Final Report
Toilet linked biogas slurry applied to crops

Report on physicochemical and microbiological analyses of slurry from toilet linked biogas plants and evaluation of its economic aspects through application of such slurry on agriculture lands as manure on the yields of different crops and vegetables and analyze chemical constituents of nutrient values in grains of crops

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1. Executive Summary

Toilet linked biogas plants have been implemented at some scale in different villages in some districts of Gujarat by WASTE, Netherlands and FINISH Society, India. In an earlier study, the performance of such toilet linked biogas plants was compared to non- toilet linked biogas plants. The economic benefits of application of toilet linked biogas plant slurry on agricultural lands for different crops and vegetables, however, was not studied ta that time.

The slurry of the toilet linked biogas plants had no coliforms and helminths. The inlet point for human excreta to underground digester is connected with a PVC pipe as a Y to the biogas chamber. The other "leg" of the Y is the inlet pipe from the mixing chamber of animal dung. All feeding into the digester is below the ground level. Therefore, samples of inlet from human wastes could not be taken for analysis. As per WHO guidelines for the safe use of wastewater, excreta and grey water (2006) Vol. II, helminths eggs per litre of treated wastewater should be equal to or less than 1/litre. For unrestricted use in agriculture number of E. coli for root crops should be less than 10^3/100 ml.

The absence of coliform could be due to anaerobic condition inside biogas plants and further its storage in pits under anaerobic condition. In a storage pit, aerobic conditions occur at initial stage, but after a few days when slurry is covered with the layers of incoming slurry anaerobic condition develop. Most of the coliforms are aerobic in nature and can't survive in prolonged anaerobic condition. Furthermore, sun drying of slurry helps eliminate coliforms. In the storage pits, there is thermophilic condition where inside temperature goes beyond 50^0C where helminths can't survive[1].

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[1] It has been reported that inactivation of all Ascaris eggs take place if the temperature of the compost heaps exceeds 45^0C for at least 5 days (Katherina Gallizzi, SANDEC Switzerland, in Afield study in Kumasi, Ghana. Co-composting reduces Helminths egg in Faecal Sludge 2003).

The toilet linked biogas slurry has a higher percentage of plant macronutrients like nitrogen, potassium and phosphate than non-toilet linked biogas slurry. Therefore, the basic concept was to test biogas slurry on crops in different plots and compare this with control plots where either chemical fertilisers in recommended doses are applied or where no additional inputs are applied.

Effect on wheat: Yields of wheat was higher by over 70% in comparison to control having no fertilizer or other inputs. Wheat yield was higher by 6% in comparison to control having di-ammonium phosphate (DAP) and urea. Wheat grains with experimental plot having slurry only have higher percentage of soluble proteins and carbohydrates than control plot having chemical fertilizers like DAP and urea[2]. There is good quality of wheat yield with economic return applying this slurry as manure in agriculture lands.

Effects on brinjal (eggplant): In addition to higher yield, it was observed that the infection of fungi / insects on slurry applied plot was either nil or rarely observed in comparison to control having chemical fertilizers. In control set, fungicides were used by farmers to overcome such infections. Further, shining effects on brinjal from the slurry plots were much better and longer lasting than brinjal from the control plots.

Application of the slurry on coriander: Grains of coriander were distinctly larger with yield of 16 % higher than the control set with chemical fertilizer (DAP only). The higher rate could be due to presence of several micro-nutrients present in slurry, which may not be available in the soil.

Likewise, yields of vegetables like cabbage, cauliflower, fenugreek, onion, spinach and carrot were considerably higher in comparison to respective controls.

The use of toilet linked biogas slurry on crop yields of crops are encouraging and economically interesting. In addition to higher yields with better quality, there is improvement of soil ecosystem, quality of yields and improvement of environment. A demonstration project like this helps in motivating farmers to apply this type of slurry.

[2] It only shows difference in constituents of proteins, carbohydrates and sugar in both the samples. Protein is the important nutrient having higher percentage in slurry applied field grains of wheat.

2. Background

Technical support for implementing toilet linked biogas plants was provided by WASTE, the Netherlands and FINISH India through co-financing from ICCO. Well over 2,000 plants were implemented in Valsad district in the State of Gujarat. For this the Government[3] provided a financial subsidy.

All biogas plants are fed with cow dung. Some 730 are toilet-linked. Earlier, a detailed study was conducted to determine the rate of production of biogas from the toilet linked and without toilet linked biogas plants. The study detailed difference in physico-chemical constituents of biogas from the two sources as well as the microbiological analyses of slurry from the two sources.

Result from this study showed that toilet linked biogas plant had a higher rate of production of biogas than non-toilet linked biogas plants. The slurry from toilet linked biogas plants has a higher percentage of plants macro-nutrients like nitrogen, potash and phosphorus than slurry from only cow dung fed biogas plants. There is no helminthes reported in the slurry of toilet linked biogas plants.[4] However, a low number of coliforms were reported in such slurry[5]. More samples were analysed in the NABL accredited laboratory, Surat, Gujarat and the Navasari Agricultural University of the Government of India, Gujarat.

It was realized that the economics of toilet linked biogas plants in terms of use of slurry for agricultural outputs needs to be properly demonstrated to farmers for their motivation and awareness. For that purpose, the FINISH Society of India assigned the works with the following objectives:

i. Awareness building and demonstration to households regarding operation of toilet linked biogas plants, proper feeding, utilization of biogas for cooking, lighting etc.
ii. Demonstrate the benefit of using slurry from toilet linked biogas plants in agriculture. Crops selected are wheat and vegetables. Controls are selected as plots without any fertilizer or with chemical fertilisers. The beneficiary use the land to grow vegetables/ crops as per his/ her plan. Vegetable seedlings are procured from local nurseries.
iii. Chemical analysis of slurry from toilet linked and non-toilet linked biogas plants including pathogens

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[3] Ministry of New and Renewable Energy, Government of India and Gujarat State Government as per their norms

[4] Sludge Treatment Wetland (STW) as a Post-Treatment for Toilet-Linked Biogas Plant A pilot-scale case study in Gujarat, India, Grover Hector Mamani Casilla, UNESCO-IHE MSc Thesis, 2014.

[5] Enhanced pathogen die-off in slurry from household size toilet linked anaerobic digester, Apurva Sahu, UNESCO-IHE MSc Thesis, 2014

iv. Chemical analyses of food crop grains obtained using slurry from toilet linked biogas plants and chemical fertilisers
v. Rectification of possible problems during operation of biogas plants and their remedies, etc.
vi. Demonstrate effects of slurry on different crop and vegetables in comparison to control having chemical fertilizers or without any fertilizer.

3. Toilet linked biogas plants

All biogas plants linked with household toilets are modified Deenbandhu Model, reinforced cement concrete (RCC) made, underground dome shaped structure, having one inlet cum mixing tank and an outlet chamber for storage of slurry. A half inch pipe emerges from the dome of biogas plant that is connected with cooking burner in kitchen where it is used for cooking purpose. The plants that are toilet linked have aspirate inlet for the black water from the toilet.

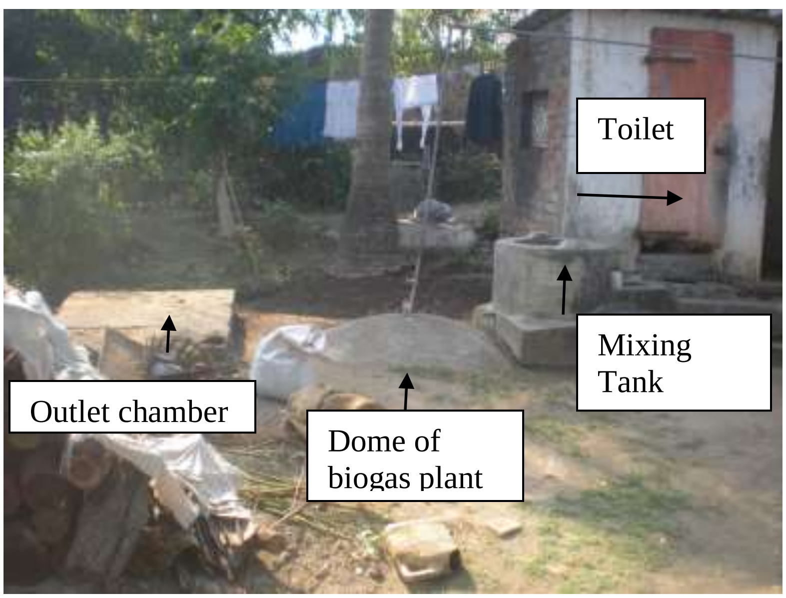

Fig 1: A toilet linked biogas plant

Fig 2: Slurry from a Toilet linked biogas plant

Fig 3: Use of biogas for cooking

4. Selection of plots for agriculture

After visiting several villages and having discussion with several farmers the following villages were selected for conducting experiments in Navsari, Somnath and Valsad districts:

i. Panikharak, Topal Phalia, Valsad district for wheat plots
ii. Patheri village Navsari district for Brinjal (eggplant) plots
iii. Boriach village. Navsari district for cauliflower, fenugreek, onion, spinach
iv. Nawa Goan village Navsari district for cluster bean
v. Lakhapara, Sutrapada, Somnath district for wheat and coriander

Village and District	Crop	Treatment area with toilet linked biogas slurry	Control area with chemical fertilisers (DAP recommended dosage)	Control area no fertlisers, no slurry
Panikharak, Topal Phalia (Valsad district)	Wheat	30 m^2		30 m^2
Lakhapara, Sutrapada, (Somnath district)	Wheat	54 m^2	10,000 m^2	
Patheri village (Navsari district)	Brinjal (egg plant)	70 m^2	1400 m^2	
Lakhapara, Sutrapada, (Somnath district)	Coriander	150 m^2	3,000 m^2	
Boriach village. (Navsari district)	Cauliflower, Fenugreek, Onion, Spinach			
Nawa Goan village (Navsari district)	Cluster bean			

4.1. Wheat plots

A 30 m^2 experimental plot and a 30 m^2 control plot were selected for wheat growing in the village of Panikharak, Topal Phalia in Valsad district. Another wheat experiment was carried out in the village Lakhapara, with a 54 m^2 experimental plot and 10,000 m^2 control plot. In this case, the farmer was reluctant to provide more experimental space due to fear that he would be losing products/yield in the experimental plot.

Control set

Control sets for both the sites were different. In case of Panikharak village, control set was without any use of fertilizer, whereas for Lakhpara village, DAP and urea were used as control set of plot. By having controls without any fertliser and with chemical fertilizer, it gave result to find out economics both in terms of with and without fertilizer.

Use of slurry for experimental set

In all the experimental sets of wheat as well as other vegetables stored semi-dried slurry was applied at the rate of 10 kg/m^2. This quantity was calculated based on the moisture content of the slurry and its percentage contents of N, P and K.

4.2. Results with wheat plants

Growth pattern

There were visibly distinct patterns of growth of wheat in experimental set in comparison to the respective control sets. Growth of wheat in slurry plot was much better than the control having no additional inputs. This difference continued till the harvesting of wheat.

In case of plots having DAP and urea as control, there was no visible difference between control and experimental plots. However, during ripening stage, wheat plants in experimental set were still greenish in comparison to control having DAP and urea. The following photos are taken from both sites.

Fig 4. Left side plot with slurry. Right side control without fertilizer (Panikharak village) early stage

Fig. 5. Left side control. Right with slurry (Panikharak village) at later stage

Fig. 6: Left side control plot DAP and urea. Right side experimental plot (Lokhanpara village)

There was a remarkable difference in the physical appearance between the control and experimental plot, particularly with the control without any fertilizer (Figs 4-5).

Yield of wheat grains

There was clear difference in the size of grains from two plots. Size of the grains from experimental set was larger than the control set without any fertilizer (Fig 7) and with chemical fertilizer.

Fig. 7 Wheat grains: Left is control. Right is from experimental plot kept on white paper for better comparison

Yield of grain from control set was 2.30 kg / 30 m^2 whereas from experimental plot it was weighed to be 4.03 kg / 30 m^2 in Panikharak village plots. The increase in yield in experimental plot was 75.2 %!, a significant increase. Higher difference in yield was likely because in the control set, no fertilizer was used and natural plant nutrients in soil might be lower.

Fig 8. Wheat grains from control plot Fig 9 Wheat grains from experimental plot (village Lokhanpara)

In case of wheat plots in the village Lokhanpara, it was observed that even during harvesting of wheat, experimental set looked more greenish in comparison to control set- where DAP and urea were used. There was marked physical difference in size and appearance of grains of wheat between the two sets, as evident from the following Fig 8. There was increase of yield by 4.7% in experimental set in comparison to control set having DAP and urea (Table -1).

Table -1

Sr. no	Demonstration field	Control field
Land areas	54 m^2	10,000 m^2
Fertiliser used	Nil	DAP 100 kg+ Urea 200kg
Slurry applied	600 kg	Nil
Yield	29 kg	5024 kg
Rate of yield / 100m^2	53.7 kg	50.24 kg
Percentage in increase in yield		4.7%

As per the government rate cost of DAP is € 363/t and that of urea € 90/t (this includes 12% taxes). Farmers will have pay at least 20% higher than total government costs including transportation cost. In case of slurry plot, there was no such cost. Agriculture fields are just a few meters away from the residence, there is no cost of transportation. Households took the slurry manually and put into fields.

Also, there is definite increase in soil ecosystem and texture of soil, its water holding capacity by using slurry. Such parameters are difficult to evaluate in a short study.

Chemical constitutes of nutrients of wheat grains

Chemical analyses of wheat grains for carbohydrates and nitrogen from both the sets were conducted through the NABL Accredited Laboratory of the Navasari Agriculture University, Gujarat. The report revealed that total soluble protein in the experimental set was higher (13.8%) than control set (13.2%). Likewise, total carbohydrate was also higher (17.2%) than the control set (70.1%). However, total soluble sugar in experimental set was marginally lower (2.6%) than the control set (2.7%). Total sugar in both the cases were almost similar.

4.3. *Results with coriander*

In Lokhanpara village control set of coriander plot was 30,000 m^2. One part of it (150 m^2) was used for the experiment with slurry, In the experiment set 400 kg semidried slurry was used. Growth of coriander in experimental plot was visibly much better than control plot having both DAP and urea as chemical fertilizers. Such difference was observed right from the beginning of growth of the plants. The vegetative growth in the experimental plot was higher with dark green colour. Even during harvesting time, it appeared greenish. Farmer was requested to harvest this plot after a few more days after the control was harvested as he could get some more yield. However, he refused to allot more time, as it would require more additional labour.

Fig 10-A farmer with the staff of GHCL in experimental plot of Coriander at early stage

Fig 11 Coriander experimental plot at a later stage

Fig13 Control sets of Coriander

Fig 14 Control sets of Coriander

Yield of coriander

In experimental plot, yield of coriander was 16.6% higher than the control set with DAP and urea. The quality and physical appearance of the produce was better in the experimental than in the control plot (Fig.15 and 16).

Fig15 Grains of coriander of control set

Fig 16 Grains of coriander of experimental set

Information about coriander plots

Sr. no	Experimental plot	Control plot
Land	150 m^2	3,000 m^2
Fertiliser used	Slurry 400kg	DAP- 250 kg, Urea 150 kg
Yield	28 kg	4,800 kg
Yield per m^2	0.19 kg	0.16 g

Urea and DAP are applied as per normal practice, prices are as given earlier, slurry had no transport cost.

4.4. Results with Brinjal

In the experimental plot, brinjal (eggplant) was planted in 70 m^2 land having 3 rows of 35m length. In the control, in another 50 rows of 35m length brinjal was planted and DAP and urea were applied. In the experimental plot no fertilisers were added. Growth of brinjal plants was good and distinct in experimental rows than control rows

Brinjal was harvested at 3 days' intervals. From 50 rows (where chemical fertilisers were used) 150 kg of brinjal was harvested. Whereas from the experimental 3 rows, 10 kg of brinjal was harvested during the same interval. The yield was slightly more in the experimental plots than in the control plots with chemical fertilizers. Selling price of brinjal at Mandi house was INR 10/kg, i.e. about € 0.14/kg.

Information about brinjal plots

Sr. no	Experimental plot	Control plot
Land	108 m^2	1,800 m^2
Fertiliser used	Slurry 500 kg	DAP 100 kg, Urea 75 kg
Yield	10 kg	150 kg
Yield per m^2	0.93 kg	0.83 kg

Furthermore, it was interesting to observe that brinjal with chemical fertilisers had about 10% rotten or infected vegetables. Whereas in case of slurry application rows there was no rotten or infected vegetables are very rare. Photos of brinjal plots in Figures 17 and 18 below.

Fig 18 Rows with slurry application

Fi fertiliser used rows

It was also observed that in slurry used rows, there was a good shining of brinjal that continued for longer period. In case of chemical fertilizer, such shining was less and continued for shorter period. That could be the reason that the "*experimental*" brinjal got a higher market price than brinjal grown using chemical fertiliser. However, the farmer preferred to use slurry grown brinjal for their own consumption. It was also observed that slurry rows have least infection of insects/ pests than chemical fertilizer used rows.

4.5. Results with cauliflower, fenugreek, onions, spinach and carrot

All the above vegetables were experimented at one place in different plots owned by the single farmer. There was were no control plots with chemical fertilisers.

Fenugreek had a good growth. It started harvesting at early days as its growth was much better. Since it was harvested almost daily to sell in market, its growth could not be quantified. Farmer was happy with the yield of fenugreek (Fig 20).

In case of **cauliflower,** s ... ol plot. The farmer however rep ... previous year. In a nearby plot of another farmer cauliflower was sown without slurry or fertiliser. Growth and yields of cauliflower from slurry applied to the farm land was much better than the growth and yields of the neighbours having the same cauliflower.

There was one plot each for **spinach** and **carrot**. Growth of plants was very good in the slurry plots. There was no separate plot for control. Spinach was harvested regularly and sold by the farmer. Carrot was also harvested almost daily and sold in market. Therefore, total yield could not be calculated for these vegetables. A neighbour farmer had carrot and spinach in his field grown without any chemical fertliser or slurry. Growth of the vegetables with slurry was much better than in the neighbor's plot growing same vegetables.

Fig 21 Spinach plot with slurry

Onions were sown in different small plots. There was one small control plot with chemical fertiliser (DAP) and an experimental plot with slurry. The growth of the onions in the experimental plot was much better. It was harvested as per the demand of consumers and sold by the farmer almost daily. It was not harvested once. Therefore, such records were not maintained by the farmer. As per the farmer yield of onion with slurry was higher by 15-20 % over the control plots.. Therefore, total yield of onion could not be calculated.

Fig 22. Onion experimental set (left) control set (right)

Fig 23. Onion plots without slurry

Fig 24 Onion plots with slurry

4.6. Results with Cluster bean and sweet potatoes

Cluster beans had been grown in about 8,000 m^2. A part of the this, i.e. 3 rows were used as slurry applied plots. The growth of cluster bean was not very good. It was due to late sowing and incidence of diseases in all plants and the whole plot. There was very little flowering in the plants. Farmer applied different pesticides for flowering and to overcome such diseases. However, there was no desired result. Clustered beans were destroyed by the farmer.

Fig 25 Cluster beans plot

Adjacent to the cluster bean plot, there were two small plots where sweet potatoes were sown. In the plots slurry was applied without control. Growth of sweet potatoes was very good (Fig 26).

Fig 26 Plot of sweet potatoes

5. Economic return from vegetables

In almost all cases yields of vegetables were much better with high income when slurry was used as manure, when compared to no additions but also when compared to applying chemical fertilisers. The combination of slurry with chemical fertilisers has not been tested.

Spinach

Spinch leaves were used for fresh salad. It was sold as salad, usually about 2-3 times a week in the one and a half months' season. Its price was INR 200 / 20 kg (€ 0.15/kg) to the market. For 100 m^2 plot total income from Spinach was INR 1200 (€17.50). Retail price was higher than the market mandi rate.

Coriander

Coriander leaves were used as raw for making salad and food items. From a land space of 100 m^2 total income from selling leaves of coriander was INR 2500 for 20 kg (€ 1.8/kg) of leaves. Our experimental plot had a slightly higher yield of 28 kg.

Fenugreek

Total income from selling Fenugreek from 100 m^2 land was INR 2,500 (€ 36). Selling price of Fenugreek leaves was INR 10 / kg (€ 0.15/kg).

Onion

Income from onions from a 100 m^2 land was INR 2,200 (€ 32). Selling price of onion was INR 10/kg (€ 0.15/kg) at vegetable market mandi.

Wheat

Wheat was not sold by farmer. It was consumed.

6. Awareness and motivation to farmers

This experiment was closely observed by farmers. It was a continuous motivation and awaress to farmers for the applocation of slurry in their agriculture lands so as to obatin higher yields.

During the experiments many farmers approached for guidelines to apply the slurry . Many of them were advised and guided accordingly.

It is expected that at least some of them will be using slurry to cultivate different vegetables in the next season.

Biochemistry Lab.	NAVSARI AGRICULTURAL UNIVERSITY FOOD QUALITY TESTING LABORATORY N.M.COLLEGE OF AGRICULTURE NAVSARI-396450 GUJARAT (INDIA)	

No. NAU/FQTL/BC/ 491 /2017 Date. 20/04/2017

TEST REPORT

Name & Address of the customer	Test Report No.	FQTL/BC/028-029/03/2017
Rangi Khetgar Finish Society, State Head, At Post Nizar, Dis. Tapi Pin. 394370	Date of Sample Receipt:	23/03/2017
	Sample received by:	Kelvin Gandhi
	Date of analysis started:	14/04/2017
	Date of analysis completed:	18/04/2017

Test Results: Wheat Seed

Parameters	Control	Sample
Total Carbohydrate (%)	70.1	71.2
Total Soluble Sugar (%)	2.7	2.6
Total Soluble Protein (%)	13.2	13.8

NOTE: OUR ANALYTICAL FINDINGS REFLECT THE QUALITY OF THE TEST ITEM AT THE TIME OF TESTING

(Signature of Analyst)

Professor & Head
Food Quality Testing Laboratory
Navsari Agricultural University
Navsari-396 450 (Gujarat)
(Name and designation of Authorized Signatory)

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