ENERGY PRODUCTION AS A KEY COMPONENT IN FOSTERING CAMPUS ENVIRONMENTAL SUSTAINABILITY AND GREEN ECONOMY

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ABSTRACT: Astounding pollution levels, energy and water scarcity, prevalence of diverse diseases, diminishing forest cover and biodiversity loss, unpredictable disasters and climate change necessitates a coordinated effort for the sustenance of life and ecosystems. Globally, several eminent scientists and professionals are constantly warning the Governments about the “Perfect Storm”, a potential worldwide crisis by 2030, where “a whole series of events come together” like rise in world's population by 33% which in turn triggering the demand for food by 50%, water by 30%, energy by 50% coupled with manifold multiple disasters. To meet such inevitable challenges, this paper demonstrates a pilot scale “green campus initiative” with local site specificities, not only addressing the environmental challenges we are facing today but also prepare the present generation to face the future. The case in study is a residential school, Jawahar Navodhaya Vidhyalaya (JNV) located in the south of India. The vision of green campus initiative at JNV is to transform itself into a model self-sufficient campus, envisaging a system of evolved, self-sufficient strategies, not only to sustain the needs of the campus, but also to reduce costs and generate income through integrated sustainable technologies. One installed biogas plant produce biogas which substitutes 10.34 % of petroleum gas every month. Apart from energy generation the spent slurry is composted with the biomass of the campus resulting in the production of bio-fertilizer. Waste water management integrated with the cultivation of Jatropha curcas Linnaeus (JCL) for the production of “biodiesel”, supplements the petroleum fuel for generators, along with the production of value added byproducts like - glycerin, pesticide, press cake, and carbonized briquette. Both of the integrated component not only produces sustainable renewable energy, but also fosters a green economy. Green campus initiative informs, inspires and engages the faculty, students, staffs and also the community in a voluntary and self-guided perspective promoting best environmental practices in the campus and the surrounding environment and act as a leader for campus environmental sustainability.

Keywords: Green campus initiative; self-sufficient strategies; Green economy

INTRODUCTION

Ecologically, sustainable campus development is the environmental component of sustainable development. Comprehensive organic kitchen waste management is one of the

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greatest challenges to achieve environmental campus sustainability[6] [7]. The aim of the present study is to determine the amount of organic waste generated its composition and the current management practices within the key campus operational areas and to evolve an action frame work for organic waste management, with higher rates of energy and nutrient recovery thereby improving the overall sustainability of the campus's waste management program. This framework was evolved based on the research studies done globally in various educational campuses.

Precautionary principle 15 of the Rio declaration - "where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation" plays a major role in facilitating campus sustainability in developing countries such as India. This is also supported by the principle of Intergenerational Equity, "the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of the future generations; the conservation of biological diversity with ecological integrity; and improved valuation, pricing and incentive mechanisms, for the up-gradation of environmental factors should be included in the valuation of assets, liabilities and services". Since 2002, the International gathering of The Earth Summit on Sustainable Development which was held at Johannesburg, affirmed and confirmed the commitment to the 'full implementation' of Agenda 21, along with the other MDG's to be achieved through educational institutions. To facilitate this in the Indian scenario, the methodological approach is proposed under "Green Campus Initiative" for the residential school, Jawahar Navodhaya Vidhyalaya (JNV). This is adopted from the conceptual framework developed for Pondicherry University's Action Plan towards Environmental Sustainability[8].

"Vision for 2020" of Puducherry clearly describes pollution related problems and it has called for the attention of NGOs, educational and research institutions to supplement their effort on minimizing environment related issues. Therefore, this project was selected to address the pressing issue of energy and ecosystems security with multi-dimensional advantages like:

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[6] Danielle PS, Arthur LF, Annie LB. *Reducing solid waste in higher education:* The first step towards 'greening' a university campus, Resources, Conservation and Recycling, 54 (11): 1007-1016, 2010.

[7] Nandhivarman Muthu, Golda A. Edwin, Arunprasath , and Poyyamoli Gopalsamy "Integrated *Organic Kitchen Waste Management for Campus Sustainability*- a case study of Pondicherry University, India". Peter Lang Publishers, Sustainable Development at Universities: New Horizons, 2012.

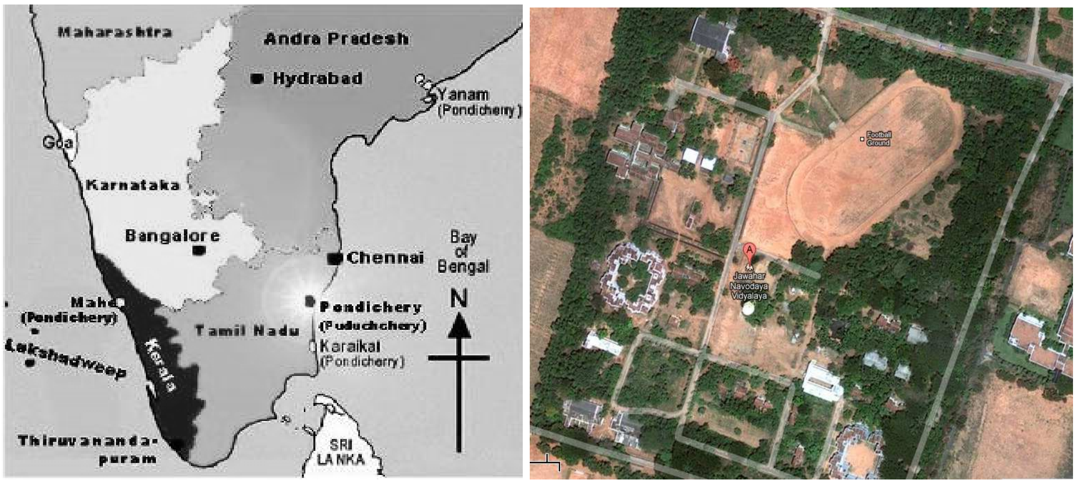
[8] Nandhivarman M, Poyyamoli G and Golda AE (2011a**)** *Environmental Sustainability* – a conceptual frame work for Pondicherry University, Puducherry, India - a case study, Proceedings of the 11th International Congress of Asian Planning Schools Association, Tokyo, Japan.

- Improvement of the local environmental conditions,
- Students empowerment,
- Increase in renewable energy generation,
- Top soil rejuvenation through slurry management
- Protection and conservation of ground water aquifers,
- Habitat restoration and biodiversity conservation
- Create awareness about waste and waste management.

PROJECT SITE

Puducherry is one of the Union territories of India, situated on the Coromandal coast, 160 kms. South of Chennai, (11° 56’ N; 79° 53’E) comprising of four geographically disconnected regions (Figure 2). JNV is a Central School, founded in the year 1985 by the Government of India.

Figure 2: Map showing the 4 geographically disconnected regions of Puducherry and Location map showing Jawahar Navodhaya Vidhyalaya (JNV)



Since then, it has emerged as India's fastest growing residential central school of the region, principally focused on the development of rural children. Figure 3 shows the location map of JNV, on the Northern border of the state.

STUDY DESIGN

JNV is the only central residential school in the Union Territory of Puducherry, it has more responsibilities to educate the young and vibrant minds, catering the needs of the present and future generation in a sustainable and holistic manner. Conducting organic kitchen waste audit is the first critical and crucial step in successful waste management, planning and advancing for the overall campus sustainability. Due to the fact that it is the campus central kitchen and is strategically located, adjacent to it is selected as the principle area for the implementation of the "ABCD – Hybrid" model of waste management for campus sustainability. The waste, especially organic waste, is dumped in open places causing heavy environmental pollution to soil, groundwater and ecosystems[9]. To address this, we have evolved a frame work to recover energy through bio digester, to recover nutrient through vermicomposting, and carbon sequestration through organic farming. Effective Solid Waste Management (SWM) requires a complete understanding of the composition of the waste stream as well as the activities that determine its origin and generation in the first place. The generated preparatory food residues like vegetable peelings, leafy vegetables etc, in the kitchen are collected in gunny bags (primary collection) along with the uncooked food residues and uneaten food waste in dining hall and are transported to the AD plant for processing.

WASTE CHARACTERIZATION

Examining waste generation source is very important, as the characteristics and composition of solid waste vary according to its source[10]. SWM programs based on origin and generation of the source are far more successful than mimicked programs that have been implemented elsewhere[11]. Conducting a waste characterization and quantification study is a critical first step in successful waste management planning and advancing for the overall sustainability of the educational institution.

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[9] *Environmental Sustainability*. Op. Cit.

[10] Tchobanoglous G, Theisen H and Vigil S. *Integrated Solid Waste Management*. McGraw-Hill, 1996.

[11] Armijo de Vega C, Ojeda Benitez S, Ramirez Barreto ME. *Solid waste characterization and recycling potential for a university campus*. Waste management, 28, Supplement I, S21-S26, 2008.

WASTE QUANTIFICATION

To manage these scenarios, a detailed action plan was evolved for segregating inorganic waste for recycling and safe disposal, followed by recycling of organic waste for the generation of biogas for kitchen in the first phase. Based on the kitchen waste audit conducted for a period of 28days, with 20 full working days and 8 days of weekends, it was estimated that the JNV mess alone generated 15 to 25 kgs of organic waste per day, and without proper waste management strategies it is either dumped or buried.

EVOLVING BEST MANAGEMENT PRACTICES "ANAEROBIC CO-DIGESTION"

By the year 1962 the First Biogas Plant, KVIC Floating Dome Model, Popularly known as Indian Model was commissioned in India. Biological treatment is already demonstrated as one of the most advantageous methods for maximizing recycling, with energy and nutrient recovery. Anaerobic digestion (AD) of sorted organic fraction of generated solid wastes, especially food wastes, is the utmost attractive alternative and the most cost-effective technology[12] [13] [14]. In recent years anaerobic digestion technology has been well established and showing satisfied performance in organic kitchen waste stabilization. Due to the coupling of pollution reduction and energy production, various types of anaerobic digester have been installed and have been operated[15] [16]. The biogas programs developed quickly in some developing countries only because of substantial support from governments and aid agencies[17] [18]. However, in case of

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[12] Bolzonella D, Pavan P, Mace S, Cecchi F. *Dry Anaerobic digestion of differently sorted organic municipal solid waste:* a full scale experience. 4th International Symposium of naerobic digestion of Solid Waste (Copenhagen-Denmark), 1:85-92, 2005.

[13] Bouallagui H, Touhami Y, BenCheikh R, Hamdi M. *Bioreactor performance in anaerobic digestion of fruit and vegetable wastes.* Proc. Biochem., 40: 989-995, 2005.

[14] Rao MS, Singh SP. *Bio energy conversion studies of organic fraction of MSW:* kinetic studies and gas yield-organic loading relationships for process optimization. Bioresource Technology, 95:173-185, 2004.

[15] R. J. Frankin, *"Full-scale experiences with anaerobic treatment of industrial wastewater"*, Wat. Sci. Tech.vol. 44 (8), pp. 1-6, 2001.

[16] P. Kullavanijaya, N. Paepatung, O. Laopitinun, A. Noppharatana, P. Chaiprasert, *"An overview of status and potential of biomethanation technology in Thailand"*, KMUTT Res. J., vol. 30 (4), pp. 694-700, 2007.

[17] Martinot E, Chaurey A, Lew D, Moreira JR, and Wamukonya N. *Renewable energy markets in developing countries.* Annual Review of Energy and the Environment, Vol. 27: 309 -348, 2002

organic kitchen waste stabilizing biogas plants, the long run efficiency influencing the long-term profitability is sometimes critique, which is mainly due to low consistency of biogas production. Consequently, the total amount of single waste used as biogas feedstock at a certain time and in the same place is often insufficient to maintain the consistency of gas production and accomplishes to cost-effectiveness of the plant[19]. To overcome this, the attempts to increase the total gas production by addition of other sources of organic wastes have been investigated[20] [21]. However, most of the previous studies play much attention to anaerobic co-digestion of lipid rich waste, manure, and agro-wastes[22] [23]. Based on the current research done by Savaporn Supaphol, with three components, to initiate hydrolysis and acidogenesis prior to entering the main digesting reactor, which helps improve the bioconversion efficiency, and the microbial community structure was effected by the different stages and found that seeding the waste at the beginning of the process resulted in community stability[24]. Anaerobic co-digestion is an attempt to enhance biogas production and improve the economic efficiency of large scale plant operations[25]. We at Union Territory of Puducherry, India, have developed a "ABCD - Hybrid" anaerobic digester as a consortia of all technologies, as the first of its kind in India.

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[18] Marchaim U. *Biogas Processes for Sustainable Development*. Bull. FAO Agric. Services, Rome, 95: 165-193, 1992.

[19] R. P. J. M. Ravena, K. M. Gregersenb, *"Biogas plants in Denmark: successes and setbacks"*, Renew. Sust. Energ. Rev., vol. 11, pp. 116-132, 2005.

[20] F. J. Callaghan, D. A. J. Wase, K. Thayanithy, C. F. Forster, *"Co-digestion of waste organic solids - batch studies"* Bioresource. Technol., vol. 67 (2), pp. 117-122, 1999.

[21] T. Amon, B. Amon, , V. Kryvoruchko, V. Bodiroza, E. Potsch, W. Zollitsch, *"Optimising methane yield from anaerobic digestion of manure: effects of dairy systems and of glycerine supplementation"*, International Congress Series, vol. 1293, pp. 217-220, 2006.

[22] M. S. Fountoulakis, I. Petousi, T. Manios, *"Co-digestion of sewage sludge with glycerol to boost biogas production"*, Waste Management, vol. 30, pp. 1849-1853, 2010.

[23] N. Kolesarova, M. Hutnan, I. Bodik, V. Spalkova, *"Utilization of biodiesel by-products for biogas production"*, J. Biomed. Biotech., vol. 2011 (ID: 126798), pp. 1-15, 2011.

[24] Savaporn Supaphol, Sasha N. Jenkins , Pichamon Intomo , Ian S. Waite , Anthony G. O'Donnell, http://www.sciencedirect.com/science/article/pii/S0960852410019279 *"Microbial community dynamics in mesophilic anaerobic co-digestion of mixed waste"* Bioresource Technology, http://dx.doi.org/10.1016/j.biortech.2010.11.124, Volume 102, Issue 5, March 2011, Pages 4021–4027.

[25] Pratin Kullavanijaya*, Patthama Thongduang, *" Enhanced Biogas Production in Anaerobic Digestion of Cassava Wastewater Though Supplementation of Biodiesel Waste as Co-Substrate"*, INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH, Pratin Kullavanijaya et al., Vol.2, No.3, 2012.

As a result of the rapid expansion and growth, proper planning is of utmost importance to address the challenges fostering sustainable development. The recently evolved strategic green action plan for campus sustainability by the consortia of organizations, promoted by APSCC, is in tune with the principles of Sustainable Development, which affirmed and confirmed the commitment to the full implementation of Agenda 21 along with the other Millennium Development Goals. The eco technology, "ABCD – Hybrid" (Anaerobic Bio-baffled Co-coupled Double-digester) is designed and modeled by M/s Gazing Glory, Puducherry, India, with multiple components such as

- front end treatment reactor (FETR)
- feed holding hydrolysis reactor (FHHR)
- the phase separated anaerobic double digester (PSADD)
- mesophilic
- thermophilic
- inbuilt mechanical reciprocating device (MRD)
- anti-rotary floating gas holding reactor (ARFGHR)
- coupled spent slurry inoculator (CSSI)
- rear end spent slurry junction reactor (RESSJR)

This biogas plant is one of the innovative approaches for the sustainable management of organic kitchen waste, preventing environmental degradation and fostering water security, food security, energy security and green economy.

FEASIBILITY STUDY REPORT

Among the cost effective treatment methods, anaerobic digestion of biodegradable organic wastes is the most popular, due to the high energy recovery and low environmental impact[26]. Anaerobic digestion (AD) is a suitable and easily available method for the treatment of wastewater and organic wastes[27]. Moreover methane has more than 20 times the global warming

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[26] Mata-Alvarez J, Macé S, Llabrés P. *Anaerobic digestion of solid wastes.* An overview of research achievements and perspectives, Bio resource Technology 74, 3-16, 2000.

[27] Jantsch TG, Matttiason B. *An automated spectrophoyometric system for monitoring buffer capacity in anaerobic digestion processes.* Water Research. 38: 3645-3650, 2004.

potential like that of carbon dioxide[28]. The biogas is therefore a highly recommend option for new and renewable energy resources[29]. Apart from this, bio fertilizer production from the biogas slurry makes it distinct[30]. One plant produce biogas substituting approximately 6.2 cylinders/ month with the potential reduction in petroleum gas by 10.34 % with a saving of around INR 7864/- per month

REDUCTION OF FOSSIL FUEL CONSUMPTION BECAUSE OF BIOGAS

1m^3 of plant generates	= 0.43 kg of biogas/day
7m^3 of plant generates	= 3 kg of biogas/day
Generated 3 kg of gas equals	= 15.8 % of cylinder (Commercial)/ day
	= 20.7 % of cylinder (Residential)/ day
No of cylinders used at JNV per day	= 2 nos residential
% of reduction in fossil fuel	= 7.9 **%** of commercial cylinder @ 19 Kg
Consumption	= **10.34 % of residential cylinder @ 14.5 Kg**

CALCULATED CARBON REDUCTION EMITTED BY DELIVERY VEHICLE

Nature of fuel used	= Diesel
Total Kms run by the vehicle	= 80 Kms/month
Total diesel consumed	= 10.66 lts@15 kms/lit
1 lit of diesel emits	= 2.7 kg of co2
10.66 lts of diesel emits	= 28.79 Kg of CO_2
Vol. of CO_2 emissions reduction/day	= 28.79 Kg of CO_2/day
Vol. of CO_2 emissions reduction/month	= 115.19 Kg of CO_2 /month
Vol. of CO_2 emissions reduction/year	= **1,382.39 Kg of CO_2/year**

LPG CYLINDER REQUIRED AND ASSOCIATED COSTS FOR JNV PUDUCHERRY

[28] Kumar et al., 2004.
[29] Taleghani and Kia 2005.
[30] Murphy et al., 2004.

NO of cylinder per day using	= 2.5 cylinder
No of cylinder in per month (September)	= 77 cylinder
Total no of cylinder delivery per month	= 75-100 cylinder
No of cylinder each delivery	= 25 cylinder
Cost of one cylinder	= INR 1267.10/-
Rent for the vehicle per delivery	= INR 700/-

Cost of 80 cylinders = **INR 1,01,368/-** (INR 1267.10/- x 80 Nos.)

Rent for the vehicle for 4 deliveries = **INR 2,800/-** (INR 700/- x 4)

Total cylinder expenses for 1 month = **INR 1,04,168/- per month**

JATROPHA CURCAS LINNAEUS FOR POLLUTION CONTROL AND RENEWABLE ENERGY

The National Planning Commission’s integrated "National Mission" and mass movement program wants to mobilize a large number of stakeholders including individuals, communities, business, entrepreneurs, oil companies, industry, the financial sector as well as Government and most of its institutions to cultivate Jatropha curcas Linnaeus (JCL) for the production of “biodiesel”, with a industrial value added byproducts like - glycerin, pesticide, press cake, and carbonized briquette. Researchers and scientists conclude that energy crops will have high water footprint and should not be irrigated with fresh water neither to be planted near water bodies. Hence, in this Green Campus Initiative we integrate this with grey water treatment and reuse.

- Erosion control, As a hedge plant, medicinal uses, plant protectant, monkey repellant, fire wood, green manure, combustibles
- Waste water generated at the JNV campus is redirected for use in the Jatropha cultivation
- Reduces the load on municipal treatment system and helps close the water cycle
- The carbonized briquette are non-conventional source of energy, renewable in nature, ecofriendly, non-polluting & economical
- Glycerine can be used for the manufacture of industrial soaps

CONCLUSION

It is possible to design on-farm anaerobic digesters in a way that waste treatment using anaerobic digestion is economically self-sustaining or even a source of farm net profit. The researches address the effect of incorporation of environmental benefits of anaerobic digestion costs into the calculation of digester viability. Anaerobic digestion is an attractive, cost effective, eco-friendly route, to minimize landfill dump that generates a high-quality renewable fuel, and reduces GHG emissions. Co-digestion strategies are widely applied in order to enhance the methane production in agricultural biogas plants. It is established based on the principles of environment, economy, and systematic engineering fostering campus environment sustainability. This type of approach provides students with a knowledge learned in the classroom to their immediate campus experience. It also provides opportunity for students to participate in some of the decision making processes on campus.

REFERENCES

AMON, T., AMON, B., KRYVORUCHKO, V., BODIROZA, V., POTSCH, E., ZOLLITSCH, W. Optimising methane yield from anaerobic digestion of manure: effects of dairy systems and of glycerine supplementation. *International Congress Series*, vol. 1293, pp. 217-220, 2006.

ARMIJO, de Vega C, OJEDA, Benitez S, RAMIREZ, Barreto ME. Solid waste characterization and recycling potential for a university campus. *Waste management*, 28, Supplement I, S21-S26, 2008.

BOLZONELLA, D., PAVAN, P., MACE, S., CECCHI, F. Dry Anaerobic digestion of differently sorted organic municipal solid waste: a full scale experience. *4th International Symposium of Anaerobic digestion of Solid Waste* (Copenhagen-Denmark), 1:85-92, 2005.

BOUALLAGUI, H., TOUHAMI, Y., BENCHEIKH, R., HAMDI, M. Bioreactor performance in anaerobic digestion of fruit and vegetable wastes. *Proc. Biochem.*, 40: 989-995, 2005.

CALLAGHAN, F. J., Wase, D. A. J., THAYANITHY, K., FORSTER, C. F. Co-digestion of waste organic solids - batch studies. *Bioresource. Technol.*, vol. 67 (2), pp. 117-122, 1999.

DANIELLE, P.S., ARTHUR, L.F., ANNIE, L.B. Reducing solid waste in higher education: The first step towards ‘greening’ a university campus. *Resources, Conservation and Recycling*, 54 (11): 1007-1016, 2010.

FRANKIN, R. J. Full-scale experiences with anaerobic treatment of industrial wastewater. *Wat. Sci. Tech*.vol. 44 (8), pp. 1-6, 2001.

JANTSCH, T.G., MATTTIASON, B. An automated spectrophoyometric system for monitoring buffer capacity in anaerobic digestion processes. *Water Research*. 38: 3645-3650, 2004.

KULLAVANIJAYA, P., PAEPATUNG, N., LAOPITINUN, O. A. Noppharatana, P. Chaiprasert. An overview of status and potential of biomethanation technology in Thailand, *KMUTT Res. J.*, vol. 30 (4), pp. 694-700, 2007.

KULLAVANIJAYA, Pratin, THONGDUANG, Patthama. Enhanced Biogas Production in Anaerobic Digestion of Cassava Wastewater Though Supplementation of Biodiesel Waste as Co-Substrate. *International Journal of Renewable Energy Research*, Pratin Kullavanijaya et al., Vol.2, No.3, 2012.

M. S. FOUNTOULAKIS, I. PETOUSI, T. MANIOS. Co-digestion of sewage sludge with glycerol to boost biogas production. *Waste Management*, vol. 30, pp. 1849-1853, 2010.

MARCHAIM U. Biogas Processes for Sustainable Development. *Bull*. FAO Agric. Services, Rome, 95: 165-193, 1992.

MARTINOT, E., CHAUREY, A., LEW, D., MOREIRA, J.R., and WAMUKONYA, N. Renewable energy markets in developing countries. *Annual Review of Energy and the Environment*, Vol. 27: 309 -348, 2002.

MATA-ALVAREZ, J. *Biomethanization of the organic fraction of municipal solid wastes*, 2003.

MATA-ALVAREZ, J., MACÉ, S., LLABRÉS, P. Anaerobic digestion of solid wastes. An overview of research achievements and perspectives, *Bio resource Technology* 74, 3-16, 2000.

MSW. *Municipal Solid Wastes Management and Handling Rules*. Available at http://envfor.nic.in/legis/hsm/mswmhr.html, 2000.

N. KOLESAROVA, M. HUTNAN, I. BODIK, V. SPALKOVA. Utilization of biodiesel by-products for biogas production. *J. Biomed. Biotech*., vol. 2011 (ID: 126798), pp. 1-15, 2011.

NANDHIVARMAN, M, POYYAMOLI, G. and GOLDA, A.E. (2011a) Environmental Sustainability – a conceptual frame work for Pondicherry University, Puducherry, India - a case study. *Proceedings of the 11th International Congress of Asian Planning Schools Association*, Tokyo, Japan, 2011a.

NANDHIVARMAN, Muthu, GOLDA, A. EDWIN, Arunprasath , POYYAMOLI, Gopalsamy. *Integrated Organic Kitchen Waste Management for Campus Sustainability- a case study of Pondicherry University, India"*. Peter Lang Publishers, Sustainable Development at Universities: New Horizons, 2012.

RAO, M.S., SINGH, S.P. Bio energy conversion studies of organic fraction of MSW: kinetic studies and gas yield-organic loading relationships for process optimization. *Bioresource Technology*. 95:173-185, 2004.

RAVENA, R. P. J. M., GREGERSENB, K. M. Biogas plants in Denmark: successes and setbacks. *Renew. Sust. Energ. Rev.*, vol. 11, pp. 116-132, 2005.

SUPAPHOL, Savaporn, JENKINS, Sasha N., INTOMO, Pichamon, WAITE, Ian S., O'DONNELL, Anthony G. Microbial community dynamics in mesophilic anaerobic co-digestion of mixed waste. *Bioresource Technology*, http://dx.doi.org/10.1016/j.biortech.2010.11.124, Volume 102, Issue 5, March 2011, Pages 4021–4027

TCHOBANOGLOUS, G, THEISEN, H. and VIGIL, S. *Integrated Solid Waste Management*. McGraw-Hill, 1996.

VAIBHAV R. SAPKAL, MISTRY, N.J., VAIDYA, A.N. Development of hybrid anaerobic digestion and membrane separation technique. *2011 International Conference on Environment and Industrial Innovation IPCBEE* vol.12, © (2011) IACSIT Press, Singapore, 2011.