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Cradle-To-Gate Life Cycle Assessment of Poultry Production System

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Abstract

The study assesses environmental impacts of hatchery production processes to point-of-lay and investigates effects of different scenarios on environmental load impacts in the Life Cycle Assessment (LCA) results. Functional unit of this LCA study is one poultry bird at point of lay and the activities associated within the system boundary. Results obtained showed that total contributions of the egg-point of lay system to global warming was 9.708kg of CO_2 *equivalents, 11.34 kg of* CH_4 *equivalent, 0.2kg of* NO_2*, acidification was* 2.713×10^{-4}*kg of* SO_2 *equivalents,* 1.948×10^{-3} *kg of* NH_3 *equivalents,* 2.167×10^{-3} *kg of* NO_x *equivalents and energy consumption was computed at 59.79KJ per bird. Hatchery process accounted for the highest consumption of energy of about 543.2J per bird, waste disposal accounted for about 6J per bird, while water pumping process consumed about 16J per bird, while feed production process-required about 46.5J of energy. The LCA results showed that minimizing energy consumption in the hatchery process is the way forward in reducing environmental impact loads in a poultry system. Scenario analysis showed that using 100% public power supply will reduce the* CO_2*,* NO_x *and* SO_2 *equivalents by 95.56%, 10.64% and 15.58%, while using 50-50% diesel-public power supply will reduce* CO_2*,* NO_x *and* SO_2 *equivalents by 47.78%, 5.22% and 21.50% respectively.*

Keywords: *Poultry production, Greenhouse gases, Environmental loads, Life cycle assessment.*

1. Introduction

An overview of the global estimates for livestock's impact on climate change suggests that the global contribution of anthropogenic green house gas (GHG) emissions from the agricultural livestock sector is approximately 18-20% of global anthropogenic GHG emissions (Monteny *et al.*, 2006; Pitesky *et al.*, 2009). In comparison of the agricultural sector to global fossil fuel burning that accounted for approximately 13% of the global anthropogenic GHG emissions (Steinfeld *et al.*, 2006), the environmental load is a cause for concern. The worrying situation stems from the fact that Smith *et al.*, (2007) reported that approximately 80% of the world population live in developing countries and this population emits approximately two thirds of all anthropogenic agricultural GHG emissions. As a result of the awareness of environmental problem of global warming and because of the societal concern over environmental issues, the animal industry has recognized the need to solve environmental problems in this industry by identifying and quantifying environmental loads or impacts such production system have on the environment (Ogino *et al.*, 2007). The source of the three primary GHGs (CO_2, CH_4 and N_2O) considered to be of concern in environmental pollution has been linked to agriculture, which can also be a sink for CO_2 through Carbon sequestration into biomass products and soil organic matter (Johnson *et al.*, 2007).

Methods developed to assess these environmental impacts and which has been standardized internationally is the Life Cycle Assessment (LCA), it is a type of integrated environmental impact assessment (Ogino *et al.*, 2008). Taking into consideration the concept of sustainability, the most internationally accepted methods of examining the global impact associated with production activities, systems or products is the LCA. The LCA application has been extended to the identification of environmental improvement opportunities; strategic planning or development; product and process optimization, design; and environmental reporting and marketing (Hospido, et al., 2003).

The dynamics of global climate change includes increased sea level, changes in rainfall distribution and storm intensity; current strategies for coping with this phenomenon is by reducing fossil fuel combustion, curbing GHGs emissions and increasing Carbon sequestration (Johnson *et al.*, 2007). Environmental protection practice has become inevitable due to the wide felt effects of global warming, it is therefore important to assess the various effects of different activities of a poultry production on the immediate and global environment. Thus, the aim of this study is to investigate the life cycle impact assessment (LCA) of the production of point of lay birds from egg stage using deep litter system of management. The study also investigates the environmental impacts of the sole use of public power supply against 50-50% diesel-public power supply scenario.

The study scope is limited to the assessment of the environmental impact of greenhouse gases (GHG), as well as other waste generated from hatchery production processes to the point-of lay birds in a deep litter management system with Nera Black Breed of layers.

2. Materials and methods

The functional unit of this LCA is defined as one chicken at point of lay. According to Ogino *et al.*, (2007) "functional unit is a reference to which all other materials and associated environmental loads in the LCA are related". The study LCA is classified as a cradle to gate, since it takes care of part of the chicken's life cycle. The system analyses the life cycle of incubated egg for 21 days through a period of 18 weeks. The cradle to gate system is as shown in figure 1.

2.1 Life cycle inventory

An inventory of the all the resources used, energy inputs/requirements and emissions released within the system boundary of the incubated eggs to point-of-lay stage. Calculated total feed input for the 30,000 birds was 248,469.9 kg (Tables 1 and 2), the total water usage was 1,920,000 litres. All the energy inputs into the system and their approximate values are shown in table 3. The analysis in the table assumes that energy involved in transportation as well as emissions are exempted from the calculations. The table 3 also shows some of the emission coefficients computed using the United States Environmental Protection Agency (US EPA) online Greenhouse Equivalencies Calculator while the total energy from the combustion of charcoal for brooding purpose was computed using a calorific value of 29,600 kJ/kg obtained from the online Engineering Toolbox table for higher calorific values for some common fuels. Table 4 shows the values of coefficients used in computing environmental loads associated with the incubated eggs to point-of-lay production. The table analyzes the emission outputs from the various activities involved such as feed production, water pumping and supply, power generation and the waste management. Waste from farms considered was spread on land as a form of treatment; therefore odour emission from the waste was calculated using the coefficient chart provided by Gay et al., (2002). The study scope does not consider transportation during the various activities. The US EPA Greenhouse Gas Equivalence Calculator was used to compute the CO_2 equivalent for the various machines used in feed production while diesel fuel consumption chart was used to compute the average fuel consumption by the generators according to Fuglestvedt *et al.*, (2009). Pollutants emitted by feed production stage were obtained by;

$$P_A = \sum_i \left[D_i \times \left(\sum_i F_{ij} G_{Aj} + L_i M_A \right) \right] \quad (1)$$

where; P_A: Emission of pollutant A from feed production, g/day
D_i: Intake of feed i, in kg/day
F_{ij}: Consumption of fuel j, in production of feed i, MJ/kg-feed
G_{Aj}: Emission coefficient of pollutant A from production and combustion of fuel j, g/MJ
L_i: Consumption of electricity in production of feed i, kWh/kg-feed
M_A: Emission coefficient of pollutant A from electricity production and consumption, g/kWh
Feed i, : corn, wheat bran, concentrate
Fuel j: Diesel.
Source: Ogino *et al.*, (2007)

2.2 Life cycle impact assessment

The lifecycle inventory is interpreted in terms of environmental impact by sorting environmental loads and assigning them to specific environmental impact categories and characterization of environmental loads by multiplying them by equivalency factors for each impact category. The weighted environmental loads from impact categories were added.

2.3 Scenario analysis

The LCA applied the use of 100% purchased or public power supply and a scenario of 50-50% use of diesel-public power supply. This is to investigate if there will be a significant difference in level of the environmental pollution coefficients. Environmental loads associated with the use of 8663 MW of electricity from public power source calculated using the coefficients for thermal and hydroelectric processes obtained from the Leonardo academy using the current installed power generation capacity in Nigeria while emissions from diesel generators was obtained using the diesel consumption chart and diesel combustion CO_2 coefficient. Total electricity usage for the period was estimated at 1,820 kWh.

3. Results and discussion

3.1 Environmental impacts of the egg-point of lay system

Analyzing the effect of the chick-point of lay stage on the environment, the investigation shows that on the average solid waste accounted for about 68%, liquid waste about 23% while gaseous waste accounts for about 9% as shown in figure 2. This shows solid waste in poultry should be given adequate attention as they usually have high volume and strength may also be strong depending on the age, physiological state of the animal and other conditions. Liquid wastes have a relatively lower volume and strength may also vary depending on the management practice, drugs and chemicals usage. On the other hand the hatchery process had an average gaseous output of about 10%, liquid output of 41% while solid waste accounts for about 49% as shown in figure 3, this shows that adequate attention should be given to the treatment of both solid waste and liquid effluent. The wash water usually has high strength due to the use of chemicals and disinfectants like formalin, potassium permanganate and a high volume due to the need for sanitary conditions while the solid waste is dependent on a variety of factors which may include hatchery management practices, animal breed, and animal management practice. The solid waste consists of dead in shell eggs, egg shell, cartons, and empty chemical containers.

Investigation of the contributions of each of the stages involved to global warming potential i.e. hatchery process, energy generation, feed production, waste disposal, water supply and biological activities as shown in Table 5. The total CO_2 equivalent accounted for 8.76% of the total emission, CH_4 emission accounted for about 90.64% of the total emission while N_2O was about 0.70%. Feed production accounted for 2.5% in form of CO_2, energy production from diesel generator accounted for the highest amount of CO_2 of about 73.96% while water pumping was the lowest with 1.13% of CO_2 equivalent. While CO_2 is seen as a major contributor to rising global temperatures, black carbon (sooth) is also a concern to global warming.

Methane (CH_4) is produced by the microbial degradation of soluble lipids, carbohydrates, organic acids, proteins, and other organic components. It is paramount to state here that the H_2S emitted by the waste from the poultry house was calculated as 1.386×10^{-5} Kg per functional unit. CH_4 is known to be a strong greenhouse gas since its presence in the atmosphere has contributed largely to the rapidly increasing climate change. It has been reported that CH_4 contributes 9-20% of the total global warming potential (Sommer and Moller, 2000).

The power consumption analysis was also investigated to determine if actually there is an energy balance and also to verify the effect of the current practice in most developing countries on the environment. The result shows that the feed production process consumed about 46.5 J of energy per bird, while pumping of water accounted for about 16J per bird and the waste disposal was just about 6J per bird. The power involved in waste disposal was calculated on a man-hours per day basis taking into account the average power rating of human labour as 0.075kw, this value was then multiplied by the total time used in waste disposal. The hatchery process had a value of about 543.2J per bird of energy input which was the highest. The result shows that if total energy consumption is to be minimized the hatchery process aspect should be considered.

Ammonia and its chemical constituents are important components responsible for acidification in addition to this are sulfur compounds (SO_x), nitrogen oxides, and volatile organic components (Koerkamp, 1994; Koerkamp *et. al.*, 1998). This implies that these compounds are also very crucial to the acidification potential of the system on the environment. The result from table 6 shows that biological process stage on the system has the highest NH_3 and SO_2 output coefficient of 119kg and 5.43kg; hatchery process has the highest NO_x value of 7.21kg. Energy production stage had the lowest SO_2 and NH_3 values while water production had the lowest value of NO_x. This shows that adequate attention needs to be given to the waste disposal of hatchery waste and treatment methods in other to reduce the strength of the waste before final disposal, biological treatments like use of composting pits, and septic tanks may be adopted.

3.2 Scenario analysis

Results obtained from the two scenarios shows that there was a significant reduction in each of the environmental loads coefficients in the system for both scenarios. The first scenario with 100% dependence on purchased or public power source shows a reduction in environmental loads of about 85%, 80%, 86%, 94%, 96% & 95.3% in CH_4, CO_2, NO_x, NH_3 and SO_2 respectively. The 50-50 case also shows a reduction in CH_4, CO_2, NO_x, NH_3 and SO_2 emission by about 45.8%, 48.3%, 45.8% 45.3%, 48%& 44.6% respectively. It was observed that emission reduction was almost uniform for the various environmental loads. It can therefore be deduced from the results in figure 4 that the use of diesel generator as power source is not environmentally friendly as this emits a relatively large volume of greenhouse gasses leading to an increase in global warming and acidification potentials as well as noise pollution when compared to the use of public power supply.

4. Conclusion and recommendations

To reduce the environmental impacts, frequent and total removal of litter and manure from poultry houses would reduce ammonia emissions, but due to the cost of cleanout and replacement of bedding, this may not be a viable option for most farmers. A more feasible approach will be to control litter moisture by reduction in water spillages in deep liter poultry houses as more moisture there is in the litter, the more potential for ammonia emissions from that litter. Ferguson *et al*., (1998) confirmed the relationship between higher litter moisture and increased litter ammonia. Ventilation is also critical to maintaining proper litter moisture.

Water usage should be as economical as possible as a large chunk of energy usage was on pumping water and where possible reuse of water should be encouraged. Also the usage of novel pest repellant composition is encouraged against the usage of organophosphates due to the toxic nature of these compounds while novel pest repellant composition is more environmental-friendly. Novel pest repellant composition contains gallic juice, water, neem oil, organo-polysiloxane and pepper wax.

Compost method of waste (manure) treatment should be employed as it reduces the presence of pathogens and makes the organic matter more biodegradable. The method also suppresses or eliminates the possibility of eutrophication due to effect of run-off containing phosphate and nitrogenous compounds. The use of septic tanks can also be used as a form of anaerobic treatment before waste is disposed. This leads to lower odour emission from process of waste treatment.

Other environmental friendly alternative power sources such as wind, hydroelectric and solar should be employed where possible in production process in order to reduce reliance on fossil fuel (petrol and diesel) generators.

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Table 1: Animal age, weight and quantity of feed for the chicken from day old to point of lay used in the LCA study

Day old chick							
Age (weeks)	1	2	3	4	5		
Weight (gm)	62.50	239.7	414.44	589.16	751.21		
Cereals (gm/day)	0.11	11.26	14.72	19.45	22.90		
Concentrates (gm/day)	2.19	4.82	6.31	8.33	9.82		
Growers							
Age (weeks)	6	7	8	9	10	11	
Weight (gm)	973.32	1200.10	1289.11	1472.78	1537.48	1812.2	
Cereals (gm/day)	24.44	28.98	40.82	43.75	47.92	53.48	
Concentrates (gm/day)	10.48	12.40	17.50	18.75	20.45	22.92	
Growers							
Age (weeks)	12	13	14	15	16	17	18
Weight (gm)	1987	2161.60	2436.36	2513.91	2789.95	2900.8	3210.21
Cereals (gm/day)	59.03	63.19	68.06	72.92	78.47	86.29	87.5
Concentrates (gm/day)	25.30	27.08	28.17	31.25	33.63	36.98	37.50

Source: Radar farms March, 2011

Table 2: Composition of Feed Used in Life Cycle Assessment Study

	% of Diet**	DM (%) *	CP (%DM) *	TDN (%DM) *
Chicks Mash				
Maize	47.5	86.5	10.2	92.4
Wheat bran	22.5	87	17.7	72.3
Concentrate	30		38.38	
Total	100		20.34	
Growers Mash				
Maize	40	86.5	10.2	92.4
Wheat bran	30	87.0	17.7	72.3
Concentrate	30	82.6	41.28	8.32
Total	100			

DM: dry matter, **CP:** crude protein, **TDN:** total digestible nutrients

* Ogino *et al.*, 2007

** Flomix Concentrates

Table 3: Analysis of power rating of equipments involved in LCA study

	R(Kw)	FR(min/ton)	M(KG)	Q(L/min)	C(KJ/KG)*	T(Hrs)	Ω(KJ)
Candler	15.00					45.00	675.00
Incubator	28.80					432.00	12,441.60
Hatcher	44.14					72.00	3,178.08
Mill	11.00	15.00				62.13	683.38
Mixer	8.00	7.00				28.99	231.92
Water Pump	1.80			120.00		266.7	480.00
Brooding			60.00		29,600.00		1,776,000.00
Total Energy Input							1,793,689.98KJ

R- Power rating of equipment, **FR-** Feed rate of equipment, **Q-** Flow rate, **T-** Operating time, **Ω-**Total energy requirement
C- Energy released from burning of charcoal, **Q-** Quantity of charcoal used, ***-** Calorific value of Charcoal = **29,600KJ/KG**
M-mass of charcoal used

Table 4: Analysis of output coefficients of environmental loads associated with the chick-point of lay production

	Output Coefficient	Reference
Feed Production and Water Supply		
CO_2 emission from feed mill	Online values	EPA GHG Equivalence Calculator
CO_2 emission from water pump		"
CO_2 emission from power generator	3.0 (Kg CO_2 e/L)[a]	Fuglestvedt *et al.*, 2009
Animal management		
NH_3 emission from poultry house	148.80(g N lu^{-1} d^{-1})[b]	Misselbrook *et al.*, 1999 Koekamp *et al, 1998*
NH_3 land spreading emission	177-261(g NH_3 AU^{-1} day^{-1})	
Emission from Poultry house	0.09(kg CH_4 $animal^{-1}$ $year^{-1}$)	Safley and Casada (1992)
H_2S emission from poultry house	3.3 (g H_2S AU^{-1} day^{-1})	Zhu et al., 2000a
N_2S emission from poultry house	See the text	IPCC(1997)
CO_2 emission from bird respiration	70-80g d^{-1}	"
Odour emission from poultry house and spreading	0.3-3.5 (OU m^2 s^{-1})	Gay *et al.*, 2002

a - Emission factor for diesel fuel is taken as 3Kg CO_2 e/L, **b** – **lu** is equivalent to 500kg live weight,

Table 5: Contribution of the egg-point of lay process to global warming

	CO_2 equivalent (10^2 kg)	CH_4 equivalent (10^{-4} kg)	N_2O equivalent (10^{-3} kg)
Hatchery Unit	13.50	4034	45
Energy Generation	71.80	5.91	1.04
Feed Production	2.13	6.95	18.8
Water Pumping	1.10	3.47	0
Biological Processes	4.83	7360	125
Waste Disposal	3.72	102000	11

CO_2=1, CH_4=23, N_2O=298 were the global warming potentials used (Intergovernmental panel on climate change, 2007

Table 6: Contribution to acidification of each processes considered in the chick-point of chick system

	SO_2 (10^{-5} Kg)	NO_x (10^{-5} Kg)	NH_3 (10^{-5}Kg)
Hatchery Process	5.10	7.21	31.53
Energy Generation	3.21	6.71	0.01
Feed Production	4.42	2.11	37.4
Water Pumping	4.54	1.06	2.34
Biological Processes	5.43	2.13	119
Waste Disposal	4.43	2.45	4.40

NH_3=1.88, NO_x =0.7, SO_2= 1 were the acidification potentials used (Intergovernmental panel on climate change, 2007)

Table 7: Global Warming and Acidification Potential of Different Scenarios

	Global Warming Potential			Acidification Potential		
	CO_2 equivalent (10^{-2} kg)	CH_4 equivalent (10^{-4} kg)	N_2O equivalent (10^{-3} kg)	SO_2 equivalent (10^{-5} kg)	NO_x equivalent (10^{-5} kg)	NH_3 equivalent (10^{-5} kg)
Diesel Engine Generator	97.08	113,419.33	200:84	23.13	21.64	194.68
50-50% Diesel-Public Power Supply	48.588	56,709.67	100.42	11.56502419	10.824506	97.32004004
100% Public Power Supply	0.095	0.0018179	0.0001774	0.000048375	0.0090119	0.000080113

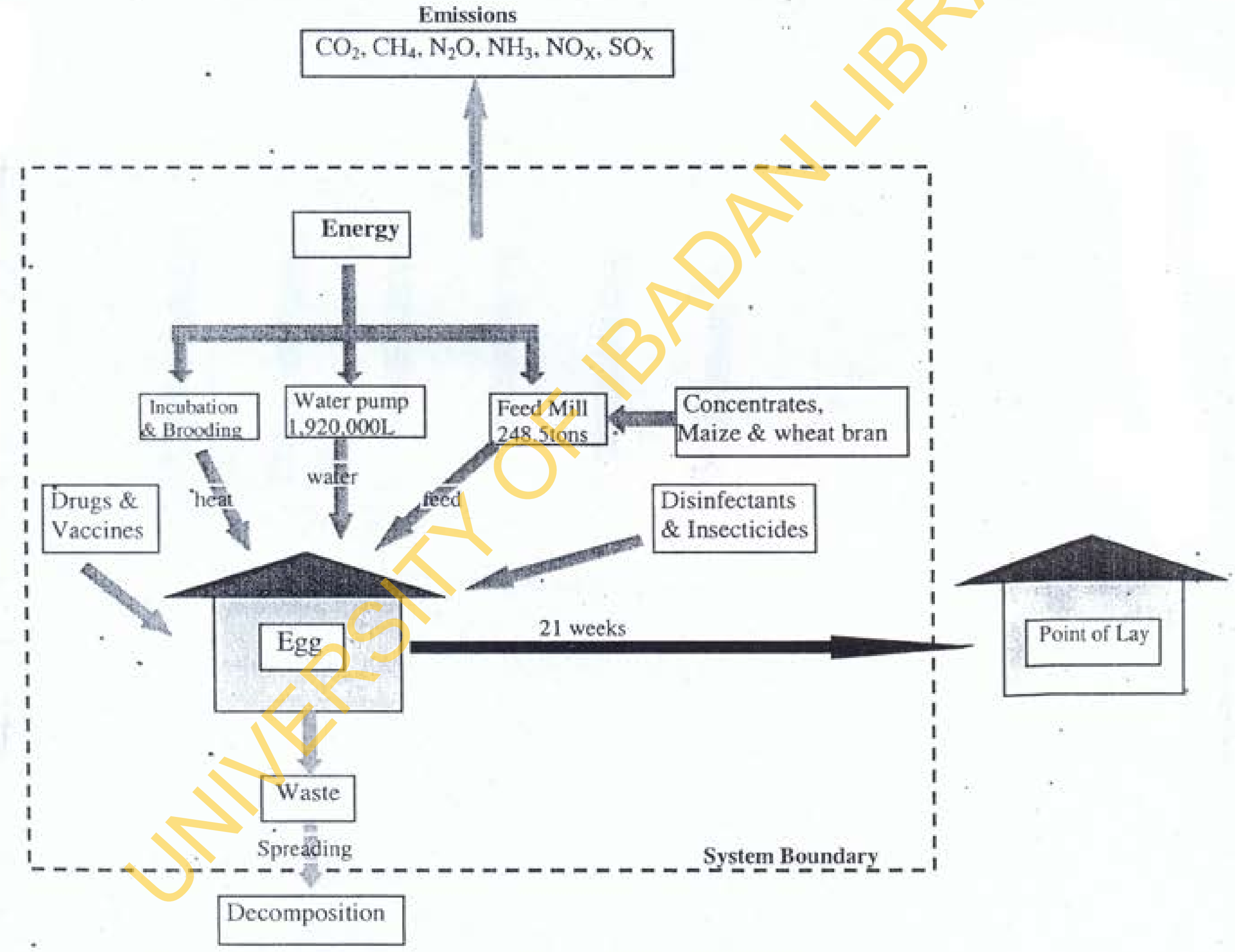

Figure 1: Description of the egg-point of lay system investigated in the LCA study

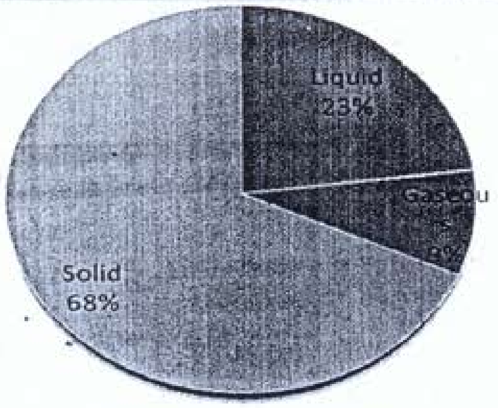

Figure 2: Average Poultry Waste Distribution

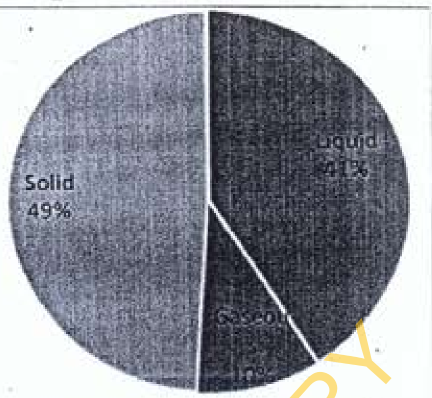

Figure 3: Waste Distribution in Hatchery System

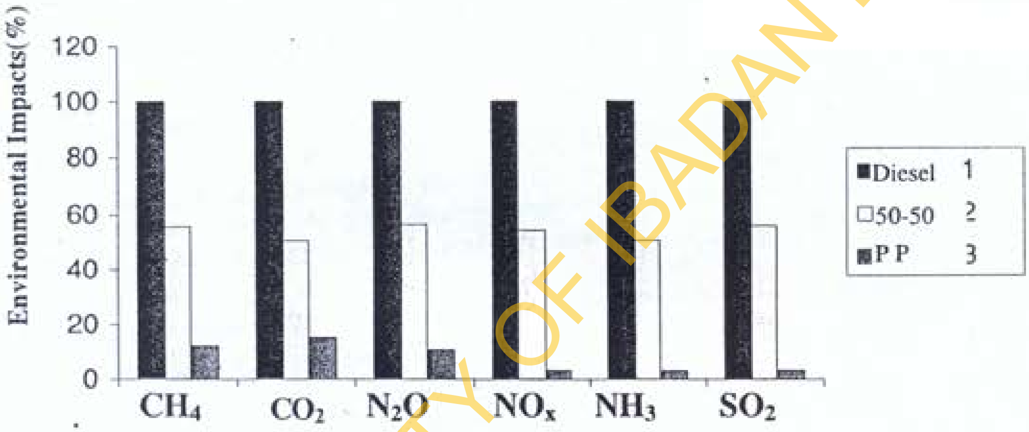

Figure 4: Power Source Variation on Environmental Impacts