Gurung, J. B. **Review of Literature on Effect of Slurry Use on Crop Production**. Biogas Support Programme. June 1997. 102p. BSP Lib Temp No. 20.

Objectives
The overall objective of this study was to review currently existing literature on the effect of bio-slurry (digested effluent from biogas plant) on crop production with a view to prepare a comprehensive volume for use by slurry extension workers and biogas policy makers.

Approach and Methodology
The approach followed to prepare the review was (a) to interview various persons involved in slurry extension and research in Nepal and India, and (b) to consult the relevant literature by visiting various renowned libraries in and outside Kathmandu in Nepal as well as India (e.g. Tata Energy Research Institute, New Delhi).

This review was centred mainly on the effects of bio-slurry (slurry produced from biogas plant) utilisation in crop production. Brief attentions to the works carried out in the area of nutrient research (especially, nitrogen), the health and sanitation aspects of bio-slurry utilisation in agriculture and slurry was also given.

Main Gist of Literature Review
Manorial Value of Bio-slurry in Relation to Other Manures
There seems to have built a general consensus on the ability of bio-slurry to improve the physical and biological quality of soil besides providing both macro and micro-nutrients to crops. These improvements in physical and biological qualities include: improvement in soil structures, improvement in water holding capacity, cation exchange capacity, lesser soil erosion and provision of nutrients to plants and soil micro-flora including fixing and phosphorous solublizing organisms. In addition, bio-slurry is free of weed seeds. Anaerobic digestion kills more seeds than any manure processing system. It is not the methane that kills the seeds; it just inhibits germination. Most importantly, it is the free ammonia that kills the seeds. On the other hand, FYM, if left to itself, (open pool manure) looses nutrients, most importantly, nitrogen, and thus possess relatively lower manorial value than biogas slurry. Fresh dung also contains viable weed seeds that compete with the crops and requires farmers to put extra labour and environmental preservation.

The review reveals that analysing the composition, and thus determining manorial values, of fresh slurry, sun dried slurry, and slurry compost is an exceedingly complicated endeavour, effected by numerous varieties of circumstances ranging from sampling procedures to animal species to feedstock fed both to the animals and biogas plants. The literature reveals an almost idiosyncratic constitution of these different forms of biogas slurry. Furthermore, research reports often to not clearly elaborate the research protocols and procedures about how different figures are arrived at. Because of these, comprehensive picture of the composition of different forms of bio-slurry is lacking. Even with these limitations, following extension educational messages could be given to the farmers.

Extension Educational Messages
Storage handling, treatment and application procedures are very important for nutrient conservation and increased crop yield. In not way manures in all these forms should be recklessly exposed to the vagaries of nature. As there may not be congruence between the time of availability of fresh slurry and the time of field application, liquid slurry be properly stored or composted. If liquid application is not practical, composting is the best alternative. Here lies the importance of having 2 to 3 compost pits close to the biogas plant.

No form of biogas slurry can be profitably left spread on the field. Fields should be ploughed immediately, or if the manure is used as top-dresser, should be covered by soil immediately to conserve nutrients.

Biogas plants with toilets attachments can significantly improve health and sanitation of community and community members.

Use of fuelwood, agricultural and animal wastes for fuel will gradually deplete soil nutrients and thus contributing to the emergence of unsustainable agricultural systems. Although FYM can be directly returned to the soil or composted to complete the nutrient cycle, its utilisation in biogas generation has two pronged advantages i.e. energy and better manure (if handled and treated properly).

In addition, the review reveals a number of findings on the comparative effects of slurry and other organic manures and chemical fertilisers on yields of a number of crops. These may be of potential benefits to farmers if they are suitably translated to the local situations.

Some of the major findings pertaining to the comparative effects of slurry and other organic manures and chemical fertilizers on crop yield are summarised below for their potential use by Slurry Extension Officers. However, these findings are presented to serve 'sensitising' purposes only, for both the manorial value of slurry and their potential applications for different crops are dictated by numerous factors including animal and biogas plant feedstock, treatment and handling procedures, agro-climates and geophysical environment.

Effects of Bio-slurry on Crop Yields
A combination of biogas slurry @ 12.5 t/ha and 100 percent NPK had pronounced effect on rice yield. Application of bio-slurry @ 10 t/ha to the first rice crop favourably influenced the following blackgram crop. Slurry increased rhizobium nodules and increased the blackgram yield by around 78 percent. Bio-slurry applications on wheat, sunflower, safflower, hybrid cotton, and groundnut gave an average yield increase of 24 percent over the control.

Application of bio-slurry @ of 10 t/ha in potato, tomato, brinjal, groundnut, jowar, maize, and okra gave better yields than FYM. Seed coating with a combination of digested slurry at 50 percent (W/W) of seed + inorganic nutrient at 2 percent + bio-fertiliser at 2 percent enhanced growth and yield attributes of rice.

Gypsum enriched slurry when applied in combination with 75 percent recommended NPK gave maximum grain yield in rice-blackgram cropping system. Estimations showed that 25 kg N/ha was saved. Seed coating with 50 percent (W/W of seed), organic nutrient at 2 percent and bio-fertiliser at 2 percent also increased the growth and yield of soybean, blackgram, greengram, and jowar.

A combination of liquid bio-slurry and chemical fertiliser enhanced carbon nitrogen transformation with substantive effect on crop yield. The yields in many instances are reported to be higher than that given by the combination of ordinary FYM and chemical fertiliser. In China although the average yield increment reported is not as high as in India (somewhere around 10 to 18%), experiments in bio-slurry-chemical fertiliser utilisation showed yield increment by as high as 37 percent in maize as compared to 16.8 percent and 9.4 percent respectively for effluent and chemical fertiliser alone. A comparatively lower, nonetheless increased yield has also been recorded for rice with such combinations.

Yield increase due to bio-slurry application have also reported for many other crops including peas, mustard, watermelon, cabbage, banana, bajra, turmeric, sugarcane, deccan hemp, mulberry, tobacco, castor and onion. Vegetable crops produced with bio-slurry have better quality as compared to those produced with chemical fertiliser. Studies have not pinpointed the differences between bio-slurry and FYM in this regard.

Nitrification in the Context of Anaerobic Digestion Process
Nitrification research carried out so far indicates that properly handled bio-slurry, as manure is superior to ordinary farmyard manure. Mineralisation rate of nitrogen is higher in bio-slurry than in ordinary, undigested manure, which alone provides a sound empirical basis for slurry extension programmes.

With nitrogen losses during conventional manure processing of 18 percent or higher, anaerobic processing of manure would seem very attractive, because in principle, nitrogen losses during this processing can be zero. Moreover, it may be expected that manure processed in anaerobia contains a large amount of nitrogen that is readily assimilated by plants. Various laboratory experiments support the contention that these advantages hold. However, there is a difference between what is possible in principle and how things turn out in practice' (Van Brakel, 1980:104). Thus, the way slurry is handled after it comes out of the digester for Van Brakel, is a matter of utmost importance. His conclusion is that superior manorial value of slurry cannot be taken for granted just because it is anaerobically digested; attention must be given to nutrient conservation from the moment it comes out of the digester to the moment it is applied in the field.

In the field condition, the effects of fresh slurry (cattle and buffalo) vis-à-vis-sun-dried slurry, was at times, ambiguous. Toxicity, mainly due to hydrogen sulphide and excess ammonia accumulation, is often presumed to be the reasons in many cases.

Pathogens in Relation to Temperature

The anaerobic digestion process eliminates significant number pathogens/parasitic species. However, both temperature and Hydraulic Retention Time (HRT) is an unsettled issue among the researchers. It has been accepted by all the researchers that the level of temperature is the determinant of not only the elimination rate of pathogens, it is also an important determinant of which group of methanogenic bacteria will function in the digester. Reports from the various experiments have shown that pathogens are killed faster and the slurry well digested in the thermophilic range of temperature (48 to 60°C). But the production of this range temperature requires external source of energy. Mesophilic methanogenic bacterial digestion (30 to 40°C) is considered ideal for household biogas plants, but again maintenance of a common temperature range is important—a temperature fluctuation by a mere 2 to 3°C affects the methane forming bacteria. The idea of fixing appropriate temperature for the elimination of different parasites and parasitic ova has not reached consensus in the literature. The design aspect also enters into the debates and controversies. Nonetheless, it is accepted that the remaining number of pathogens and parasites/parasitic ova can be substantially reduced if bio-slurry is used for composting.

On the whole, liquid bio-slurry (fresh) is better in terms of manorial value than ordinary farmyard manure and other forms of slurry (sun-dried, slurry compost). Field results are however highly dictated by soil, moisture conditions, slurry storage modes, and application procedures. Nutrient conservation during liquid storage, composting and drying is very important to utilise the true potential of fresh slurry. Transportation of liquid slurry, however, is a major constraint in the South Asian context.

Slurry Produced from Human Waste

Slurry derived from human excreta is far more superior in terms of manorial value, but wide scale adoption of this technology has not taken place in Nepal and India. In comparison, China is doing far better in this aspect. Socio-cultural traditions rather than scientific facts seemed to be dominant in this aspect. Slurry utilisation in agriculture affected public health and sanitation in very positive and substantive ways (the case of China). Some indications of these are also available from India and Nepal. Utilisation of human waste in biogas generation can be expected to significantly improve health and sanitation in the rural areas of Nepal. In India, it has been reported that 80 percent of the human diseases are due to the inability to manage human and animal waste properly. The annual loss in medial expenses and lost labour is estimated be around IRs. 4.5 billion. The Nepali situation cannot differ much as far as pathogen contamination through unmanaged human and animal waste is concerned.

Slurry Research in Nepal

Slurry research in Nepal has ceased to exist since the late seventies. Information on slurry utilisation suitable to Nepal's agro-ecology and climate is conspicuously lacking. Many research report reviewed were vague. This indicates the relatively lower level of scientific sophistication and statistical rigorousness in slurry utilisation research.