellenbosch	Veolia water Technologies / Distell	1000 m^3 wastewater per day	
Stellenbosch Franschhoek	Rhodes Food Group	35 kg per day(testing feedstock)	
	Selectra	Sewage, silage, manure	0.5 MW
	Selectra	Sewage, silage, manure	1 MW
	Selectra	Sewage, silage, agricultural waste	1 MW
Table view	Jeffares and Green / Bayside Mall	0.6–1 t of food waste per day	
KZN	Khanyisa projects	Manure from 2+ cows, school organic and sewage waste	Rural cooking fuel
KZN	SANEDI	Manure from 2+ cows, school organic and sewage waste	Rural cooking fuel
EC (Alice, Fort Corx and Melani villages), WC (Phillipi), KZN	AGAMA	Manure from 2+ cows, school organic and sewage waste	Rural cooking fuel
Gauteng	Zorg	Vegetable pulp + silage plant	7200 m^3 methane

[3,9–15].