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Utilizing cow dung and slurry for energy sufficiency of farms and households: Experiences of field studies across three Indian states

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ABSTRACT

Studies were undertaken at the appraisal phase (2003), concurrent stage (2005-2010) and terminal phase (2012). At the appraisal stage, PRA exercise was done by a multi-disciplinary team of scientists in the villages of Ureeka and Pipli of Chirawa Tehsil of Jhunjhunu district of Rajasthan; Achhej and Pahripur of Jhajhar district in Haryana and Nekpur , Siriyal, Chak and Jahagirpur of Bulandshahar district in Uttar Pradesh (UP). Data were collected from the above eight (8) villages on longitudinal basis, i.e. during pre-project stage (appraisal stage), ongoing snowballing of the intervention (i.e. concurrent stage) and after the closer of the project (i.e. terminal stage). Data were collected from 250 biogas users on the parameters of most acceptable technical requirements for the unit, output analysis of biogas, use analysis of biogas slurry, economic analysis of the unit, the intangible benefits from biogas and also the constraints experienced therein. These data were collected from individual farmers as well as from their group to arrive at most agreeable information. The simple statistics of average, percentage and unitary derivations were worked out to draw meaningful conclusions. Results indicated that in general farmers across the three states preferred the smaller size (3.0 m^3) of the plant which required the lower cow dung quantity (75 kg/day). The cost of construction of the smaller unit was found to be affordable in three states which ranged from ₹ 14-15 thousand/unit. The quantity of usable quantity of gas produced from the unit ranged from 40-45 kg/month/household. The quantity of gas produced was estimated to be equivalent to three LPG cylinders/household/month which was sufficient for meeting the kitchen and other requirements of the family on daily basis. From the gas produced, every household could utilize the light energy equivalent to 300 watts for 4 hr every day and even the small engine of 15 HP could also be operated for an hour every day. Another very important output of such smaller unit was estimated to be quantity of usable slurry produced in every house and this was observed to the extent of 145-150 l of slurry every day which if stored properly could be around 1000 l every week. Thus, by investing the ₹ 15000 in installation and running of the family size unit of bio-gas, there was saving to the extent of ₹ 33000 per family per year and the net profit in the first year was 120% higher (₹ 18000) of the operational cost whereas in the second year and subsequent years, the net profit was computed to be 200% higher of the investment. Other intangible benefits of biogas as experienced by the respondents were reduction in drudgery among the women and lessoning the pollution at the household level. Few constraints were also delineated by the users of the biogas.

Key words: Biogas plants, Biogas slurry, Biogas technology, Constraints, Economics of biogas

Advent of high-yielding varieties, chemical fertilizers and other related productions catapulted India's food grain production from 76.67 million tonnes in 1959-60 to the highest ever production of 265.57 million tonnes in 2013-14. The last decade of Indian agriculture, however, are showing the symptoms of fatigue and food grain production is hovering around 210 million tonnes even when the production inputs like fertilizers, agro-chemicals and irrigation water and farm machinery consumption is constantly showing the upward trends. As a result, the cost of production has jumped up with simultaneous deterioration in soil health and production environment. Traditionally, however, farmers have been dependent upon inorganic sources for crop nutritional requirements. The sole dependence on chemical fertilizers in post green–revolution have lead to declining the organic carbon content and useful soil microflora. These are one of the major factors responsible for the deteriorating soil health, which is one the major cause for plateau in food grain production with increasing cost of production. Declining use of organic sources of nutrients such as FYM is another major issue

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of Indian agriculture.

Biomass is an important source to meet the cooking energy needs of most rural households and half of the urban households (Shukla 1996). Biomass based traditional fuels continues to dominate energy supply in rural and traditional sectors despite the fact of significant penetration of commercial energy in India during last few decades. Biomass energy constitutes wood fuels (including charcoal, wood waste wood), crop residues (such as bagasse, rice husk and crop stalks) and animal dung (including biogas). Wood fuels contribute 56% of total biomass energy in India (Sinha *et al*. 1994). Biogas is a combustible gaseous mixture, produced in the process of anaerobic fermentation of organic material like cattle dung or other digestible biomass. Although India has large livestock population and animal dung is available in abundant quantity, but the biogas technology has not find adoption with many farmers in the rural areas. The evolution of use of biogas in India states that by the year 1975 it was considered that there existed a well-tested technology of biogas and required infra-structure for carrying out nation-wide dissemination. AICPB was created with the aim to install 1.5 million biogas units by 2001. The main initiators were IARI, PRAD, and the Indian Institute of Management (IIM). The main responsibility for the implementation of the programme was, however, held by KVIC. In 1978 the Gobar Gas Research Station in Ajitmal, Uttar Pradesh, came up with a prototype of a new design called *Janata* biogas plant, meaning public or people in Hindi. The *Janata* design was not equipped with a manhole on the top of the digester, which was a common feature of Chinese designs. The manhole on the top made it possible to use other feedstock than manure, as feedstock that floated on top of the slurry could be lifted out. Floating biomass inside the digester can cause blockage of gas pipes as well as the digester volume is not used efficiently with reduced gas production as a result. The main advantage seen in the *Janata*- over the KV1C design, was the reduced cost for construction. Two technology designs, the floating dome and fixed dome, are being used in biogas plants. India has one of the largest biogas programme in the world. However, against the estimated potential of about 12 million family type biogas plants based on availability of cattle dung in the country, a total of 4.31 million family type biogas plants have been setup in the country (Anonymous 2014). Against the above background, it was imminent to carry out a systematic and long-term field based study on upscaling the bio-gas technology and its effect on different techno-economic parameters

MATERIALS AND METHODS

The present study is based on the long term (12 years) phase wise action research carried out on the use of biogas for the farmers to its stability stage among them. Studies were undertaken at the appraisal stage (2003), concurrent stage (2005-2010) and terminal stage (2012). At the initial stage, PRA exercise (Mukherjee 1993, Carolyn 1995) was done by a multi-disciplinary team of scientists in the villages of Ureeka and Pipli of Chirawa Tehsil of Jhunjhunu district of Rajasthan (Dabas *et al.* 2009). Experiments with biogas were conducted in Ureeka and Pipli of Jhunjhunu district of Rajasthan, Achhej and Pahripur of Jhajhar district in Haryana and Nekpur , Siriyal, Chak and Jahagirpur of Bulandshahar district in Uttar Pradesh (UP). These villages are located approximately 20-40 km away from the nearby city area and represent semi-arid as well as irrigated situation. The team visited in group in the year 2003 (for appraisal) to collect first hand information using participatory analytical tools and their subsequent triangulation utilizing other sources of information. The major problem in relation to soil nutrient status and its consequences were identified through focused PRA and accordingly the mutual consensus was built among all the partners (farmers, farm women, scientists and development officials) to start work on biogas plants in the villages. The construction of biogas plants in these eight villages of three states namely Rajasthan, Haryana and Uttar Pradesh were done in phased manner under different outreach projects of ICAR-Indian Agricultural Research Institute, Pusa, New Delhi. Almost by the year 2010, most of the households of the villages especially Ureeka, Pipli, Achhej and Paharipur had biogas unit constructed. These households were given enough time period for getting perfect situation to have adequate feedback on the performance, utilization, advantages and limitations of biogas plants so that generalizable implications can be drawn and recommendations could be suggested. Data were collected from the above eight (8) villages on longitudinal basis, i.e. during pre-project stage (appraisal stage), ongoing snowballing of the intervention (i.e. concurrent stage) and after the closer of the project (i.e. terminal stage). Data were collected from 250 biogas users on the parameters of most acceptable technical requirements for the unit, output analysis of biogas, use analysis of biogas slurry, economic analysis of the unit, the intangible benefits from biogas plants and also the constraints associated with use of biogas. These data were collected from individual farmers as well as from their group to arrive at most agreeable figure. The simple statistics of average, percentage and unitary derivations were worked out to draw meaningful conclusions.

RESULTS AND DISCUSSION

Appraisal of rural situation supporting biogas installation: The existing agricultural situations of the village were analyzed utilizing PRA tools with special reference to local agro-ecology, technology adoption, existing farming systems, production system followed, social structure, rural socioeconomic parameters and farmers' needs. The details of some PRA tools and technique used are discussed below with respect to one representative village of Rajasthan to get an overall idea of the agro-ecological and socio-economic conditions of other villages as well.

Participatory agro-eco analysis

Participatory transect walks were conducted by involving and walking with the villagers across the village area and discussing about village natural resources helped in getting deeper insight into different aspects of rural life farming situation, natural resources such as soils, trees, crop, topography, availability and use of water, crop rotation, livestock and micro-ecological conditions as presented in the Table 1.

Pipli village has a total population of 5500 people with about 700 households. The main occupation of inhabitants is agriculture and about 80% of the village population is engaged in agriculture. Those who are in service are in army or teachers in schools and drivers in roadways. About 10% of the households are landless. Joint family system is prevalent in majority of the households. Since last 30 years, most of the families have moved their households from village to their farms with installation of tubewells and electrification in the village. One primary health centre, Panchayat Ghar, four Anganwadi and separate primary school for both boys and girls exist in the village. Co-operation exists among the villagers. The literacy level among males is 80-85% while it is 60% among females. Among younger generation almost all boys and girls are now going to school.

The resource map of Pipli village was drawn by village youth based on information given by elders of the village. The village has about 18000 *bigha* (3600 ha) land under cultivation. Bajra, lobia, moong, guar, cotton, moth bean and groundnut are major *kharif* crops, whereas wheat, barley, mustard, gram, onion and methi are major *rabi* crops. During summer season families having tubewell grow bajra as green fodder on about 1000 sq m area and also grow some vegetables for domestic consumption. Due to sandy soil, symptoms of nutritional deficiency are observed in almost all crops. Termite is a serious problem in almost all crops largely due to use of under composed manures. The soil is mostly sandy with low water-holding capacity and lacks organic matter. Villagers are rearing buffaloes, cows, goats, sheep and camels. On an average each household has 2-7 animals. Majority (about 90%) are buffaloes in comparison to cows. Camels are used for ploughing. Cowdung was found to be used either as semi-decomposed or used for fuel purpose.

Table 1 Transect of the representative village Pipli (Rajasthan)

Attributes	Particulars of the village	
Topography (Undulated)	Upland	Lowland
Soil Type	Sandy to sandy loam	loam in few low lying areas
Crops	Bajra, cluster bean, greengram/ cowpea, moth bean (rainfed), groundnut, cotton	Wheat, mustard, methi, barley, gram, carrot and onion
Trees	Khejri, peepal, babul, ker, neem, kikar, rohera (dessert teak), jal, ber	Khejri, peepal, babul, ker, neem, kikar, rohera (dessert teak), jal
Livestock	Buffalo, cow, camel, sheep, goat	Buffalo, cow, camel, sheep, goat
Primary land use	Crops, livestock, houses	Crops, livestock, houses
Irrigation	Tube well and sprinkler	Tube well and sprinkler

The agro-ecology of village represent a semi-arid climate where temperature ranges from 0° C (Min) in winters to 48 ° C during summers (Max). The average annual rainfall is below 500 mm. The ground water table is at the depth of 250 ft. The principal weed is orobanchae which causes loss from 10 to 90 % in mustard crop. It is total root parasite. Sometimes farmers are compelled for change with another crop due to heavy loss. Out of 800 households majority, i.e. about 500 households are small farmers having land size less than 2 ha and only 40 households are medium to big farmers having more than 2 ha land, about 200 families have land size ranging from 2-5 ha. The Timeline gave the account of important events/happenings, crops of the village over period of time regarding infrastructure facilities, livestock, tree species, outbreaks of epidemics, social changes, ecological degradation etc. Timeline analysis indicated that first biogas unit was established in the village in the year 2002.

Problem identification and consensus building for biogas plant

Rank based quotient (RBQ) technique (Sabranatham and Vennila 1996) was used to identify the top most researchable problem of the area under study.

$$RBQ = \frac{E\ fi(n+1-i) \times 100}{N \times n}$$

where, i= Concerned ranks (1 to 3), N= Total number of farmers (50), n=Number of rank, fi=Frequency (Number of farmers reporting that particular problem).

The problem with the maximum value based index was identified as top most researchable problem. Accordingly, the three major thrust area identified, prioritized and mutually agreed were as follows (Table 2): 1. Ensuring sufficient moisture in the soil to control termite infestation in all crops sown in the area. 2. Improvement of soil health with increased organic contents and higher water-holding capacity. 3. Exploring the possibility of biogas plants in the village to overcome the above issues.

Table 2 Problems identified based on ranks

Identified problem	RBQ	Avg loss %	Area (acre)/ animals	VBI	Rank
Termite in all crops sown in the area	94.67	60	200	1128000	I
Poor water holding capacity and fertility of soil in the area	24.67	10	150	37005	III
Lack of knowledge about balanced use of plant nutrients	44.67	30	263	746946.3	II

Thus, the introduction of biogas plant was initiated in the project village and other villages. Farmers' capacity was developed and they were constantly persued to take up this intervention which directly or indirectly had the potential to address the other two above prioritized problems. The outcome results are described as under.

Preferred technical specification of biogas: In general, it was observed that farmers across the three states preferred the smaller size (3.0 m^3) of the plant, i.e. family type bio-gas plant which required the cow dung quantity (75 kg/day) that could be easily available at the household level with smaller animal holding size (Table 3). With respect to quantity of water required per day to operate this unit was observed slightly varying across the districts. Whereas as, it was higher in Rajasthan (75 l/day), Uttar Pradesh and Haryana farmers could maintain such plant even at lesser quantity of water, i.e. 10 l/day water. Relative higher temperature in Rajasthan could be the plausible cause of such difference. Likewise, the cost of construction of the smaller unit was found to be affordable in three states which ranged from ₹ 14-15000/unit. Relatively lesser cost of construction in Uttar Pradesh may be due to cheaper labour availability in the state.

Output analysis: The output of any production unit is an important parameter to assess its efficacy. The data as shown in the Table 4 indicate that the quantity if usable quality gas produced from the unit ranged from 40-45 kg/month per household from the smaller sized unit. This much quantity of gas was estimated to be equivalent of 3 LPG cylinder/household/month which is, by any standard, sufficient for meeting the kitchen and other requirements of the family. From this much quantity of the gas produced, every household could utilize the light energy equivalent to 300 watts for 4 hr every day and even the small engine of 15 HP could also be run for an hour every day. Thus, gas produced had the multiple use option which the household used as per their priority. Another very important output of such smaller unit was computed to be quantity of usable slurry produced in every house and this was to the extent of 145-150 l of slurry every day which if stored properly was around 1000 l every week. The use pattern of slurry produced from the bio-gas by every respondent was also analyzed and presented below (Table 4).

Use of biogas slurry: It was estimated from the response of the users of biogas that every year each household was producing more than 5000 l of usable slurry. The data as contained in the Table 5 indicated that this much quantity of slurry was adequate for meeting the nutrient requirements for two crops in the first year for the area of 3 acres of land. While in the second year onward, there was quantitative use advantage in application of slurry for the given area of 3 acre and it came out to be 7%, i.e. 350 q lesser than the first year's requirements. After the continuous use of slurry for the 5 years in the same unit of land, farmers enjoyed the manure holiday for one year and there was no need to apply any chemical fertilizer or manure to the given piece of land (Table 5).

Economics of family size biogas plant: The economic analysis of family size type biogas unit was also carried out to ascertain their efficacy. The related data were taken from the sampled respondents on cost and return axis and they were analyzed to get the results as shown in Table 6. Results showed that though the total cost of constructing such biogas unit came to be around ₹ 20000, the provision of subsidy to the extent of 40% (₹ 8000/unit) made it more affordable. To run this unit, the only input required was cow dung costing ₹ 3000 (20%) per year. Thus the total cost involved was ₹ 15000/unit/year.

On the axis of saving component, the per year monetary saving of chemical fertilizer was computed to be ₹ 9000 for an ha of area which was the second most (27.27%) saving preceded by the saving of fuel gas to the extent of ₹ 18000/year which was about 54% of the total saving (Table 6). The other saving components were lesser use of weedicide and irrigation water (each saving to the extent

Table 3 Technical requirement for family size biogas unit for medium livestock holders

Particular	Unit	Value		
		Rajasthan	Haryana	Uttar Pradesh
Preferred size	M^3	03.0	03.0	03.0
Quantity of dung/ day required	kg/day	75.0	75.0	75.0
Water requirement	l/day	75.0	65.0	65.0
Cost of construction	₹/Unit	15000.00	15000.00	14000.00

Table 4 Output analysis of family size biogas unit (3 m^3) for small farm holder

Particular	Unit	Value
Quantity of usable gas produced	kg/month	40-45
LPG cylinder equivalent	No/month	3.0
Light energy delivery	Watt/hr/day	300 watt for 4 hr/day
Engine running capacity	HP/hr/day	15
Quantity of usable slurry produced	l/day	145-150 (5159/year)

Table 5 Use analysis of biogas slurry

Particular	Unit	Description
Meeting the nutrient requirement of crops in first year	Crop/ area/year	2 crops/ year in 3 acres of land
Quantitative use advantage in second and third year	q	350 q
Qualitative advantage of use up to 5th year		No need of additional manure/fertilizer for one year (manure holiday)
Additional yield of crops grown	%	10-15%

Table 6 Economic analysis of family size biogas plant of 3 m^3

Particular	Total amount	Percent share
Cost component	*Cost (₹)*	
Cost of construction of 3 m^3 unit	20000 (fixed)	
Cost of cow-dung for running the unit for 1 year	3000	20.00%
Subsidy	8000	40.00%
Total cost	15000 in 1st year	
Savings component	*Savings (₹)*	
Savings on chemical fertilizer	9000/ha/yr	27.27%
Savings on weedicide	2500/ha/yr	07.57%
Savings on irrigation water	2500/ha/yr	07.57%
Savings on fuel gas	18000/yr	54.54%
Total savings	33000/ha/yr	100.00%
Net profit in 1nd yr	18000/ha	120%
Net profit in 2nd yr and in subsequent years	30000/ha/yr	200%

Table 8 Operational constraints faced by the respondents (N=250)

Constraint	Mean perception score (MPS)	Rank
Reduction of gas during winter season	85.0	I
Poor and irregular gas supply	73.8	II
Clogging of inlet and outlet pipeline	47.5	IV
Disposal of slurry in rainy season	36.3	VI
Frequent cleaning of digester tank	16.3	VII
Accumulation of water in gas pipeline	13.8	VIII
Social unacceptability for use of human faeces	83.8	II
Unhygienic conditions in the surroundings of house	61.3	III
Foul smell while mixing cow dung in water	42.0	V

of 7.57%). Thus by investing ₹ 15000 in installation and running the family size unit of biogas, there was saving to the extent of ₹ 33000/family/year and the net profit in the first year was 120% over (₹ 18000) the operational cost, whereas in the second year and subsequent years, the net profit was computed to be 200% more of the investment. This analysis clearly indicates the economic efficiency of the biogas plant as per the users' data.

Intangible benefits of biogas: Apart from the direct economic benefit of biogas and the slurry, several indirect benefits as experienced by the respondents were also documented. The findings are shown in Table 7. The results show that almost every respondent (98%) expressed that the biogas was extremely helpful in reducing the drudgery to the farm women who suffered to the great extent in carrying fire-woods and facing its fumes while cooking. It was also estimated by the respondents themselves that their womenfolk could save at least one hour every day for

Table 7 Perceived intangible benefits to the users (N = 250)

Perceived benefit	Percent response	Mean benefit score	Rank
Reduction in drudgery of from women	98.00	83.33	I
Productive time sharing to the extent of 60 min/days for alternate use	82.00	72.22	II
Saving of trees and leaves biomass against fuel	69.00	50.00	V
Reduction in health hazard due to smokeless condition	72.00	61.11	IV
Reduced environment pollutions	65.00	55.56	IV
Enhanced water holding capacity in soil	78.00	66.67	III

better alternative use because of installation of biogas unit and using it as the clean energy source. From soil points of view, farmers expressed that regular application of biogas slurry helped to enhance the water-holding capacity of their soil which in turn helped to save the irrigation water. Other significant intangible benefits as experienced by the users of biogas were reduction in the health hazard due to smokeless condition and reduction in the environment pollution and finally, respondents felt that such system has the tremendous effect on saving of trees and leaves biomass against the fuel.

Constraints experienced in using biogas: It was found that reduction of gas supply in pipe during winter season and slow gas availability were the major operational constraints faced respondents with mean percent score of 85.0 and 73.8, respectively (Table 8). The social unacceptability for use of human faeces in biogas plants and unhygienic conditions in the surrounding of house were considered the most serious socio-psychological hindrances. High cost of construction of biogas plant and less amount of government subsidy were the major financial constraints. Study reveals that the financial constraints were most important constraints followed by socio-psychological and operational constraints.

The experiences of field based action research on introduction and popularization of biogas and its effect on making clean gas available for multiple purpose showed that family size biogas unit at the households level in every village is a viable option. It is not only economically affordable, the produced gas is also sufficient for meeting the fuel and electricity requirements of the family. The byproduct-slurry thus produced has greater role to revive the physic-chemical property of the soil and thus reducing the frequency of irrigation and quantity of chemical fertilizers and weedicides. Thus, biogas may be the potential option for clean and green agriculture with essence of sustainability.

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