ASSESSMENT OF POTENTIAL EMISSION OF DIOXIN AND FURAN FROM OPEN BURNING OF AGRICULTURAL WASTE IN BIU LOCAL GOVERNMENT AREA OF BORNO STATE, NIGERIA

BY

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A THESIS SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY, FACULTY OF SCIENCE, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE OF ENVIRONMENTAL MANAGEMENT

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MAY, 2015

DECLARATION

I hereby declare that this thesis entitled 'Assessment of potential emission of dioxin and furan from open burning of agricultural waste in Biu Local Government Area of Borno State, Nigeria' is a record of my own research work under the supervision of Dr. J. O. Folorunsho and Dr. I. J. Musa. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this has been submitted for the award of degree in any other university.

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CERTIFICATION

This thesis entitled 'ASSESSMENT OF POTENTIAL EMISSION OF DIOXIN AND FURAN FROM OPEN BURNING OF AGRICULTURAL WASTE IN BIU LOCAL GOVERNMENT AREA OF BORNO STATE, NIGERIA' meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my beloved parents, teachers and those striving to restore the balance between people and nature wherever they are.

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ABSTRACT

Potential emission of dioxin and furan from open burning of agricultural crop residue Post-harvest waste generated in Biu local government area of Borno state, Nigeria was estimated. This is with a view to knowing the types, quantity and strength of these crop residues generated and the estimate of dioxin and furan released annually so that an inventory of UPOPs can be created. The method adopted was field survey and focus group discussion using a set of structured questions. The total hectare of land cultivated for the selected crop type as contained in the UNEP standard toolkit from the host communities were estimated to be 1450ha. for the period of the study. The study revealed that; maize, sorghum and rice were produced in large quantity in the area. For maize alone in ten communities, 140 tonnes of waste was generated, sorghum118 tonnes, millet 115 tonnes, rice 111 tonnes and cowpea 53 tonnes of waste was generated. The major waste management measure adopted is 'open burning'. The annual quantity of agricultural crop residues generated for burning in these communities was estimated to be 381 tons; the UNEP standard toolkit was used to categorize the crops based on their high chlorine content. For maize the emission potential was 3060µg, Sorghum 2580µg, rice 2130µg and millet 2100µg, TEQ/per was generated in all the communities surveyed. Using the emission factor of 30µg and the amount of agricultural crop residue generated of about 381 tons/per year, an estimate of 11,088µg emission TEQ/year in the area was generated. Among the communities selected, Maina Hari has the highest land area cultivated during the period of this field survey followed by Mangada and Mandafuma. The survey also revealed that farmers have difficulties in accessing information on environmental health hazard of open burning of agricultural waste, while some still lack basic knowledge on health risk arising from open burning of crops residues. Regulatory efforts should focus on the identification and control of airborne environmental sources of pollution resulting from burning activities, which are currently the major origin of food chain contamination.

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ACRONYMS

BCF	Bioconcentration factor
BW	Body weight
CDD	Chlorodibenzo-*p*-dioxin
CDF	Chlorodibenzofuran
UPOPs	Unintentional persistent organic pollutants
HCH	Hexachlorocyclohexane
PAHs	Polycyclic aromatic hydrocarbons
PBBs	Polybrominated biphenyls
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo-p-dioxins
PCDFs	Polychlorinated dibenzofurans
PEC	Potency equivalency concentration
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzofuran
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4,5-TCP	2,4,5-trichlorophenol
TEFs	Toxicity equivalency factor
TEQs	Toxicity equivalency concentrations
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Wastes are materials that are not prime products (that products produced for the market) for which the initial user has no purpose of production, transformation or consumption, and of which the user wants to dispose. Waste may be generated during the extraction of raw materials, the processing of raw materials, into intermediate and final products, the consumption of final products, and other human activities, (UNSD, 1997). Miller (1980) defined waste as substances and materials that are disposed of according to the provision of natural law. Zero waste America (2003) also defines waste as a resource that is not safely recycled back into the environment or market place. Waste (residue, trash, refuse, garbage, Junk or litter) is an unwanted or useless material (ISWA and UNEP, 2002). The compositions of different wastes have varied over time and location, with industrial development and innovation being directly linked to waste materials. There are three types of waste which include; solid, liquid and gas, these waste are also classified into various category, which are industrial, domestic, commercial, institutional, and agricultural wastes.

Agriculture is the major sector upon which the majority of Nigeria's rural poor depend on for their livelihood; the sector employs over 70 percent of the active labor force in the country (World Bank, 2007). In addition; over 90 percent of Nigeria's rural population currently depends solely on agricultural and forest resources for livelihood and economic survival (Nigeria, FMEH and UD, 2008). Nigeria is one of the countries in West Africa sub-region with total population of 170,123,749 in 2012 and an annual growth rate of 2.55% (CIA, 2012). Agricultural land constitutes approximately 74,500,000 ha of the total land area of 91,077,000 ha for the country. About 41.2% of the agricultural land is arable land, 11.3% forest area and 3.3% are permanently

cropped area. Close to 70% of Nigerian population are involved in agricultural production with more than 70% of the farming population being smallholder farmers (< 5 ha per person). About 48% of the country's population lives in the rural areas with more than 70% of the country's population living below the poverty line (CIA, 2012). Nigerian agricultural production is characterized by large number of dispersed small scale producers employing traditional manual tools based on rain-fed crops but providing the major food needs of the country.

Agricultural waste, which includes both natural (organic) and non-organic materials, is a general term used to describe waste produced on a farm through various farming activities. These activities can include but are not limited to dairy farming, horticulture, seed growing, livestock breeding, grazing land, market gardens, nursery plots, and even woodlands (Nix, 2002).The by-products of agricultural activities are usually referred to as "agricultural waste" because they are not the primary products. These wastes chiefly take the form of crop residues (residual stalks, straw, leaves, roots, husks, shells etc.) and animal waste (manures). Agricultural wastes are widely available, renewable and virtually free, hence they can be an important resource (Sabiiti *et al.,* 2005). They can be converted into heat, steam, charcoal, methanol, ethanol, bio diesel as well as raw materials (animal feed, composting, energy, and biogas construction).

Agricultural crop residues are one of the oldest domestic fuels. Currently, crop residues are the fourth largest energy resource after coal, oil, and natural gas. There are about one-half of the people in the world who use crop residues for domestic heating and cooking, especially in many parts of the developing world. Before 1979, the crop residue energy had covered about 70% of the rural energy consumption in China. Up to now, the crop residue energy is still an important part of the rural energy for cooking or heating in China (Edwards, Smith, and Zhang, 2004), even

though the energy conversion efficiency is only 10% to 20% (Zhang and Laquil, 2001; Yuan and Huang, 2002).

Persistent Organic Pollutant (POP) are essentially products and by-products of human industry that are relatively recent in origin (Ezemonye, 2003). Before the mid-twentieth century, pollutants with these harmful characteristics were virtually non-existent. Their origin and actual production is traced to after the World War II. This era witnessed increased production of chemicals and their by-products. POP can defy natural boundaries and when released in one part of the world can travel to remote areas (regions) far from the source. Dioxins are environmental pollutants, which belong to the so-called "dirty dozen" - a group of dangerous chemicals known as persistent organic pollutants (POPs).

Open burning of agricultural residues is an inexpensive means to advance crop rotation and control insects, disease, and the emergence of invasive weed species. While the economic and practical benefits of burning agricultural residues are apparent, the environmental and health risks of this activity need to be fairly recognized (Bamidele, 1998; Nilanthi, Badara and Patrick, 2010). Burning of agricultural residues also emits polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs), because of the presence of Chlorine in the residue (USEPA, 2000). In particular, open burning usually occurs at low temperatures of 250–450 °C and in uncontrolled conditions, which are favorable for forming incomplete combustion products, and, thus, more PCDD/Fs are emitted than those from high-temperature and well-controlled burnings. Dioxins and furans (PCDD/PCDF) are formed during incomplete combustion of organic material where chlorine is available in the feedstock or in the air supply during the combustion process, and they are also produced as trace contaminants in various industrial processes (USEPA, 2000).

Dioxin is a general term given to a large group of very toxic chemical, that get created as a byproduct during the manufacturing or burning of organic materials, chemicals and plastics that contain chlorine. The 2,3,7,8 -TCDD and 2,3,7,8 -TCDF compounds represent the most toxic compounds of their respective families. Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are a group of tricyclic aromatic hydrocarbons substituted with one to eight chlorine atoms (Olie, Addink and Schoonenboom, 1998). These compounds, commonly known as 'dioxins' or 'dioxins and furans', are found virtually everywhere on earth, with the main transport mechanism being atmospheric dispersion and deposition (Mukerjee, 1998).

Focus on dioxins and furans as contaminants began in the 1940s and 1950s in industrial settings, where chloracne was observed in workers populations involved in the manufacture of chlorinated phenoxy herbicides and exposed during the manufacturing process or during chemical reactor accidents (Suskind, 1985). Thus, knowledge about dioxin formation and rates of release to the environment is relatively new and still evolving. Direct exposure of human populations occurs primarily due to accumulation of dioxins in the food chain. Unintentional Persistence Organic Pollutants (UPOPs) are unintentionally generated chemicals from anthropogenic sources, which remain intact in the environment for long periods, become widely distributed geographically, and accumulate in the fatty tissue of humans and wildlife, and have carcinogenic, toxic and adverse effects on human health and the environment globally. Studies conducted in laboratory on animals have concluded that dioxins are highly toxic to certain species of animals at very low levels of exposure (Tosine, 1983). Observations include effects on the malformations of the foetus, liver-damage, decreased reproduction and growth rates, cancer promotion and behavioural changes.

Tetrachlorodibenzo-p-dioxin (TCDD), was evaluated by the WHO's International Agency for Research on Cancer (IARC) in 1997. Based on animal data and on human epidemiology data, TCDD was classified by IARC as a "known human cancer" (IARC, 1997). According to (WHO, 2000) the tolerable daily intake of PCDD/PCDF is 1-4 picogram/kg body weight and 70 picogram/kg body weight per month (WHO and FAO, 2001). PCDDs and PCDFs are not commercially produced but are formed as trace amounts of undesired impurities in the manufacture of other chemicals, such as chlorinated phenols and their derivatives, chlorinated diphenyl ethers and polychlorinated biphenyls (PCBs). Ongoing or earlier use of pentachlorophenol is considered to be a major source of PCDDs and PCDFs in many industrialized countries (Bremmer, 1993). PCDDs and PCDFs are also formed in combustion processes such as waste incineration and in the production of iron and steel (Rappe, 1994). Chlorine-alkali plants using graphite electrodes have been identified as a point source (Rappe, 1991), and car exhausts, mainly exhausts from leaded petrol in which chlorinated solvents have been used as so-called "scavengers", also produce these compounds (Ballschmiter, 1986; Hagenmaier, 1990). Although a variety of sources of PCDDs and PCDFs have been identified, including sewage sludge (Öberg, 1992) and garden composts (Öberg, 1993), in which they are formed naturally, there may well be a substantial fraction that originates from unidentified sources (Rappe, 1991). There is no known technical use for PCDDs and PCDFs.

In developed countries, intentional open burning of wastes is strictly controlled and has long been considered as an outdated technology. The numerous studies pointing to open burning as a major source of hazardous emissions prompted these countries to impose stringent restrictions on these activities, among the groups of noxious gaseous emissions from open burning are polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), volatile

organic carbons (VOC), semi-volatile organic carbons (SVOC), carbonyls, and chlorobenzenes (Andreae and Merlet, 2001).With the entry of the Stockholm Convention into force, concerns have been focused by various countries on polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) as these are known toxic products of incomplete and less than ideal combustion conditions (Costner, 2005). To meet their obligations to the Convention and in response to the national regulatory measures imposed, developed countries have applied the best available techniques and effectively abated some toxic emissions particularly in the incineration of municipal solid wastes.

In the developing world, however, the application of these technologies is found wanting and open burning continues to be the cheapest, easiest, most sanitary means of volume reduction and disposal of combustible materials (UNIDO, 2008). Although environmentally unacceptable, people in these parts of the world continue to practice open burning especially those in the communities where organized waste handling has not been established and people are left with their own approaches for materials disposal.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Dioxins are one of the emissions of greatest concern even in very small quantities, and are associated with disruption of multiple endocrine pathways, increased risk for ischemic heart disease, cancer, cognitive and motor disabilities, and endometriosis (USEPA, 2000). In recent years, it has been observed that open burning of agricultural residues contributes to the emissions of harmful air pollutants, which causes severe impacts on human health, including polycyclic aromatic hydrocarbons (PAHs), Korenaga, Liu and Huang (2001), as well as polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs), referred to as dioxins (

Gullett and Touati, 2003; Lin, Lee, Li, Wang and Chang-Chein, 2007). These air pollutants have significant toxicological properties and are notably potential carcinogens. Air pollution not only affects human health and the environment, but also indirectly the economy of a country (Meesubkwang, 2007).

Inadequate disposal management and re-utilization of agricultural waste causes environmental pollution and improper agricultural waste burning and disposal in rivers, streams and ponds pollutes the water by introducing bacteria or nitrate etc. which are harmful to man and other animals. Odours from animals' dwellings may cause problems with neighbours and create a negative public perception of agriculture. More importantly soils or water bodies are contaminated by the PCDD/Fs after open burning either because of the debris left in the soils or via the atmospheric transport and deposition processes. The PCDD/Fs ultimately enter the plants, fruits, poultry, fishes, or even humans via foods. A number of studies concerning agricultural waste, utilization of solid waste for agricultural purposes and difference in rural and urban waste have been conducted. A few of them are examined to put this study in proper perspective.

Shaban, Hussein, Abou and Omaima (2010), examined the utilization of agricultural waste as one of the environmental issues in Egypt. Agricultural wastes generated in Egypt range from 30-35 million tons a year of which only 7 million tons as animal feed and 4 million as organic manure are being utilized. The finding of study was the problem of agriculture wastes becomes very obvious and aggregated after the harvest of summer crops. That is because at this time of the season, the farmer is in a rush to re-cultivate his land therefore clearing of these crop wastes was his major concern, usually by burning. This method, burning not only is considered an economic loss but also has harmful effects on the environment.

Therefore, the finding is that utilization of agriculture wastes in any other environmentally friendly way is very important, which can be done by either compost production by fermenting the agricultural waste through recycling the waste which will help in re-fertilizing the soil organically and reduce the cost of producing inorganic fertilizer. Also, animal feed production can be prepared by treating crop wastes such as rice straw with urea or ammonia to increase the nitrogen content and nutritional value of the food. The conversion of wastes to economic saving, nutritional human food, growing vegetables on rice straw compacted bales in areas where soil disease and salinity are constrains and energy production such as biogas, will reduce waste mis-management and negative environmental pollution arising from agricultural waste burning well as economical saving.

John (2011) conducted a research on agricultural and forestry wastes and their opportunities as an energy source in Nigeria. The study examined the uses of agricultural residues, their conversion routes and utilization systems. Various agricultural and forestry biomass convertible to energy products were identified. The study highlighted the benefits to be derived from the use of agricultural and forestry residues as energy source in Nigeria, using gasification, bio-gasification, liquefaction, briquetting process and composting. The research suggested that all the techniques of conversion discussed could form an agricultural complex utilizing briquettes as a renewable energy source; using anaerobic digestion (biogas) to produce energy and fertilizer; composting for soil conditioner; pyrolysis to produce medium grade fuels and chemical preservatives and production of animal fodder through the process of pelletizing. The study concluded that, finding practical and economic uses for the agricultural and forestry residues will create an opportunity to build a bio economy which will deliver sustainable economic growth with job creation and social cohesion as key outcomes.

Kwaghe, Gwary, Abdulsalam and Oppong (2011) in their study on the economic analysis of agricultural waste management among farming households, in Jere Local Government of Borno State, Nigeria, generated data by the administration of structured questionnaire to farming households used for the analysis. The finding of the study revealed that about 62.5% of the respondents indicated that crop residues constitute the major agricultural waste in the study area. Animal waste is also generated in the study area with cattle producing the highest animal waste as attested by 85% of the respondents. About 69% of respondents indicated that they sell their agricultural wastes while 18.75% and 16.25% revealed that they manage their agricultural wastes by dumping and burning respectively. From this result, it can be seen that huge amount of wastes are mismanaged by the households of the study area. In addition to economic losses because of the dumping and burning, it also causes unhygienic environment and environmental pollution. The study suggested that extensive training on waste management is to be undertaken for the farmers. It is also suggested that government should involve the farmers and other stakeholders to come up with appropriate policies and legislative measures to discourage dumping and burning of agricultural wastes.

Studies by Adeoye, Adebayo and Musa (2011) on post-harvest waste generations in selected local government areas of Niger state, north central Nigeria was evaluated. The method adopted was investigative approach. Questionnaire was administered and results collected. Five major crops were being propagated on large scale in Niger state. But the way and manner they are being grown varies throughout the state. The crops are groundnut, maize, yam, sorghum and rice. From the study, maize, groundnut and rice are being produced in large quantity in the place visited. For maize alone in twelve local governments, 3,423 tonnes of waste was produced, 3,481 tonnes for Rice and 1,742 tonnes of groundnut waste was produced. The farms visited were all

privately owned establishment and all the farmers had no formal education. The major management measure adopted in the study is burning which was not environmentally friendly. The results obtained from the study can be used to design waste management plants for these local governments. From the in-situ inspection done and the responses from the focused group discussion done, the entire farms visited are not having definite waste management practice. The residues were left on the soil to degrade and in some area; they have formed heaps where weeds grow and become another threat to the nearby farms**.** In some places, they are subjected to burning. Burning, apart from its bad environmental effect of depleting ozone layer, is also harmful for soil micro- organisms. It may also pose health hazard to the nearby villagers that inhale the smoke from this combustion process.

Also Biu like most northern Nigerian society is agrarian where several tons of agricultural crop residues are either misused or left unused. To the best of the researcher's knowledge and based on accessible literature by Shaban, Hussein, Abou and Omaima, 2010; Adeoye *et al.,* 2011; John, 2011 and Kwaghe *et al.,* 2011, there is no research carried out on the assessment of potential emission dioxin and furan from open burning of agricultural crop wastes using UNEP standard toolkit estimation technique in Biu local government area of Borno State. For these reasons, therefore, this study intends to fill the gap in knowledge about the potential environmental consequences of dioxin and furan emissions in the agricultural crop wastes in the study area. The following are specific research questions that will be addressed in the study area:

1. What is the variation in the size of land under different crop cultivation?
2. What is the volume (tons) of agricultural crop residues generated per crop type?
3. What are the different ways/ means of disposing agricultural residues?
4. What are the classes of agricultural crop residues used based on the UNEP toolkit?

5. What is the quantity of PCDD/PCDF emission from each crop type that is annually generated?

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to assess the potential emission of dioxin and furan from open burning of agricultural crop residues in Biu local government area (LGA) of Borno State.

Specific objectives of the study are to:

i. assess the hectares of land used for crop types in the study area
ii. quantify (in tons) agricultural crop residues generated per crop type in study area
iii. examine the different mechanism for disposing agricultural residues
iv. classify the types of agricultural residues based on the UNEP standard toolkit
v. quantify PCDD/PCDF emissions from each crop in the study area using well known emissions estimation techniques

1.4 SCOPE OF THE STUDY

In terms of spatial extent, the scope of the study was limited to 10 selected communities in Biu L.G.A. which are Buratai, Garundana, Kimba, Maina Hari, Mandafuma, Mandagirau, Mangada, Miringa, Tum and Yamarkumi. Temporally, the 2013 period of harvesting on-site post-harvest agricultural crop wastes (residue) was used. In addition, only crops residues that have been categorized in UNEP standard toolkit were considered in the study area considered due to the cost implication and the security challenges in the region. This study estimates only the amount of crop residue generated annually, hectares of land and quantity of dioxin and furan emission in agricultural crops residues.

1.5 JUSTIFICATION OF THE STUDY

Dioxins are of concern because of their highly toxic potential, once dioxins enter the body, they last a long time because of their chemical stability and their ability to be absorbed by fat tissue, where they are then stored in the body. Their half-life in the body is estimated to be 7 to 11 years. In the environment, dioxins tend to accumulate in the food chain; the higher an animal is in the food chain, the higher the concentration of dioxins. Biu local government area of Borno state has over the years experienced increase in agricultural activities as a result of increase in population, demand for food, increased in farming practice, increased agricultural production and other related factors. However the level of agricultural crop waste (residue) generation and form of management in Biu local government area has not been well documented through research. This is rarely investigated, hence the environmental salvation, ecological remediation and economic potential of such management are not known. This makes this study necessary and timely particularly considering alternative environmental management options that could be evolved

This study will help stakeholders in agricultural farming and environmental officers would provide the needed information to enable local farmers realize the multiple importance of agricultural crop waste in addition to those they are aware of, as most agricultural wastes have reuse values which are beneficial in maintaining the environment. This study will also bring awareness to the people on the need to protect the environment against environmental degradation such as open burning, air pollution and soil contamination etc. as a result of uncontrolled burning activities of agricultural crop waste.

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 CONCEPTUAL FRAMEWORK

In order to remove any ambiguity in the usage of some words in this study, concepts relevant to the research are defined below. The concepts are waste, waste management, agricultural waste, persistent toxic pollutants, emission factor and dioxins.

2.1.1 Waste

In general, one can say that waste is useless, unwanted or discarded material resulting from agricultural, commercial, communal and industrial activities. Waste includes solids, liquids and gases. On the other hand, one person's waste can be a source of income a resource for another. This potential for recycling and reuse can support people by buying; collecting, sorting, selling and recycling waste. Barry and Horton (1974) see waste as unwanted and undesirable materials which originated from industrial, mining projects, agricultural and livestock activities, residential, commercial and municipal uses. Similarly, solid waste refers to any non-gaseous or liquid material that is discarded because it has no further use to the owner. This concept embraces all unwanted by- products dumped at any given place within an environment (Udanwu, 2007). The United States Solid Waste Act (1965) defined solid waste as garbage, refuse, and material generated from commercial and agricultural operations as well as from community activities.

According to Nigeria Federal Environmental protection Agency (1997), solid waste also refers to solid or semi-solid materials, resulting from human and animals activities that are useless, unwanted or hazardous (Doan, 1998). On the other hand, Cointreau (1982) sees solid waste as any non-air and non-sewage emission created within and disposed of by an area,

including household garbage, commercial refuse, construction and demolition debris, dead animals and abandoned vehicles. Odanwu, (2007) had different view on the actual sources of solid waste. According to the researcher, there is no specific source of solid waste. Solid waste can be generated from everywhere depending on what the individual sees as a solid waste. Solid waste may also be classified into two types, which includes; organic and inorganic solid waste, or Biodegradable and non-biodegradable solid waste (Nabegu, 2008; Akpu and Yusuf, 2009). However, this research is concerned with the organic agricultural crop residues source of solid waste; hence further attention may not be given to other sources.

2.1.2 Waste Management

Waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of wastes in a manner that is in accordance with the best principles of public health, economics, engineering, conservations , and that is also responsive to public attitudes (Tchobanoglous, Theisen and Vigil, 1993). The nature and operation of solid waste management varies significantly from nation to nation, regardless of scale, these differences are to some extent attributable to prevailing socio-economic, financial, legal and political variables at that level. Solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in solution to all problems of solid wastes. The solutions may involve complex interdisciplinary relationships among such fields as political science, city and regional planning, geography, economics, public health sociology, demography, communications, and conservation, as well as engineering and material science.

Waste management methods cannot be uniform across regions and sectors because individual waste management methods cannot deal with all potential waste materials in a

sustainable manner (Staniškis, 2005). Conditions vary; therefore, procedures must also vary accordingly to ensure that these conditions can be successfully met. Waste management systems must remain flexible in light of changing economic, environmental and social conditions (McDougall, White, Franke and Hindle, 2001; Scharfe, 2010). In most cases, waste management is carried out by a number of processes, many of which are closely interrelated; therefore it is logical to design holistic waste management systems, rather than alternative and competing options (Staniškis, 2005).

Methods of waste reduction, waste reuse and recycling are the preferred options when managing waste. There are many environmental benefits that can be derived from the use of these methods. They reduce or prevent greenhouse gas emissions, reduce the release of toxic pollutants such as dioxins and furans into the environment, conserve resources, save energy and reduce the demand for waste treatment technology and landfill space. Therefore it is advisable that these methods be adopted and incorporated as part of the waste management plan.

2.1.3 Waste Reduction and Reuse

Waste reduction and reuse of products are both methods of waste prevention. They eliminate the production of waste at the source of usual generation and reduce the demands for large scale treatment and disposal facilities. Methods of waste reduction include manufacturing products with less packaging, encouraging customers to bring their own reusable bags for packaging, encouraging the public to choose reusable products such as cloth napkins and reusable plastics and glass containers, backyard composting and sharing and donating any unwanted items rather than discarding them. All of these methods of waste prevention however require public participation to be effective. In order to get the public onboard, training and educational programmes need to be undertaken to educate the public about their role in the process. Also the

government may need to regulate the types and amount of packaging used by manufacturers and make the reuse of shopping bags mandatory (ibid).

2.1.4 Waste Recycling

Recycling refers to the removal of items from the waste stream to be used as raw materials in the manufacture of new products. Thus from this definition recycling occurs in three phases: first the waste is sorted and recyclables collected, the recyclables are used to create raw materials. These raw materials are then used in the production of new products. The sorting of recyclables may be done at the source (i.e. within the household or office) for selective collection by the municipality or to be dropped off by the waste producer at a recycling centre. The pre-sorting at the source requires public participation which may not be forthcoming if there are no benefits to be derived.

Another option is to mix the recyclables with the general waste stream for collection and then sorting and recovery of the recyclable materials can be performed by the municipality at a suitable site. The sorting by the municipality has the advantage of eliminating the dependence on the public and ensuring that the recycling does occur. The disadvantage however, is that the value of the recyclable materials is reduced since being mixed in and compacted with other garbage can have adverse effects on the quality of the recyclable material, (www.unpluggedliving.com).

2.1.5 Zero Waste

Zero waste refers to waste management and planning approaches which emphasize waste prevention as opposed to end of pipe waste management (Snow and Dickinson, 2001; Spiegelman, 2006). Zero waste encompasses more than eliminating waste through recycling and reuse; it focuses on restructuring production and distribution systems to reduce waste (Young, Ni

and Fan, 2010). An important consideration of the zero waste philosophy is that it is more of a goal, or ideal rather than a hard target. Even if it is not possible to completely eliminate waste due to physical constraints or prohibitive costs, zero waste provides guiding principles for continually working towards eliminating wastes (Snow and Dickinson, 2001) and there are many successful cases around the world which resulted from the implementation of the zero waste philosophy (Townend, 2010). The zero waste philosophy has been adopted as a guiding principle by several governmental organizations as well as industries (Snow and Dickinson, 2001; Townend, 2010).

Because the focus of zero waste is on eliminating waste from the outset, it requires heavy involvement primarily from industry and government since they are presented with many advantages over individual citizens. In fact, zero waste will not be possible without significant efforts and actions from industry and government (Connett and Sheehan, 2001). Industry has control over product and packaging design, manufacturing processes, and material selection (Townend, 2010). Meanwhile, governments have the ability to form policy and provide subsidies for better product manufacturing, design and sale; and the ability to develop and adopt comprehensive waste management strategies which seek to eliminate waste rather than manage it (Snow and Dickinson, 2001). Due to the heavy involvement of industry in eliminating waste, extended producer responsibility is often an essential component of zero waste strategies (Spiegelman, 2006).



Figure 1: Solid Waste Management Hierarchy
Source: http://www.sustainabilityed.org/pages/example2-2.htm

2.1.6 Agricultural Crop Wastes

Agricultural crop wastes are classified into crop residues and agricultural industrial by-products. Crop residues are the materials left on the farm after harvesting the target crops. Crop residues in Nigeria include straw, leaves and stalk of cereals such as rice, maize/corn, sorghum, millet, and cassava stalk/peelings. Agro-industrial by-products, on the other hand, are produced mainly after crop processing, and include cocoa husk, coconut shell and husk, rice husk, oil seed cakes, sugar cane bagasse, and oil palm empty fruit bunch (EFB) (Dominik and Rainer, 2007; Ajueyitsi, 2009).

2.1.7 Persistent Organic Pollutant

Persistent Toxic Substances (PTSs) and Persistent Organic Pollutants (POPs) are a set of chemical substances that persist in the environment, undergo long range transport, bio accumulation through the food chain, and pose a risk of causing adverse effects to human, wildlife and the environment. There have been more and more evidences that these pollutants, upon exposure of human population and wildlife, may cause serious health effects such as induction of cancers, damage to the nervous system, disruption of the immune and hormonal system, etc. resulting in various abnormalities (Harrad, 2001; Meekera, Altshulb and Hauser, 2007; Petersen *et al.*, 2007; Lignell, Aune, Darnerud, Cnattingius and Glynn, 2009; Todaka *et al.*, 2009).

The PTSs emission sources could come from many natural and socioeconomic activities such as active volcano, forest fire, agricultural cultivations (include use, store and disposal of agricultural pesticides, open burning of biomass for land clearing activities), industrial activities such as (Chemicals, pulp-and-paper, metallurgy, refinery and other industries, etc.), transportation and dumping sites. Besides that, PTSs emission sources are also formed from the burning of industrial, municipal, medical and hazardous waste, diesel fuel, etc. (UNEP, 2002).

To protect human and environment from PTSs in general and POPs in particular, by 23 May 2001, 92 countries and EU had approved Stockholm Convention on POPs. Convention came into force in May 2004, when it was ratified by 50 nations. The ultimate goal of the Stockholm Convention is to decrease the concentration of POPs in the environment and human. Vietnam ratified the Stockholm convention in 22 July 2002 and is the 14th country in 160 countries which had ratified convention until August 2008. Vietnamese government also approved the National Implementation Plan (NIP) for participating, performing and validating Stockholm convention

with decision No. 184/2006/QD-TTg of Prime Minister on the 10th of August 2006. Signatories to Stockholm Convention agree to reduce or eliminate releases from intentional or unintentional production and use of POPs and perform monitoring POPs levels in environment (Stockholm Convention, 2001).

Another property of PTSs is accumulation capacity into organisms especially in adipose tissues. This property is lipophilicity. High lipophilicity of PTSs results in the substance bio-concentrating from the surrounding medium into the organism such as from water or sediment to fish (Gabos, Wicockson, Russell and Haffner, 1999). Combined with environmental persistence and a resistance to biological degradation, lipophilicity of PTSs also results in bio-magnifications through the food chain. Bio-magnification results in much greater exposures in organisms at the top of the food chain such as marine mammals (Ross and Birnbaum, 2003).

2.1.8 Emission Factor

The term “emission factor” is used to mean the quantity of an unintentional persistent organic pollutant (UPOP) that is released per unit of activity. Emission factors are specific to each receiving medium (air, water, land, residues, and products) so several emission factors are necessary for determining total releases from most sources. For example, an air emission factor, a residue emission factor , and, in some cases, a water emission factor and a product emission factor are required to estimate total releases of UPOPs from a various waste incinerator (UNEP, 2005).

2.1.9 Dioxins

The term Dioxin is used to describe a family of compounds with a similar chemical structure; dioxin compounds contain carbon, hydrogen, oxygen and chlorine. Dioxin is an unwanted by-product of activities such as burning refuse, metal smelting, and in the process of producing some chemicals. The term “dioxins” refers to 75 congeners of polychlorinated dibenzo-

p-dioxins (PCDD) and 135 congeners of polychlorinated dibenzofurans (PCDF) (Öberg, Glas and Swanson, 1990; Wagner, Schramm and Hutzinger, 1990).

2.2 LITERATURE REVIEW

This section contains the review of the relevant literature in relation to this work. It examines the sub themes such as agricultural crop waste (residue), agricultural waste management, open burning, dioxins, and environmental issues in Nigeria.

2.2.1 Agricultural Crop Residue

Crop residues are organic and inorganic materials produced as byproduct during the harvesting and processing of agricultural crops. Agricultural residues which are produced at the time of harvest are primary or field based residues while those produced along with the product during processing are secondary or processed based residues. Agricultural residues are heterogeneous, varying in bulk density, moisture content, particle size and distribution depending on the mode of handling. They are usually fibrous, low in nitrogen and vary with geographical location (Smith, 1989). Some of the field residues are used as fertilizer, for erosion control and as fodder for livestock. Close to 50% of the residue are however burnt on cropland before the start of the next growing season. Process residues offer high promise as energy source (Cooper and Laing, 2007). Chemical composition of a crop residue varies depending on factors such as variety, age of residue or stage of harvest, physical composition including length of storage and harvesting practices (OECD/IEA, 2010).

2.2.2 Benefits of Agricultural Residues use in Nigeria

Agricultural waste is a biomass that is renewable source of energy and its use does not contribute to global warming. In fact, it has been found to reduce the atmospheric level of carbon

dioxide as it acts as a sink (Musa, 2007). Biomass fuels have negligible sulphur content and therefore do not contribute to sulphur dioxide emissions that cause acid rain. The ash produced by combustion of agricultural residue is less than coal combustion and this ash can be used as soil additive on farmland to recycle materials such as phosphorous and potassium (Musa, 2007). Furthermore, finding practical and economic uses for the residues will create an opportunity to build a bioeconomy, which will deliver sustainable economic growth with job creation and social cohesion as key outcomes (Oladeji, 2011). Creating such a bioeconomy involves the substitution of fossil materials with renewable carbon. As a consequence of increasing the use of renewable resources for industrial feed stocks and for energy, the bioeconomy will bring benefits in a number of areas. This will save a considerable amount of money and avoid negative environmental impacts and health hazards as a result of field burning process or decomposition of the agricultural wastes (Oladeji, 2010).

Most previous studies provide a combined estimate for agricultural residues that are burnt as fuel and those that are burnt in the open fields to dispose of the stubble and to return nutrients to the soil. Seiler and Crutzen, (1980) and *A*ndreae (1991) proposed that 80% of available residues are burned in developing countries and 50% in developed countries. Crutzen and Andreae (1990) suggested that 25% of crop waste is burned in the fields of developing countries in the tropics, while Hao and Liu (1994) assumed that 23% of residues are used as fuel and 17% are burned in the field. Billions of tons of agricultural waste are generated each year in the developing and developed countries. The single largest category of crops is cereals, with global production of 1800 Tg in 1985 (FAO, 1986a). Wheat, rice, maize, barley, and millet and sorghum account for 28%, 25%, 27%, 10%, and 6%, respectively, of these crops. The waste products which are the main contributors to biomass burning are wheat residue, rice straw and hulls, barley

residue, maize stalks and leaves, millet and sorghum stalks. Crop residues do not usually appear in official statistics hence an estimate of the amount of crop residues produced were made based on production data that were obtained from United Nations Food and Agricultural Organization (FAOSTAT, 2012, NASS, 2012).

Available data for processing residues is generally poor, due to a wide variety of processing techniques which will result in different shares of residues (Eisentraut, 2010). The ratio between main product and residue vary depending on a set of factors including variety, moisture content, nutrient supply and use of chemical growth regulators among others. In reality, not all existing residues can be used for bioenergy production due to scattered abundance, technical constraints, ecosystem functions and other uses (animal fodders, fertilizer, domestic heating and cooking). The 2010 production data of some crops were combined with the residue-to- product ratios (RPR) of the different crops to obtain the amount of residues for each annual crop and from perennial plantation crops. An analysis showed that the estimated total amount of crop residue that is potentially available for energy is 150 million tones. Using 30% conversion that is typically obtained in biomass to energy conversion systems efficiency and the heating value data, these residues can provide 0.60 EJ (or 34% of the current energy consumed in Nigeria).

Globally, various studies have estimated the potential of crop residues for energy generation. Scarlat *et al.* (2010) presented a detailed assessment of the amount of crop residues available for energy generation from 27 nations in the EU. Crops considered in this study were wheat, rye, barley, oats, maize, rice, rapeseed and sunflower. Results showed that high amounts of crop residues are produced in this region and have an estimated energy generation of about 1530 PJ/year. High residue potential has been achieved from countries with a large agricultural sector

and high agricultural production in the EU such as France, Germany, Romania, Spain, Italy, Hungary and Poland.

In Africa, a number of studies have been conducted to determine the potential of crop residues for energy generation. For instance, Cooper and Laing (2007) presented a rough estimate of the theoretical amount of crop residues for countries in the African continent. Coconut, maize, rice and sugarcane crops were chosen for this investigation because they are regarded as the most important crops cultivated in Africa. Other crop residue assessments have been conducted in Zimbabwe, Nigeria, Sudan and Ghana (Abdallah, 1991; Jingura and Matengaifa, 2008; Jekayinfa and Scholz, 2009; Duku, Gu and Hagan, 2011). These studies determined the residue production for each crop type and their respective energy potential. Typical crops selected in these studies were maize, wheat, rice, sugarcane, sorghum, groundnuts, oil palm and millet.

Several authors have reported a global increase in the utilization of agricultural crop residues for energy generation in both developed and developing countries and numerous reasons have been suggested for the increase. Goldemberg (1988) believes that these residues are environmentally friendly when utilized in modern ways compared with the current energy sources, whereas Hayes (1998) thinks that these resources are abundant and cheap and their utilization will result in the economic benefits mentioned above. Cereal crops have been reported as having the potential to generate large amounts of crop residues (Lal, 2004). Examples of these crops are maize, wheat, barley, oats, sorghum, millet, rice, rye and sugarcane. For instance, in Malaysia, rice husk is being utilized for power generation (Kong, 2000). Furthermore, residue generation from maize, wheat, oats, sorghum, rice and sugarcane has been reported in Zimbabwe and in the European Union (EU) (Jingura and Matengaifa, 2008; Scarlat, Martinov and Dallemand, 2010).

Janssen and Rutz (2011) found that utilizing agricultural crop residues in modern ways has the potential to provide clean energy to rural households in Africa. So far, residues from sugarcane (bagasse) have demonstrated their potential for electricity generation in several countries in Africa. Up to 16 nations in sub-Saharan Africa have been mentioned as being able to provide considerable amounts of their power from bagasse-based cogeneration (Karekezi and Kithyoma, 2005). For instance, Karekezi and Kithyoma (2005) reported that 60% of factories generating bagasse in western Kenya are utilizing it as a fuel in their boilers so that they can generate steam and electricity. In Tanzania, the potential for cogeneration has been reported to be about 157GWh and only 9% has been developed (Karekezi, Kimani and Onguru, 2008).

In Kenya, crop residues represent one of the significant sources of biomass since the agricultural sector is the backbone of its economy. In 2008, this sector accounted for 27 % of the GDP (IEA, 2010).Various wastes are generated which are left in the field to decompose or are burnt**.** These are mostly found throughout rural areas. Biomass resources account for 76.9% of energy in Kenya (IEA, 2010) and amongst these resources, fuel wood has been the main source of energy for 60% of the rural population (Karekezi, Kimani and Onguru, 2008). However, the recent decline in fuel wood resources has led to a shift towards the utilization of crop residues for energy generation. The potential in utilizing these crop residues for energy generation, including the amounts available and their respective energy potentials has been well documented for Kenya and most African nations by various studies (Cooper and Laing, 2007; Jingura and Matengaifa, 2008; Jekayinfa and Scholz, 2009). However, the location and distribution of these residues have not been available and lack of information on the geographical location of these crop residues has been the main reason hindering the development of biomass conversion technologies in Kenya (Dasappa, 2011). Knowing the geographical location of crop residues is essential for their

successful utilization as it assists in the identification of potential sites for biomass power plants (Chanthunyagarn, Garivait and Gheewala, 2004; Voivontas, Assimacopoulos and Koukios, 2001).

Globally, various studies have also utilized GIS to estimate the theoretical amount of agricultural residues and their energy potential (Singh, Panesar and Sharma, 2008; Milbrandt, 2009; Vasco and Costa, 2009; Fernandes and Costa, 2010; Ćosić, Stanić and Duić, 2011; Hiloidhari and Baruah, 2011; Jiang, Wang and Fu, 2012). These studies have utilized Voivontas, Assimacopoulos and Koukios (2001) approach to estimate the theoretical amount of crop residues. The results presented comprised the amount of agricultural residues that can be generated and their energy potential and their spatial distribution. One of the characteristics of the GIS software is its ability to automate processes which has not been considered in most of these studies.

In Africa, studies utilizing GIS for crop residue assessment are limited. One of such study was conducted in Liberia where the amount of crop residues was estimated for each county and as a result the spatial distribution of these residues was presented (Milbrandt, 2009). In Liberia, (ibid, 2009) used GIS to quantify the theoretical amount of crop residues that can be produced from each county. He utilized Voivontas's (2001) approach to analyze and come up with conclusions. It was found that about 125,000 tonnes of food crop residues can be generated annually.

2.2.3 Biomass Resources in Nigeria

In Nigeria, agricultural crops that have potential as biomass feedstock for biofuel production include sugar cane, cassava, rice, maize and sorghum for ethanol and oil palm, groundnut, coconut, cotton, soya bean, jatropha and sesame (locally called biniseed) for biodiesel (Agba, Ushie, Abam, Agba and Okoro, 2010).

Biomass resources in the country include Agricultural crops, wood, charcoal, grasses and shrubs, residues and wastes (agricultural, forestry, municipal and industrial), and aquatic biomass. Total biomass potential in Nigeria, consisting of animal and agricultural waste, and wood residues, was estimated to be 1.2 PJ in 1990 (Obioh and Fagbenle, 2009). In 2005, research revealed that bio-energy reserves/potential of Nigeria stood at: Fuel wood 13071,464 hectares, animal waste, 61 million tonnes per year, crop residues 83 million tonnes (Agba *et al*., 2010). Table 1below shows the production output of some major agricultural crop residues and by-products generated in the country in 2004.

These mass of residues were calculated by using the processing residue to product ratio. As shown in table, cassava has the highest output of residues generated and its estimated value is about 29 million metric tonnes, and for yam is about 22 million metric tonnes. Crops which include groundnut, maize, rice, sorghum, and cocoyam have output from 1.5 to 6 million metric tonnes of residues. While that from other crops including oil palm, sweet potato, sugar cane and coffee, range from 200 to 400 thousand metric tonnes respectively. The quality of crop residues available for energy is highly dependent upon special environment and utilization intensity.

Furthermore, seasonal availability will seriously constrain the use of residues. Estimates of crop residues availability depend largely on the effectiveness of harvest methodology, the residual quantities required to protect the soil from erosion and the density and dispersion of the residue relative to the feasibility of collecting the material. In North American, 62 % of all residues occur between October and December while in Nigeria, about 80 % of the residues occur between April and September (Odia, 2006). The quantity of crop residues that can be realistically used is considerably less than the total produced. Environmental constraints and harvesting difficulties limits what can be captured for energy to between 20 and 50 percent.

Table 1: Estimated National Output of the Processing Based Biomass Residues in 2004, in (metric tonnes).

Crop residue Total amount	(Metric tonnes)
Cassava	29,000000
Yam	22,000000
Millet	11,000000
Maize	3,500,000
Rice	1,800,000
Potato	600,000
Cowpea	4,050,000
Groundnut	6,000,000
Oil palm	400,000
Sugar cane	300,000
Sweet potato	2,000,000
Cocoyam	1,500,000
Coffee	400,000
Cashew	300,000
Plantain	9,450,000
Sorghum	2,500,000

Source: (Jekanyinfa, 2007; Osaghae, 2009)

2.2.4 Agricultural Waste Management

Agricultural wastes are mainly disposed of to landfill, because landfill is the simplest, cheapest and most cost-effective method of disposing of agricultural waste (Barrett and Lawlor, 1995). In most low- to medium-income developing nations, almost 90 per cent of generated agricultural waste goes to landfill and burning (David and Frank, 1991). Even in many developed countries, most agricultural waste is land filled. For instance, within the European Union, although policies of reduction, reuse, and diversion from landfill are strongly promoted, more than half of the member states still send in excess of 75 per cent of their agricultural waste to landfill (e.g. Ireland 92 per cent), and in 1999 landfill was still by far the main farm waste disposal option for Western Europe (EEA, 2003).

Agricultural mechanization and technology has helped to accomplish this transformation and to achieve many of man's goals. It has however, left a profusion of environmental problems in its wake (Singh and Sekhon, 1996). The question today is whether technology and good waste

management can solve the environmental problems which agricultural mechanization and technology has helped to cause. But in order to answer in a more practical way, technological evaluation activities should be expanded and more thought devoted to determining what method is needed to solve today's pressing problems as regards agricultural waste management in a mechanized farm.

2.2.5 Open Burning

Open burning is the burning of unwanted materials in a manner that causes smoke and other emissions to be released directly into the air without passing through a chimney or stack. This includes the burning of outdoor piles, burning in a burn barrel and the use of incinerators which have no pollution control devices and as such release the gaseous byproducts directly into the atmosphere (Department of environmental quality, 2006).

Open burning has been practiced by a number of urban centers because it reduces the volume of refuse received at the dump and therefore extends the life of their dumpsite. Garbage may be burnt because of the ease and convenience of the method or because of the cheapness of the method. In countries where house holders are required to pay for garbage disposal, burning of waste in the backyard allows the householder to avoid paying the costs associated with collecting, hauling and dumping the waste. Open burning has many negative effects on both human health and the environment. This uncontrolled burning of garbage and agricultural residues releases many pollutants into the atmosphere. These include dioxins, particulate matter, polycyclic aromatic compounds, volatile organic compounds, carbon monoxide, hexachlorobenzene and ash. All of these chemicals pose serious risks to human health. The harmful effects of open burning are also felt by the environment. This process releases acidic gases such as the halo-hydrides; it also may release the oxides of nitrogen and carbon. Nitrogen oxides contribute to acid rain, ozone

depletion, smog and global warming. In addition to being a greenhouse gas carbon monoxide reacts with sunlight to produce ozone which can be harmful.

Biomass burning is used to clear fields, control pests and diseases, and return nutrients and minerals to the soil (Meland and Boubel, 1966). Seiler and Crutzen (1980) estimated that the amount of agricultural waste burned ranges from 1700 to 2100 Tg of dry matter per year, based on an extrapolation from waste production in the United States and assuming that 80% of the overall agricultural residue is burned in developing countries and 50% in developed nations.

Prescribed biomass burning is considered a significant source of air pollution throughout the world (Jenkins, Jones, Turns and Williams, 1996). Biomass burning releases large amounts of smoke into the air and contains several chemical compounds of concern including, carbon monoxide (CO), volatile organic compounds (VOC's), polycyclic aromatic hydrocarbons (PAH's), nitrogen oxides (NOx), and particulate matter (PM) (Jenkins, Jones, Turns and Williams, 1996). These pollutants are produced by incomplete combustion, which result from low combustion temperature, insufficient mixing, and inadequate residence time in the combustion zone (Werther, Saegner, Hartge, Ogada and Slagi, 2000). Some of the compounds present in smoke from biomass are highly irritating. These compounds include acrolein, formaldehyde (HCHO) and aldehydes. Others are potentially hazardous and include carbon monoxide (CO), fine particles (PM), polycyclic aromatic hydrocarbons (PAH's) and benzene (Roberts and Corkill, 1998). The last two compounds are known carcinogens, but are emitted in relatively low concentrations (Reinhardt, Otmar and Castilla, 2001).

Fine particles present in smoke (less than 2.5 mm in diameterPM2.5) can be associated with human health problems. Smaller particles can travel deeper into the long alveolar cells and can be related to health problems (Roberts and Corkill, 1998). In some cases, exposure to smoke

has been linked to early death cases (Long *et. al.,* 1998; Flowers, 2000). Reinhardt (2001), analyzed the air quality conditions in a rural town in Brazil (Rondônia) during the prescribed agricultural fire season. He documented that people living in the area are exposed to high levels of smoke for multiple days. The ambient levels of pollutants for particulate matter (P.M) for a 24-hour averaged 191 mg/m^3, 12.8 ppb for formaldehyde (HCHO), 4.2 ppm for carbon monoxide (CO), and 3.2 ppb for benzene. In addition, the author mentioned that a smoke management strategy was, in fact, implemented at the time.

2.3 Dioxin and Furan

Polychlorinated dibenzo-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) are environmental contaminants detectable in almost all compartments of the global ecosystem in trace amounts, these compound classes in particular have caused major environmental concern, in contrast to other chemicals of environmental concern such as polychlorinated biphenyls (PCB),polychlorinated naphthalenes (PCN), and polychlorinated pesticides like DDT, pentachlorophenol(PCP) or others, PCDD/PCDF never were produced intentionally. They are formed as by-products of numerous industrial activities and all combustion processes (Fiedler Hutzinger and Timms, 1990).

Dioxins are capable of producing a multitude of health problems; they can have adverse effects on reproduction, development, disrupt the hormonal systems and even cause cancer. The polycyclic aromatic compounds and the hexachlorobenzene are considered to be carcinogenic. Present knowledge about sources of PCDD and PCDF is based on experiences from a few industrialized countries of the World, conducting inventories is an essential step in implementing an international instrument on POPs. Besides the fact that there is little information available

regarding POPs produced as byproducts, technical assistance is needed for many developing countries to establish dioxin inventories.

Amongst these 210 compounds of dioxin and furan, 17 congeners can have chlorine atoms at least in the positions 2, 3, 7, and 8 of the parent molecule. These 17 2,3,7,8-substituted congeners are toxic to many laboratory animals, resistant towards chemical, biological, and physical attack, and thus many accumulate in the environment and in organisms, such as animals and humans. The 2,3,7,8-TCDD (2,3,7,8-Cl4DD) also named "Seveso-dioxin" is considered to be the most toxic man-made compound. Besides the anthropogenic sources, an enzyme-mediated formation of PCDD and PCDF from 2,4,5- and 3,4,5-trichlorophenol has been demonstrated in vitro (Öberget, Glas and Swanson, 1990; Wagner, Schramm and Hutzinger, 1990).

2.3.1 Dioxin in the Environment

The environmental processes by which PCDD/PCDF moves through the environment are reasonably well known. PCDD/PCDF is multimedia pollutants and, once released to the environment, become distributed between environmental compartments (EC, 1999). Due to their high lipophilicity and low water solubility, PCDD/PCDF are primarily bound to particulate and organic matter in soil and sediment, and in biota, they are concentrated in fatty tissues. In air, as semi-volatile compounds PCDD/PCDF can exist in both the gaseous phase and bound to particles. The two key parameters, the congener's vapor pressure, and the ambient air temperature govern the partitioning between gaseous phase and particle. Especially during the warmer (on the northern hemisphere summer) months the lower chlorinated PCDD/PCDF congeners tend to be found predominantly in the vapor phase.

PCDD/PCDF in the vapor phase can undergo photochemical transformation with dechlorination process leading to more toxic congeners if octa- and hepta-chlorinated congeners

degrade to tetra- and penta-chlorinated and finally to non-toxic compounds with only three or less chlorine atoms, PCDD/PCDF attached to particulate matter seems to be resistant to degradation. When evaluating concentrations of PCDD/PCDF in the environment, it should be taken into account that some matrices are sensitive to short-term inputs, e.g., ambient air or short-lived vegetation, whereas other matrices, such as sediments and soils, are relatively insensitive to temporal variation. Further important factors for the interpretation of results are season (e.g., in winter PCDD/PCDF concentrations in air may be higher by a factor of ten on TEQ basis than in summer), length of the sampling or exposure (e.g., few hours vs. weeks), location (e.g., urban vs. rural), the sampling method (e.g., high-volume sampling vs. particulate deposition), sampling depth (e.g., surface vs. core), etc. (EC, 1999).

PCDD/PCDF can be deposited on plant surfaces via wet deposition, via dry deposition of chemicals bound to atmospheric particles or via diffusive transport of gaseous chemicals in the air to the plant surfaces. Each of these processes is governed by a different set of plant properties, environmental parameters, and atmospheric concentrations. Investigations with native grassland cultures showed that dry gaseous deposition plays the dominant role for the accumulation of the lower chlorinated PCDD/PCDF, whereas dry particle-bound deposition played an important role in the uptake of the PCDD/PCDF with six and more chlorine atoms. There was also some evidence indicating an input of the higher chlorinated PCDD/PCDF from wet deposition (Welsch-Pausch, McLachlan and Umlauf, 1995).

PCDD/PCDF Levels in grass, reflect the exposure to vegetation as it is only exposed for a relatively short time, with new growth replacing old and crops being harvested. For agricultural leaf crops the main source of contamination is direct deposition from the atmosphere and soil splash. Root uptake and translocation of dioxin contamination into the crop has been confirmed

for zucchini and cucumber only. Grazing animals are exposed to dioxins by ingesting contaminated pasture crops and PCDD/PCDF are found to accumulate primarily in the fatty tissues and milk (Fiedler, Hutzinger, Welsch-Pausch and Schmiedinger, 2000).

2.3.2 Sources of PCDD/PCDF

Since the first overview on formation and sources of PCDD/PCDF was published in 1980 (Esposito, Tiernan and Dryden, 1980), several updates are available in the international literature. The findings can be summarized as follows (Hutzinger and Fiedler, 1993). PCDD/PCDF were never produced intentionally but occurs as trace contaminants in a variety of industrial and thermal processes; due to their chemical, physical and biological stability PCDD/PCDF are able to remain in the environment for long times. As a consequence dioxins from so-called "primary sources" (once formed in industrial or combustion processes) can be transferred to other matrices and enter the environment. Such "secondary" sources are sewage sludge/bio sludge, compost, or contaminated soils and sediments; enzymatic reactions can dimerize chlorophenols to PCDD/PCDF. However, compared to chemical-industrial and combustion sources, biological formation seems to be negligible.

2.3.2.1 Natural Sources of pcdd/pcdf

Biological formation of PCDD/PCDF from chlorinated precursors was discussed for compost and sewage sludge and questions on the possibility of a biogenic formation did arise for sediments and soils (especially forest soils). Based on the results of Öberg and Rappe the turnover to convert pentachlorophenol (PCP, the most suitable precursor) to PCDD is in the low ppm-range (Fiedler, Hutzinger and Timms, 1990; Wagner, Schramm and Hutzinger, 1990; Öberg, Andersson and Rappe, 1992). Consequently, a chlorinated precursor present in an environmental matrix, such as soil or sediment, at ppm-concentrations should be converted to not more than ppt.

levels of high-chlorinated PCDD (Cl7DD and Cl8DD). In other words, ppm-concentrations of chlorophenols would generate ppt-levels of Cl7DD and Cl8DD or ppq-concentrations in TEQ. Thus, based on present knowledge, biological formation of PCDD from chlorinated phenols under environmental conditions is negligible (Fiedler, 1995).

High concentrations of mainly PCDD were found in mined ball clay from the United States of America, kaolinitic clay from Germany, deep soil samples from Great Britain, in dated marine sediment cores from Queensland, Australia, and in man-made lake sediment cores from Mississippi, USA. Typical for all samples is the almost total absence of PCDF and the nearly identical congener and isomer distribution throughout all geographies. All the studies provide a strong indication that PCDD/PCDF was formed by natural processes (Rappe, Gordon, Vergin, and Giovannoni, 1999).

2.3.2.2 Primary Sources of PCDD/PCDF

- Industrial-Chemical Processes

Primary sources of environmental contamination with PCDD/PCDF in the past were due to production and use of chloroorganic chemicals, including the pulp and paper industry. In wet-chemical processes the propensity to generate PCDD/PCDF during synthesis of chemical compounds decreases in the following order chlorophenols>chlorobenzenes>aliphatic chlorinated compounds and to inorganic chlorinated compounds (Fiedler, Hutzinger and Timms, 1990; Hutzinger and Fiedler, 1993). Factors favorable for the formation of PCDD/PCDF are high temperatures, alkaline media, presence of UV-light, and presence of radicals in the reaction mixture/ chemical process Hutzinger, and Fiedler, 1993; Hutzinger and Fiedler, 1991).

Emissions of PCDD/PCDF into the environment via water and to soils occur from kraft pulp and paper mills. The USEPA inventory estimates annual emissions from kraft pulp and paper

mills in the range of 20 g I-TEQ. In addition, PCDD/PCDF was detected in the final product (pulp, paper) as well as in the pulp and paper sludge. With advanced bleaching technology, the PCDD/PCDF contamination in effluents, products, and sludge was reduced.

- Thermal Processes

Whereas in the past, the chemical industry and to a lesser extent the pulp and paper industry were considered to be the main source of dioxins and also the cause of today's contaminated sites in many industrialized countries, today's dioxin input is mainly due to thermal processes. The presence of PCDD/PCDF in the emissions and residues from municipal solid waste incinerators were detected first in 1997 in the MSWI in Amsterdam (Olie, Vermeulen and Hutzinger, 1977). Although much research was performed to study the formation of PCDD/PCDF in combustion processes, there is still no clear evidence, which mechanism is dominating and which parameters are important. There is some evidence that both, homogeneous reactions in the gas phase and heterogeneous reactions on surfaces of particles play a role to form these thermodynamically stable compounds (NATO/CCMS, 1988; Hutzinger and Fiedler, 1991). In addition, there are several indications that the mechanisms to generate PCDD/PCDF in the gas phase and in the particle phase are different.

2.3.2.3 Secondary Sources of PCDD/PCDF

Dioxin reservoirs are those matrices where PCDD/PCDF is already present, either in the environment or as products. The PCDD/PCDF found in these reservoirs are not newly generated but concentrated from other sources. A characteristic of the reservoir sources is that they have the potential to allow re-entrainment of PCDD/PCDF into the environment. Product reservoirs include PCP-treated wood, PCB-containing transformers and sewage sludge, compost, and liquid manure, which can be used as fertilizers in agriculture and gardens. Reservoirs in the environment

are, for example, landfills and waste dumps, contaminated soils (mainly from former chemical production or handling sites), and contaminated sediments (especially in harbors and rivers with industries discharging directly to the waterways) (EC, 1999).

2.4 Dioxin Routes of Exposure

- Air

On the basis of ambient air levels reported from Germany, it was concluded that the intake of PCDDs and PCDFs via air is low, amounting in TEQs to 4 pg/person per day (Ahlborg, Brouwer and Fingerhut, 1992). This figure assumed an average ambient air concentration of 0.2 pg/m^3 and a respiration volume of20 m^3 per day in adults. More recent data seem to indicate that the average ambient air concentrations in Europe in TEQs are about 0.1 pg/m^3 (Liebl, Buchen, Ott and Frickle, 1993; König, Theisen, Guther, Leibl and Buchen, 1993; Rappe, 1993; Wevers, De Fre, Van Cleuvanberg and Rymen, 1993; Duarte-Davidson *et al.*, 1994). Similar average figures have also been reported from the United States (USEPA, 1994), while higher figures have been reported from Japan (Sugita, Asada, Yokochi, Ono and Okazawa, 1993). It was also noted that exposure could occur in specific situations ,e.g. contaminated indoor air in houses where pentachlorophenol had been used as a wood preservative (Ahlborg, Brouwer and Fingerhut, 1992).Even higher intakes may occur under specific situations where PCB-treated coated particle boards have been used indoors. On the basis of the analysis by (Balfanz, Fuchs and Kieper, 1993), TEQ intakes of up to 50 pg/day can be estimated. Smoking 20 cigarettes/day could result in an additional TEQ intake of up to 3 pg/day (Ball, Papke and Lis, 1990).

- Drinking-water

Using data from (Rappe, Kjeller and Kulp, 1990) WHO concluded that intake of PCDDs and PCDFs through drinking water is negligible (Ahlborg, Brouwer and Fingerhut, 1992). The limited data available indicated TEQ levels of0.003 pg/litre, which could result in a daily TEQ intake of less than 0.005 pg/person, assuming an average daily water intake of 1.5 liters/day.

- Food

It is generally agreed that the general population currently receives its major exposure to PCDDs and PCDFs through the intake of food. Since PCDDs and PCDFs are lipophilic and accumulate in the food-chain, food of animal origin is the most important source. In general, plants contain only low levels of PCDDs and PCDFs, commonly close to the detection levels for these chemicals. Several studies have analyzed concentrations of PCDDs and PCDFs in a variety of food commodities and calculated the dietary intake. In Germany, independent studies indicated a daily TEQ intake of slightly less than 1.5 pg/kg body weight (bw), with food of animal origin being the most important source (Beck, Marthar and Wittkowski, 1989; Furst, Ftirst and Groebel, 1990). Figures in the same range were found for the United Kingdom (1.8 pg/kg bw per day) and the Netherlands (1.6 pg/kg bw per day) (Theelen, 1991). The calculated dietary TEQ intake in the United States has been estimated to be in the range 1–3pg/kg bw per day USEPA, (1994). Calculations based on data from Norway and Sweden (Svensson, Nilsson and Hansson, 1991; Færden, 1991) indicated a current daily TEQ intake of about 0.7 pg/kg bw based on very recent Norwegian data on levels in food and food consumption (Færden, 1991). Higher daily TEQ intakes of up to 1.6 pg/kg bw were estimated from calculations based on levels of PCDDs and PCDFs in the blood (Johansen, Boice, Mclaughlin and Oslen, 1995; Asplund, Martin and Goran,

1995) and breast milk (Johansen, et al., 1994) from background-exposed individuals in Norway and Sweden. The discrepancy is most probably due to the fact that the calculations based on human levels represent the accumulated intake over many years whereas the food data are very recent and probably mirror a decrease in environmental levels following extensive control of known sources in the Nordic countries.

Local eating habits, e.g. intake of fatty fish from contaminated waters, may significantly increase the daily intake of PCDDs and PCDFs. Thus, Swedish fishermen in the Baltic Sea with a much higher than average intake of herring and salmon were found to have blood levels of PCDDs and PCDFs about three times higher than those in the general population (Svensson, Nilsson and Hansson, 1991). Similarly, extensive consumers of crabs from a contaminated Norwegian fjord system had an intake (calculated as TEQs in pg/kg bw per day), which was 5.4 times that of background-exposed people (Johansen, Boice, Mclaughlin and Oslen, 1995). There may be other population groups with enhanced exposure due to dietary habits.

2.5 Food and Feedstuff Regulations

The Scientific Committee on Food concluded that although dioxin source reduction has been successfully accomplished in many European countries, a considerable proportion of the European population still exceeds the t-TWI. Therefore, further measures are needed to limit environmental releases of PCDD/PCDF and dioxin-like compounds (SCF, 2000).The recent incidents of food and feed contamination have shown that present regulation is not existing or inadequate and a root cause analysis is required to develop appropriate monitoring, prevention and management. Setting feed and food limits alone will not prevent further accidents and there is no way to exclude the possibility of similar incidents to occur in the future unless specific

measures are taken. However, regulatory levels would build the legal basis at least to eliminate products with extraordinary contamination levels from the market (Büchert *et al.*, 2001).

2.6 Human Exposure and Levels of Exposure in Humans

Human exposure to background contamination with PCDD/PCDF is possible via several routes:

- Inhalation of air and intake of particles from air
- Ingestion of contaminated soil
- Dermal absorption
- Food consumption.

In 1990, a WHO working group concluded that 90% of the daily dioxin intake (from background contamination) results from ingestion. Especially, foodstuffs of animal origin are responsible for the daily intake of approximately 2 pg TEQ/(kg bw· d). All other foodstuffs, especially the "non-fatty" ones, are of minor importance in terms of PCDD/PCDF intake. They are either of plant origin or do not have a high potential for bioaccumulation of lipophilic compounds (SCOOP, 2000).

2.6.1 PCDD/PCDF in Humans

The PCDD/PCDF pattern in humans may yield information as to different sources. Also, people from certain geographic regions may have specific patterns because of predominant exposures from different sources, e.g., Europeans have higher 2,3,4,7,8-Cl5DF concentrations compared to U.S. residents (Büchert *et al.*, 2001). Breast milk is a frequently used monitor for human exposure and trends of PCDD/PCDF concentrations have been established in several countries. In cooperation with the German Lander, the Federal Institute for Health Protection and of Consumers and Veterinary Medicine (bgvv) has established a database to compile results for

organochlorine pesticides, PCB, and PCDD/PCDF. However, it has been recognized that subtle effects might already be occurring in the general population in developed countries, at current background levels of exposure to dioxins and dioxin-like compounds and, due to the high persistence of the dioxin-like compounds, the concentrations in the environment, as well as in food, will only decrease slowly. For humans, chronic effects are of greater concern than acute toxicity. Amongst the most sensitive endpoints are reproductive, developmental, immunotoxic and neurotoxic effects. From these results obtained in high-exposure groups, it seems unlikely that clinically observable health effects will be found in the general adult population (Büchert *et al.,* 2001).

2.6.2 Population Groups at Higher Exposures

PCDDs and PCDFs are found in human breast milk at comparatively high concentrations. The infant receiving breast milk as the only or dominating food source will consequently have a much higher intake than adults. Measurements of the concentrations of 2,3,7,8-substitutedcongeners in human milk samples in the WHO-coordinated second round of exposure studies on human milk, in which 19 countries participated, showed that the lowest TEQ levels were found in Albania, Hungary, Pakistan and the less industrialized regions in Croatia, Norway and the Russian Federation 4–10 ng/kg of milk fat (WHO, 1996). The highest TEQ levels, around 20–30 ng/kg of milk fat, were found in samples from Belgium, Canada, Finland, the Netherlands and Spain. These figures are on average about 35% lower than those that were found in the first WHO exposure study (WHO, 1989), although such a decrease could not be observed in all countries.

When the contribution from dioxin-like PCBs is taken into account, the intake for the breastfed infant is about 50–100% higher. However this increase is highly variable from country

to country. The factors determining the levels found in humans include both lifestyle and the degree of industrialization. Monitoring programmes have indicated a declining trend in PCDD/PCDF concentrations in human breast milk during the last 5–15 years, probably reflecting the relatively recent emission control measures (Norén, 1991; Alder, Beck, Mathar and Palvanskas, 1994).

2.6.3 Absorption

Exposure to PCDDs and PCDFs may result from inhalation of contaminated fly ash, dust and soil. Only a few studies have been devoted to the question of bioavailability of PCDDs and PCDFs in connection with the inhalation of contaminated particles. Nevertheless, Nessel *et al.* were able to demonstrate effects on several biomarkers in rats indicating systemic absorption following intratracheal installation or inhalation exposure of TCDD dissolved in corn oil or bound to gallium oxide particles or soil (Nessel, Amoruso, Umbreit and Gallo, 1990; Nessel, Amoruso and Umbreit, 1992). In general, PCDDs and PCDFs adsorbed on combustion or soil particles are less available following oral uptake; a figure of 5–20% has been suggested for PCDDs and PCDFs adsorbed on combustion particles (Van Den Berg, De Jongh, Poiger and Olson, 1994).

2.6.4 Distribution

Liver and adipose tissues are the predominant storage sites of absorbed PCDDs and PCDFs (Van Den Berg, De Jongh, Poiger and Olson, 1994). However, the distribution is highly dose-dependent because of induction of specific binding proteins in the liver, and there are large differences in the distribution pattern between various PCDDs and PCDFs. PCDDs and PCDFs have been shown to cross the placenta.

2.6.5 Metabolism and Excretion

The toxicity of PCDDs and PCDFs is primarily caused by the parent compounds, since metabolites are several orders of magnitude less potent with respect to effects mediated by the Ah receptor (Mason and Safe, 1986). There are clear differences in the kinetic behavior of PCDDs and PCDFs in different species. The whole-body half-life of TCDD in the rat ranges from 17 to 31 days, depending on dose and strain (Piper, Rose and Gehring, 1973; Pohjanvirta, Vartianen, Uusi-Ranva, Monkkonen and Tuomisto, 1990). For humans it is much longer; the plasma half-life has been estimated to be approximately 7 years (Pirkle *et al.*, 1989). PCDDs and PCDFs are also excreted in human milk. Uptake following oral exposure of the most toxic PCDDs and PCDFs in experimental animals is generally in the range 50–90% depending on the vehicle (Van Den Berg, *et al.*, 1994).Uptake of higher chlorinated congeners is much lower because of lower solubility and larger molecular size (Van Den Berg, *et al.* 1994; Birnbaum and Couture, 1988). Absorption of more than 90% has been demonstrated in breastfed infants (Jödicke, Ende, Helge and Neubert, 1992; Mclachlan, 1993).

2.6.6 Health Effects

PCDDs and PCDFs are among the most extensively studied organic chemicals and there are a large number of publications on the toxicological effects of these compounds. Many recent reviews and evaluations are available. WHO has carried out a number of consultations on the subject, and has published several reports on the subject. The most important ones are: an environmental criteria document on PCDDs and PCDFs, reports on levels of PCBs, PCDDs and PCDFs in breast milk (WHO, 1996 and WHO, 1989), a report on the prevention and control of accidental and environmental exposure to PCBs, PCDDs and PCDFs (WHO, 1987) and an assessment of the tolerable daily intake of PCDDs and PCDFs (Ahlborg, Brouwer and Fingerhut, 1992; Van Leeuwen and Younes, 2000).

2.6.7 Effects in Humans

2.6.7.1 Toxicological Effects

Information on effects in humans predominantly comes from high exposure in industrial settings or accidents and intoxication incidents, e.g. the contamination of rice oil with PCBs that contained comparatively high concentrations of PCDFs in Japan and Taiwan in 1968 and1979, respectively. The effects observed are generally in agreement with what could be expected from animal experimentation, although the most typical human effect of high exposure to PCDDs and PCDFs seems to be the dermatological response chloracne. Subtle endocrinological effects, e.g. modulation of thyroid hormone and testosterone levels in plasma, and decreased glucose tolerance and subtle neurological effects have been observed in humans, but their clinical significance is currently unknown (Pluim, Kramer, Van der Slikk, Koppe and Olie, 1993; Huisman, Koopman-Esseboom, Fiedler and Lanting, 1995).

2.6.7.2 Carcinogenic effects

Numerous epidemiological studies have been performed on occupationally or accidentally highly exposed groups. WHO concluded that there is consistent evidence that workers, who were involved in high-level exposure, demonstrated an increased risk of cancer, although the statistical power of these studies is low (Ahlborg, Brouwer and Fingerhut, 1992). Data on high-dose exposure (exhibiting chloracne) were found to demonstrate that for those workers who were observed for a period of 20 years after exposure and beyond, there was a small increased risk (standardized mortality ratio (SMR) 2.01) for the category of "all cancers combined". Several recent epidemiological studies support the association between high levels of dioxin exposure and cancer (Fingerhut, *et al.*, 1991; Bertazzi, Pesatori and Consonni, 1993). The International Agency for Research on Cancer evaluated all available evidence in 1997 and classified 2,3,7,8-TCDD as a

human carcinogen (Group 1). Other polychlorinated dibenzo-*p*-dioxins were not classifiable as to their carcinogenicity for humans (IARC, 1997).

A Working Group for IARC (International Agency for Research on Cancer, Lyon, France) classified 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-Cl4DD or 2,3,7,8- TCDD) as a multi-site carcinogen in animals as well as in humans IARC (1997).For the classification of carcinogenicity in humans, the most important epidemiological studies for the evaluation of 2,3,7,8-Cl4DD are four cohort studies of herbicide manufacturers (one each in the United States and the Netherlands, two in Germany) and for the cohort of residents from Seveso, Italy. The relative risk for all cancers combined in the most highly exposed and longer-latency sub-cohorts are 1.4. In these cohorts, the blood lipid 2,3,7,8-Cl4DD levels estimated to the last time of exposure were 2,000 ng/kg (mean) (up to 32,000 ng/kg) in the United States cohort, of-the-art 434 ng/kg geometric mean (range, 301–3,683 ng/kg) among accident workers in the Dutch cohort, of-the-art 008 ng/kg geometric mean in the group of workers with severe chloracne in the BASF accident cohort in Germany and measurements up to 2,252 ng/kg in the Boehringer cohort in Germany. These calculated blood 2,3,7,8-Cl4DD levels in workers at time of exposure were in the same range as the estimated blood levels in a two-year rat carcinogenicity study. Taking all of the evidence into consideration, the following evaluations were made by IARC in 1997 (IARC, 1997):

- 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (2,3,7,8-Cl4DD) is carcinogenic to humans (Group 1).
- Other polychlorinated dibenzo-*p*-dioxins are not classifiable as to their carcinogenicity to humans (Group 3).
- Dibenzo-*p*-dioxin is not classifiable as to its carcinogenicity to humans (Group 3).

- Polychlorinated dibenzofurans are not classifiable as to their carcinogenicity to humans (Group 3).

In its recent Dioxin Reassessment, US-EPA basically follows the IARC classifications and concludes that "under EPA's current approach, TCDD is best characterized as a "human carcinogen" US-EPA (2000).

2.6.7.3 Toxic Effects in Humans other than Carcinogenicity

In humans, effects associated with exposure to dioxins are mainly observed in accidental and occupational exposure situations. There are a number of cohorts with high exposure to PCDD/PCDF (and PCB), e.g., NIOSH (National Institute of Occupational Health and Safety, USA) and Boehringer occupational studies, veterans of Operation Ranch Hand in Vietnam, residents of Seveso, etc. Seveso residents had high levels of 2,3,7,8-Cl4DD and one effect that has been observed recently were that significantly more girls were born than boys (change in normal sex ratio). Although the number of births was relatively few for seven years post-exposure, the sex ratio is altered; other sites, e.g., Ufa in Russia, have been examined for the effect of 2,3,7,8-Cl4DD exposures on sex ratio with mixed results, but with smaller numbers of offspring (US-EPA, 2000).

Other toxic effects include an increased prevalence of diabetes (Ranch Hands cohort) and increased mortality due to diabetes and cardiovascular diseases have been reported. In children exposed to PCDD/PCDF and/or PCB in the womb, effects on neurodevelopment and neurobehavior (object learning) and effects on thyroid hormone status have been observed at exposures at or near background levels. At higher exposures, children exposed transplacentally to PCDD/PCDF and PCB show skin defects, developmental delays, low birth-weight, behavior disorders, decrease in penile length at puberty, reduced height among girls at puberty and hearing

loss. It is not totally clear to what extent dioxin-like compounds are responsible for these effects, when considering the complex chemical mixtures to which human individuals are exposed (US-EPA, 2000).

2.7 Health Risk Evaluation

In 1990 WHO established a TDI for TCDD at 10 pg/kg bw (Ahlborg, Brouwer and Fingerhut, 1992). This was based on TCDD-induced liver cancer in rats (Kociba *et al.,* 1978) for which the NOAEL was 1 ng/kg bw. Owing to toxicokinetic differences between humans and rats, this corresponded to a daily intake in humans of 100 pg/kg bw, to which value an uncertainty factor of 10 to cover inter individual variation was applied. Since then, new data on hormonal, reproductive and developmental effects at low doses in animal studies (rats and monkeys) have been published. Therefore the WHO European Centre for Environment and Health and the International Programme of Chemical Safety reassessed the health risk of dioxins in 1998 (Van Leeuwen and Younes, 2000).

The consultation concluded that the human data don not lend themselves to be used as the basis for setting a tolerable daily intake (TDI). However, they were considered to constitute an important reference for comparison with a health risk assessment based on animal data. Consequently the TDI was based on animal data. It was further decided that body burdens should be used to scale doses across species. Human daily intakes corresponding with body burdens similar to those associated with lowest adverse effect levels in rats and monkeys could be estimated to be in the range of 14–37 pg/kgbw/day. By applying an uncertainty factor of 10 to this range of LOAELs, a TDI expressed as a range of 1–4 TEQ pg/kg bw was established for dioxins and dioxin-like compounds.

2.8 Bio Monitors

Fish and shellfish were frequently used as bio monitors for the aquatic environment, fish are highly bio accumulative for PCDD/PCDF so that several hundred pg TEQ/g fat were detected in these animals. The concentration of PCDD/PCDF in fish tissue is found to increase up the food web (bio magnification) as a result of the progressive ingestion of contaminated prey (EC, 1999). These concentrations are much higher than those found in terrestrial animals, such as cattle, pig, or chicken (ibid, 1999). Top-predators like sea eagles or guillemots also showed high concentrations of PCDD/PCDF: as an example in Finland, 830 to 66,000 pg TEQ/g fat were found in white-tailed sea eagles. The Swedish Dioxin Database reported a wide range of dioxin concentrations in the blubber of ringed seal: 6.3 to 217 pg TEQ/g fresh weight (ibid, 1999).

Eduljee and Gair, (1996) Analyzed the types of foods which tend to have the highest dioxin concentrations which are dairy products, meat and poultry, eggs, fish and animal fats. Green vegetables, fruits and grains are the types of foods with the lowest dioxin concentrations. Schecter, Cramer and Boggess (1997) measured dioxins in pooled food samples that were collected in 1995 at supermarkets across the U.S. The pooled sample of fresh water fish had the highest level of dioxins (1.43 TEQ1), followed by butter (1.07 TEQ), hotdog/bologna (0.54 TEQ), ocean fish (0.47 TEQ), cheese (0.40 TEQ), beef (0.38 TEQ), eggs (0.34 TEQ), ice cream (0.33 TEQ), chicken(0.32 TEQ), pork (0.32 TEQ), milk (0.12 TEQ), and vegetables, fruits, grains and legumes (0.07 TEQ). A person's intake of dioxins through the diet therefore, depends on the relative intake of foods with high or low levels of contamination and the quantity consumed. Patandin and Dagnelie (1999) investigated the dietary intake of a group of preschool children in the Netherlands and found that dairy products contributed about 50% of their intake of dioxins

and related compounds, while meat/meat products and processed foods contributed about 20% and 25%, respectively (ibid, 1999).

Deposition of airborne dioxins onto plant and soil surfaces, and subsequent ingestion of this contaminated vegetation and soil by food animals, is considered the primary pathway by which dioxins enter the food chain (Fries, 1995). The levels produced in this way are considered background levels. Fish become contaminated due to airborne dioxin deposition into the water and also from contaminated soil or industrial waste washed into rivers and lakes, leading to high sediment concentrations. Inhalation and water pathways are not considered significant sources of exposure for terrestrial animals. Contamination above background levels can occur if animals food products which are adulterated; either by natural or unnatural means, with high concentrations of dioxins.

Soil ingestion by livestock is also a significant source of exposure to dioxins (Fries, 1995b). The use of pasture for ruminants is a factor in the soil pathway, since animals on pasture ingest contaminated soil along with the vegetation. The amount of soil ingested is related inversely to the availability of forage when pasture is the sole source of feed. Soil ingestion is reduced when animals on pasture are given supplemental feed. Cattle confined to dirt lots also consume small amounts of soil that can lead to meat residues. Travis and Hattemer-Frey (1991) predicted that ingestion of contaminated soil should account for 29% and 20% of the total daily intake of dioxins in beef and dairy cattle, respectively. In another model of dioxin concentrations in beef, Lorber, Cleverly and Schaum (1994) found that soil ingestion by beef cattle only explained about 10% of final dioxin concentrations in beef. Soil ingestion is also a possible pathway for contamination in free range poultry and swine raised on pasture or dirt lots.

For terrestrial animals, the intake of vegetation or roughages is considered the most important dioxin exposure factor (Fries 1995a). Ruminants therefore are more vulnerable to dioxin exposure than poultry and swine, as their feed source is predominantly roughage based. Travis and Hattemer-Frey (1991) predicted that ingestion of contaminated grains and forage should account for 70% and 79% of the total daily intake of dioxins in beef and dairy cattle, respectively. Lorber, Clecerly and Schaum (1994) also modeled a concentration of dioxins in beef and found that the consumption of grass/hay/silage/grain explained over 90% of dioxin concentrations in their model. Finishing cattle in feedlots is thought to significantly reduce concentrations of dioxins in beef. This is hypothesized to be due to the feeding of a predominantly grain based diet for several months before slaughter (ibid, 1994).

Livestock may also be exposed to dioxins from pentachlorophenol (PCP) treated wood on production facilities. PCP treated wood was used extensively in animal housing and confinement facilities until its use was restricted by the EPA in 1980 (Fries, Feil and Davison, 1996). A 1977-79 survey of usage patterns of chemically treated wood on Michigan dairy farms indicated that about half of Michigan dairy farms exercised proper usage of treated wood, however about a third had used it improperly on areas such as feed structures, calf pens and rafters (Feil and Larsen,1999) found that the dioxin congener (chemical variations) patterns in beef fat samples were similar, after adjusting for differential congener absorption by animals, to the congener patterns identified in PCP treated wood samples from the facilities housing the animals. Fries, Feil and Davison (1996) concluded that the" frequent use of PCP treated wood, the propensity of animals to lick or chew wood, and the compatibility of congener profiles" suggest that "PCP treated wood may be an important source of residues in animal products in the U.S."

Numerous factors may influence the concentration of dioxins in food animals such as the source of the dioxins (e.g. new emissions vs. recycling in the environment), aerial transport, degree of plant uptake, fate in the soil (half-life), animal uptake via feed and soil ingestion, bioavailability to the animal, and pharmacokinetics. Since ingestion of dioxins in contaminated vegetation and soil is considered the major pathway of exposure for food animals, different feeding practices such as confinement feeding, grazing, and percentage grain fed should have significant effects on actual concentrations of dioxins in animals.

While these factors have been theoretically researched and modeled (as described in the previous section), little epidemiological or controlled research has been done to validate these hypotheses (Feil and Ellis, 1998). Concentrations of dioxins in adipose tissue of cattle at slaughter were investigated in two small surveys, one conducted jointly by the USDA Food Safety Inspection Service (FSIS) and the EPA, and the other conducted by the USDA Agricultural Research Service (ARS) (Feil and Ellis, 1998). In general, the results from both surveys indicated that dioxin concentrations varied considerably among animals. In both surveys, bulls had higher dioxin concentrations than other slaughter animals. Results from the ARS survey suggest that certain geographical areas may generate animals with higher dioxin concentrations.

Locating livestock and poultry operations and cultivating crops used for animal feed away from sources of dioxin emissions may be important in controlling dioxin concentrations in food animals. Lovett, Foxall, Creaser and Chewe (1998) conducted a survey of dioxins in eggs and poultry meat from a site close to a chemical waste incinerator, and several other urban and rural sites in the United Kingdom. Dioxin concentrations in poultry produced from the site closest to the incinerator were higher than concentrations in poultry produced from other sites. There were also variations in the chemical composition of the dioxins associated with their geographic origin.

Ramos, Eljarrat, and Hernandez (1997) compared dioxin concentrations in milk samples from dairy farms in Spain located in rural areas without specific dioxin sources (control farms), to milk from farms in the vicinity of potential dioxin emission sources (case farms), and to pasteurized milk from retail outlets. The milk samples from control farms had only slightly lower concentrations of dioxins than the milk produced near emissions sources. However, the highest concentrations of dioxins were found in samples produced near a waste incinerator and a chemical plant. The lowest levels were found in pasteurized milk samples purchased from retail outlets in Spain and in milk from one of the control farms.

Another potential source of dioxin contamination of the vegetation and soil consumed by animals is the application of sewage sludge to pasture or crops intended for animal consumption. Sewage sludge is contaminated with a complex mixture of organic compounds, including dioxins (Engwall and Hjelm, 2000). In a study of the impact of using sewage sludge to restore degraded land, Molina, Diaz-Ferrero and Coll (2000) found that sewage sludge increased the dioxin concentration in the soils and that the contamination persisted through the one year study period. Engwall and Hjelm (2000) found carrots grown in soil that had sewage sludge applied to it had higher concentrations of dioxins compared to controls; however, concentrations in the parts of the plant which grow above ground were generally low. No studies were found which investigated dioxin levels in soils to which animal manure had been applied.

In Germany, a comprehensive monitoring program of dioxins in food documented a gradual decline of food contamination from 1993 to 1997. Beginning in September 1997, a gradual increase in concentration of specific types of dioxins was noted in milk, butter and meat (beef and veal) samples. After an intensive investigation, the source of contamination was found to be use of dioxin contaminated citrus pulp from Brazil as feed material for ruminants. Feed

containing the contaminated citrus pulp contained 20-100 times more dioxins than background levels. After elimination of the contaminated feed, the dioxin level in milk in Germany decreased. Other European countries also import citrus pulp from Brazil, and in response to the findings of the German investigation, the European Community in1998 set a tolerance limit for dioxins in citrus pulp of 500 pg I-TEQ/kg. The source of the contamination of the citrus pulp was contaminated lime, which is added to the wet peel for neutralization and constitutes about 2% of the dried citrus pulp. Conclusions from the investigation highlight the importance of analyzing high numbers of food samples throughout the year for dioxins in order to detect shifts in trends, including seasonal changes (Malisch, 1994).

Soils are natural sinks for persistent and lipophilic compounds such as PCDD/PCDF, which adsorb to the organic carbon of the soil and, once adsorbed, remain relatively immobile. Soil is a typical accumulating matrix with a long memory; in other words, dioxin inputs received in the past will remain and, due to the very long half-lives of PCDD/PCDF in soils, there is hardly any clearance. Soils can receive inputs of environmental pollutants via different pathways of which the most important are: atmospheric deposition, application of sewage sludge or composts, spills, erosion from nearby contaminated areas.

Within the EU Member States, the largest databases existed for PCDD/PCDF concentrations in soil, at contaminated locations measured concentrations range from several hundred to around100, 000 ng I-TEQ/kg d.m. The highest concentrations were found in Finland at sites contaminated with wood preservatives and the Netherlands close to a scrap car and scrap wire incinerator (EC, 1999; Fiedler, Buckley-Golder, Coleman, King and Petersen, 1999).

The EPA Dioxin Reassessment document estimate mean TEQ values for background urban and rural soils to be 13.4 and 4.1 ng I-TEQ/kg of soil, respectively US-EPA (2000). US-

EPA conducted a study on sediment cores from 11 U.S. lakes/reservoirs (Cleverly *et al.*, 1996). The lakes were located in various geographic locations throughout the United States and were selected to represent background conditions (i. e., no known PCDD/PCDF sources nearby). Based on the most recently deposited sediments, the I-TEQ concentrations ranged from 0.11 ng I-TEQ/kg to 15.6 ngI-TEQ/kg with a mean of 5.3 ng I-TEQ/kg (when concentrations below the limit of quantification were set to one-half the quantification limit) Chandler Lake, an Arctic lake located in North Slope, Alaska, had the lowest concentration, and Canandaigua Lake in New York and Santeetlah Reservoir in North Carolina, both eastern lakes, had the highest concentrations.

Atmospheric concentrations have been determined by parallel sampling in Mississippi when in winter 1995/96 (December 95/January 96) and in summer1996 (June/July 1996) ambient air samples were taken with a high-volume sampler (glass-fiber filter+PUF), deposition samples were taken according to the Bergerhoff method, and pine needles were collected and analyzed (Fiedler *et al.* 1997). The sampling sites represented rural areas in the southern United States; the concentrations at both sampling sites were comparable. The concentrations of PCDD/PCDF, expressed as I-TEQ and as PCDD/PCDF were by a factor of approximately 3 higher in winter than in summer. In the deposition samples, the winter exposure was approximately 4-times higher than in summer in both counties.

In view of the results mentioned above, it should be noted that the present background levels of 2,3,7,8-Cl4DD in human populations (2–3 ng/kg) are 100- to 1,000-times lower than those observed in this rat carcinogenicity study. Evaluation of the relationship between the magnitude of the exposure in experimental systems and the magnitude of the response (i. e., dose-

response relationships) does not permit conclusions to be drawn on the human health risks from background exposures to 2,3,7,8-Cl4DD (IARC,1997).

2.9 Dioxin Inventories in Nigeria

Agriculture is a huge sector of the economy and a significant contributor to Nigeria's UPOPs problem. However, for remediation efforts to be well prepared and effective, a much better understanding of the "problem" with respect to open burning in the agricultural sector must be developed. Reliable data on specific aspects of this problem must be generated – for example, how do UPOPs differ among different types of crops given different types and volumes of crop residue and pesticide use? In Nigeria, there is no standardization for waste categorization and data generation. There is a low level of capacity and training in interpreting waste issues at state and local government levels responsible for waste management. There is an equally low level of experience among waste management professions in how to apply available emission factors for municipal and agricultural waste, and thus quantify and qualify the problem further in Nigeria.

Based on the accessible literature reviewed there is no research carried out on the assessment of dioxin and furan using estimation emission technique using UNEP standard toolkit in Biu Local Government Area of Borno State. Also from the literature reviewed the emission were measured using high gas chromatograph with emission factor of 0.5µg in the developed countries, while for the estimation, emission factor of 30µg was based on the UNEP standard toolkit of 2005 edition.

Table 2: Annual release of Dioxin and Furan in Nigeria

Category	Source	Annual Releases (µg TEQ/a)				
		Air	Water	Land	Product	Residue
1	Waste incineration	4.301	0.000	0.000	0.000	15.852
2	Ferrous and non-ferrous metal production	8.201	0.000	0.000	0.000	12.055
3	Heat and power generation	0.223	0.000	0.000	0.000	6.510
4	Mineral production	10.717	0.000	0.000	0.000	0.000
5	Transportation	8.750	0.000	0.000	0.000	0.000
6	Open burning	2751.783	0.000	2521.427	0.000	0.000
7	Chemicals and consumer goods production	0.007	0.000	0.000	0.000	0.000
8	Miscellaneous	0.001	0.000	0.000	0.000	0.000
9	Disposal	0.000	0.034	0.000	0.000	0.000
10	Potential hotspots	-	-		0.000	0.000
Total		**2783.984**	**0.034**	**2521.427**	**0.000**	**34.417**
Grand Total	**5339.862**					

Source: Nigerian National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants, 2007

CHAPTER THREE: STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This section deals with the background of the study area and methodology. The study area is Biu Local Government Area of Borno State, Nigeria. Also highlighted are the major environmental features, as well as industrial and economic activities and other general land use and human settings that are of relevance to this study. The methodology adopted for this study is organized in parts which are as follows: Types and sources of data used for the study, methods of data collection and methods of data analyses.

3.2 Study Area

3.2.1 Location

Biu Local Government is located in the north east of Nigeria, bounded on the west by the Gongola River valley, on the southwest by the Hawul River valley and on the north by the Lake Chad basin (Onlinenigria, 2003). It is located in the Sahel savannah and covers 5,200 sqkm. Biu Local Government lies between Latitude10°30′N and 11°00′N and Longitude 11°45′E and 12°30′E, because of the broad geographical extent, its physical setting is bound to be varied.

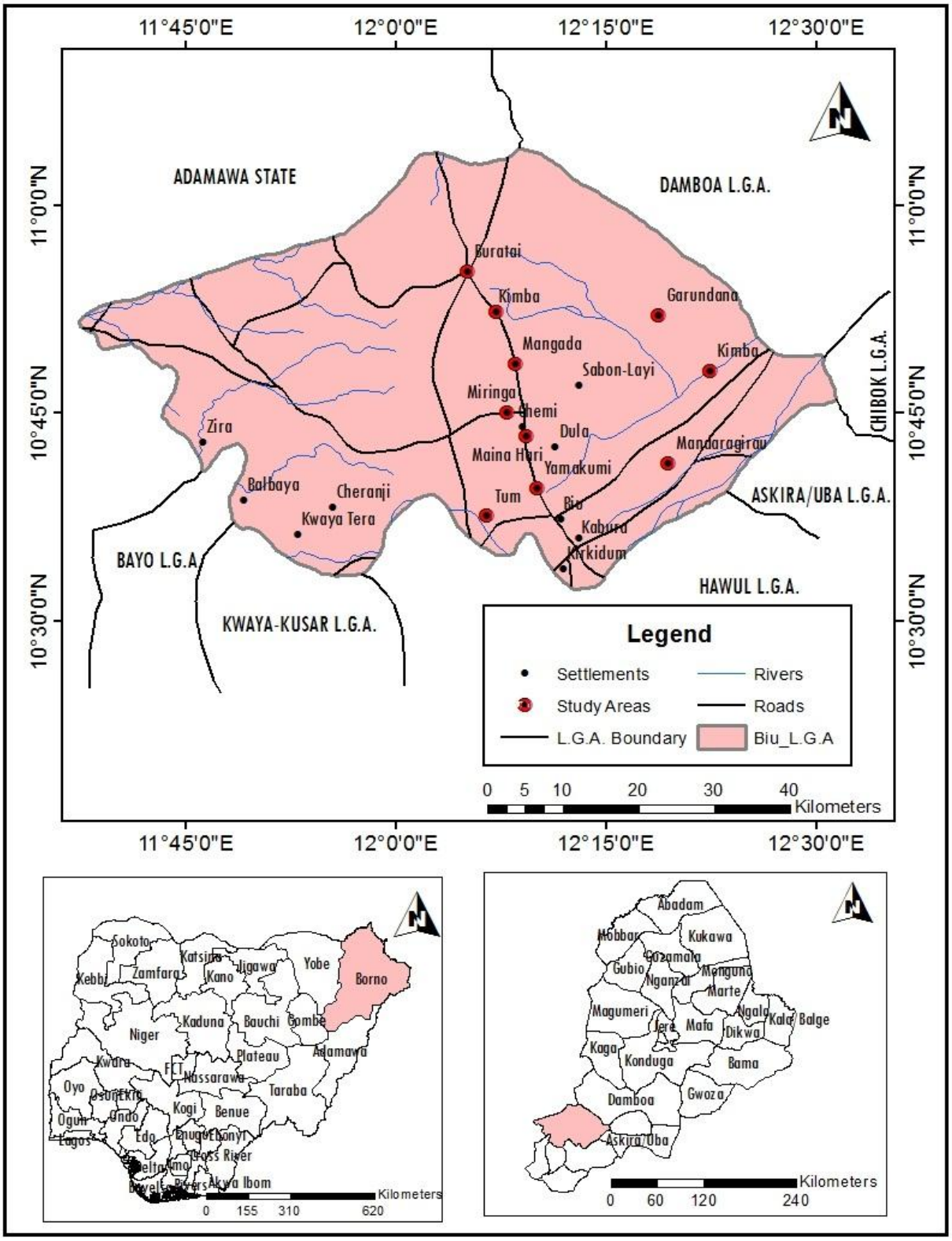


Fig. 2: The Study Area

Source: Modified from the Administrative Map of Borno State.

3.2.2 Climate

Three seasons have been identified: the cool dry (harmattan) season (October-March), hot dry season (April-June) and rainy season (July-September). Temperatures are high all the year round, with hot season temperatures ranging between 39°C and 40°C under the shade. In the southern part of the state, the weather is relatively mild. The rainy season lasts for less than eighty days in the extreme north, but is as high as 140days in the extreme south. The mean annual rainfall is over 800mm on the Biu Plateau but less than 500mm in the extreme north around Lake Chad. A mean altitude of about 650m above sea-level lies in the southeastern part of the region.

3.2.3 Geology and Drainage

The Biu Plateau is a highland area in Southeastern Nigeria containing many recently extinct volcanoes. It covers about 5,200 km^2 and has an average elevation of 700 m. There is evidence of early volcanic activity in the area during the Cretaceous, which ended about 66 million years ago (Taylor and Francis, 1971). However, the plateau was built around the end of the Miocene, and the bulk of the rocks are Pliocenebasalts that have erupted from small vents or fissures, and then spread in a thin layer over wide areas. The plateau includes many small pyroclastic cones caused by explosions when water penetrated downward and came into contact with fresh lava (Obaje and Nuhu, 2009). There are a number of well-preserved volcanic cones rising above the Plateau along a NNW-SSE axis in the Miringa volcanic zone (Online Nigeria, 2011). Biu plateau lies between the Upper Benue Basin to the south and the Chad Basin to the north, the plateau is the source of many tributaries of the Gongola River, which have cut deep gorges. To the north the plateau slopes gently to the Bauchi plains and the Chad Basin (Online Nigeria, 2011).

3.2.4 Relief

High points are Wade Hill at 775 m above sea level and Wiga Hill, at well over 800 m.The Biu plateau touches ground in a rather steep precipitous fashion at the southern end of the "table". Its opposite end evens out less slopingly. The wider ends of the plateau, to the east and west, possess escarpments naturally calibrated in steps. Several feet beneath, as you climb down the steps over the long stretch of land, you emerge into a sub-plateau many miles wide, a western "footstool" to the main Biu plateau. Stretching further along basins and hills, the plateau merges sublimely into the Hawal River, which itself empties into the Gongola and then on to the Benue River, which is the main tributary of River Niger (Taylor and Francis, 1971).

3.2.5 Soil and Vegetation

The predominant soils textures are sandy clay to silty clay are observed in some areas. The land use is arable farming (under the bush fallow/rotation system) and crops grown include maize, guinea corn, millet, groundnut and beans. The area of study is underlain by Basement Complex rocks characterized by outcrops and inselbergs. The oldest member of the rocks in the area is metasedimentary and consists of mostly granulites. The sedimentary rocks are mainly of the post cretaceous sediments and the Jessu Formations (Wright and Allen, 1985).

Several factors influence the distribution of soil types including parent material, climate, topography, organic activity and age. Sandy clay, loam and vertisols with cracking clays that have weathered from shale were identified World Reference Base for Soil Resources (HDOH, 2009).

3.2.6 Population

Principal ethnic group of Biu include the Baburawa, Fulanis, Hausas and other non-indigenous groups, with population of 176,072 according to (2006, census). The inhabitants of the region are mainly Bura, Tera, Marghi, Mina and Fulani people (Encyclopedia Britannica, 2009). Biu Local Government Area has a large number of communities in addition to Biu, which include: Balbaya, Mbulamile, Buratai, Mirnga, Sabon Layi, Tum, Yamarkumi, Zara, Filin Jirgi, Galdimare, Garundana, Kimba, Kogu, Maina Hari, Mandafuma, Mandagirau, Mangada. It is inhabited by the indigenous Hausas and other multi-ethnic groups and the languages spoken are Hausa, Fulani, English, Igbo and Yoruba, with Hausa as the common medium of communication and English language which is the conventional means of communication.

3.2.7 Socio-Economic Activities

The economy of Biu local government area is mixed agricultural based on herding cattle, goats, sheep, horse and donkeys and farming activities which include; Sorghum, Rice, Maize, Cowpea and Cotton. Agriculture consists mostly of small farms using traditional methods. About 70% of the populations in the study area engage in farming. The agricultural activity in the study area can be categorized into arable, tree crop and livestock farming. Crop farming is the main agricultural activity in the area. Crops are produced both during the raining season and the dry season. A lot of farming takes place in the study area where most of the vegetables and fruits supplied to the capital city of Borno are produced. There is a small mining industry in Biu, with iron ore, gravel, magnesite, uranium, feldspar, topaz, mica, granite and salt being extracted (RMRDC, 2011).

3.3 METHODOLOGY

3.3.1 Reconnaissance Survey

A reconnaissance survey and physical field observation of the study area was undertaken, in order to have adequate knowledge of the study area and to also spot assessment of some phenomenon regarding the socio-economic operations in the area.

3.3.2 Types of Data Required

i. Annual mass-harvest for different crop types by defined land area;
ii. Post-harvest waste fraction of different crop types;
iii. Hectares and percentage of land used for particular crops that is subject to a burn-management regime.
iv. Emission factor of agricultural crops residues as selected in the UNEP toolkit.

3.3.3 Sources of Data

3.3.4 Primary Source of Data

Direct field observation and on-site measurement of cultivated hectares and crops waste was done. The study also made use of focus group discussion (FGD) among the farmers in the study area with a view to gather relevant information and data in the field, and it is expected that this technique is to provide valuable information with respect to the research under investigation.

3.3.5 Secondary Source of Data

UNEP standard toolkit was acquired from Federal Ministry of Environment, Abuja in collaboration with United Nation Development Program (UNDP) and Global Environmental found. This was used in identifying the different emission factors of crops that are used in the

study area. Information in the Ministry of Agriculture, Biu local Government of area Borno state was also utilized.

3.3.6 Sampling Design

In selecting the communities to be sampled, purposive sampling technique was employed. This sampling technique is the most ideal in order to accommodate the varying types of agricultural crop residues (waste) in the study area. The reconnaissance survey shows that, not all the communities in Biu local government area produce/cultivate the crop types of interest as selected in the UNEP standard toolkit, thus, the selection covered only the communities that produce/cultivate the crop of interest selected in the study area. The communities selected are 10 out of the total 27 communities which are, Buratai, Miringa, Tum, Yamarkumi, Garundana, Kimba, Maina Hari, Mandafuma, Mandagirau and Mangada.

3.3.7 Data Analysis

The methodology followed is adopted and is in consistent with current international practice (UNEP, 2005), and is based on the emission factor approach. The annual releases from each source was estimated by multiplying an activity statistic by an emission factors: annual release of toxicity equivalent per year (g TEQ/yr-1) = activity (tons year-1) x emission factors (g TEQ/ tonne-1)

Objective 1: Assess the hectares of land under different crop types in Biu L.G.A

This was achieved by measuring the land areas where these crops are cultivated and it was done to ascertain the total area cultivated per year for different crop type per/hectare in the study area.

Objective 2: Quantify (tons and/or volume) of agricultural crop residue generated per crop type in the study area.

Quantification of agricultural residues (waste) was carried out in the farm directly (i.e. on-site) using scale to measure the weight and know the volume of residues generated in the farm per tons/hectares of each crop cultivated in the study area.

Objective 3: Examine the different mechanism of disposing agricultural crop residue/waste

This was achieved by using focus group discussion to know the why these different types of methods are used by the farmers to get rid of their agricultural residues (waste) prior to raining season for cultivation.

Objective 4: Classify the types agricultural residues based on UNEP toolkit

This was also achieved by categorizing the different crop type that has chlorine content under category six (6) of open burning of agricultural residues obtained in the UNEP standard toolkit.

Objective 5: To quantify the PCDD/PCDF emissions from each crop residue selected in Biu LGAs, using well known emission estimation technique

To quantify potential dioxin and furan emission, calculations and quantification of the emissions was done by weighing agricultural crop residues to get the estimated total volume that was used to analyzed using UNEP standard Toolkit (2005 Edition). Dioxin and furan emission factors of 30ug TEQ/t for air, for all agricultural crop residues (on-site) selected in category six (6) of open burning was used for the calculation of dioxin and furan emissions released into Air.

The emission factor of 30µgTEQ/t for agricultural crop residues not impacted will be used and 0.05µg TEQ/t is for agricultural crop residues that is impacted under good conditions that was used for the agricultural crops residues as selected in the UNEP standard Toolkit.

Source strength (dioxin emission per year) = Emission Factor X Activity Rate

i. The PCDD/PCDF emission is expressed in micrograms I-TEQ per year.

ii. Activity rate = the amount of product production in tons or litres per year.

iii. The emission factor for open burning of agricultural solid waste is given as 30 and 10ug TEQ/t for air and land (UNEP, 2005).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results which will be discussed sequentially as obtained from the field survey and focus group discussion of key stakeholders within the agricultural area visited during the process of land preparation before the raining season starts for cultivation and harvesting. This is followed also by the visit of various associations of farmers in the study area. The data presented and discussed in this section is the result of the field survey of potential emissions of dioxin and furan that will be released when a given quantity of the agricultural crop residues of each of the selected crops in the UNEP standard toolkit was burnt in the study area. The result of the study is presented as follows.

4.2 HECTARES OF LAND AND CROP TYPES IN THE STUDY AREA

The study area is characterized by different crop types on large hectares of land. Table 4.1 shows the various farmyards, approximate hectares of land covered and the different crops planted. From Table 4.1 it can be clearly seen that Maina Hari Community has the highest hectare of cultivated land in the communities in the year under study with a total of approximately 163 hectares of cultivated lands under different crop types. Mangada Community is the second with a total land area of about 153 hectares and Buratai has the least hectares of cultivated land. The major crop types cultivated in the study area are Maize, Millet, Sorghum, Rice, Cotton, Cowpea and Sugarcane. These crops constitute the major generators of crop residues in the study area, because most farmers grow them for their food consumption and also serve as the major source of their income due to the fact that most of them are farmers. Most of the lands are hilly which makes it very difficult to farm especially during tillage and planting, but still farmers do engage in

agricultural activities due to the fact that it was the major source of income generation to the communities.

Table 4.1: Hectares of Land and Cultivated Crops in the Study Area

Community	Total Area of Land Cultivated Per Year (Hectare)	Major Crops Planted
Miringa	144	Maize, millet, sorghum, rice, cotton
Tum	141	Maize, millet, sorghum, rice, cotton
Mandafuma	151	Maize, millet, sorghum, rice, cotton
Maina Hari	163	Maize, millet, sorghum, rice, sugarcane
Buratai	122	Maize, millet, sorghum, rice, cowpea
Mandaragirau	142	Maize, millet, sorghum, rice, cowpea
Mangada	153	Maize, millet, sorghum, rice, cowpea
Kimba	140	Maize, millet, sorghum, rice
Yamarkumi	150	Maize, millet, sorghum, rice, cowpea
Garundana	144	Maize, millet, sorghum, rice, cowpea

Source: Author's Field Work, 2014

4.3 QUANTITY OF AGRICULTURAL CROP RESIDUE GENERATED IN THE STUDY AREA

The quantity of agricultural crop residue is the total volume of crop waste generated from remnants obtained during harvesting, crop processing and food processing wastes in a study area (Kwaghe *et al.,* 2011). Table 4.2 below presents the estimated quantity (tons) of crop residue generated in the study area for a year. The total volume of agricultural residue generated in the study area is 564 tons out of which 381 tons were subjected to burning management regime. From the table, it can also be seen that Mandaragirau community generated the highest quantity of agricultural crop residues with 76 tons thereby contributing 13.48% of the total agricultural crop residue. This is because most farming households in the area are commercial farmers responsible for producing most of the food crops in the study area. Maina Hari and Miringa came 2nd and 3rd with 10.99% and 10.46% of agricultural crop residues respectively. Also Mandaragirau generated

the highest amount of residue subjected to a burning having about 13.48% of the total amount of waste burnt in the study area. Likewise, Maina Hari and Miringa came 2nd and 3rd with 10.99% and 10.46% respectively. This indicates that inadequate knowledge of residue reuse value and utilization is one of the major problems facing the people and lack of awareness on health hazards related to agricultural burning activities in those communities makes it very easier for them to burn their waste in the farm.

Table 4.2: Quantity of Agricultural Crop Residue Generated in the Study Area in a Year

Community	Estimated Quantity of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Crop Residue Generated in Relation to other Community (%)	Waste Disposed by Burning in Relation to other Community (%)
Miringa	59	47	10.46	12.36
Tum	56	40	9.93	10.50
Mandafuma	51	28	9.04	7.35
Maina Hari	62	43	10.99	11.29
Buratai	47	30	8.33	7.87
Mandaragirau	76	57	13.48	14.96
Mangada	57	37	10.11	9.71
Kimba	54	40	9.57	10.50
Yamarkumi	50	30	8.87	7.85
Garundana	52	29	9.22	7.61
Total	**564**	**381**	**100**	**100**

Source: Author's Field Work, 2014

The work of Kwaghe *et al.,* (2011) revealed that the estimated quantity or tonnage of agricultural waste for farming households in Jere Local Government area of Borno State is 264 tonnes with crops accounting for 161 tonnes of waste and animals accounting for 103 tonnes of waste. This shows that Biu local government area of Borno state generates more agricultural crop residues when compared with Jere local government area of the same state. Burning is also a predominant waste management option. This agrees with the work of El-Haggar *et al.,* (2004) where the researchers noted that despite the management options available to farmers in most

rural areas, many farmers view the practice of residue utilization as an extra cost with small returns and therefore the best way to get rid of the residues is by dumping, open burning, etc.

4.4 DISPOSAL MECHANISM ADOPTED IN THE STUDY AREA

Agricultural biomass waste converted to energy can substantially displace fossil fuel, reduce emissions of greenhouse gases and provide renewable energy to people in the study area. There are several methods that have been developed for better disposal of agricultural residues. Agricultural crop residues (grass, dry leaves, sugarcane trash, etc.) produced in huge quantities in the study area is not well utilized. The management techniques adopted in the study area are assessed subsequently.

The responses given by the farmers associations contacted on how they manage their farm wastes are presented in Table 4.3. Burning is the predominant management option as seen in the table. Most of the farmers practice mixed farming and they feed their livestock with the straws and stalks. This agrees with the work of El-Haggar *et al* (2004) where the researchers noted that despite the management options available to farmers in most rural areas, many farmers view the practice of residue utilization as an extra cost with small returns and therefore the best way is to get rid of the crop residues by dumping, animal feed and burning etc.

Table 4.3: Means of Disposal of Agricultural Crop Residue in the Study Area

Community	Primary Crop Type	Means of Disposal
Miringa	Maize, Millet, Sorghum	Burning and animal feed
	Rice	Burning and building
	Cotton	Burning
Tum	Maize, Millet, Sorghum	Burning and animal feed
	Rice and cotton	Burning
Mandafuma	Maize, Millet, Sorghum	Burning and animal feed
	Rice	Burning
	Cotton	Nil
Maina Hari	Maize, Millet, Sorghum	Burning and animal feed
	Rice	Burning/Building
	Sugarcane bagasse	Burning
Buratai	Maize	Building, burning and animal feed
	Millet and Sorghum	Burning and animal feed
	Rice	Burning/Building
	Cowpea	Burning
Mandaragirau	Maize	Building, burning and animal feed
	Millet	Burning and animal feed
	Sorghum	Burning and animal feed
	Rice	Burning/Building
	Cowpea	Burning/Animal feed
Mangada	Maize	Building, burning and animal feed
	Millet	Burning and animal feed
	Sorghum	Burning and animal feed
	Rice	Burning/Building
	Cowpea	Burning/Animal feed
Kimba	Maize	Building, burning and animal feed
	Millet and Sorghum	Burning and animal feed
	Rice	Burning/Building
Yamarkumi	Maize	Building, burning and animal feed
	Millet and Sorghum	Burning and animal feed
	Rice	Burning and building
	Cowpea	Animal feed
Garundana	Maize	Building, burning and animal feed
	Millet and Sorghum	Burning and animal feed
	Rice	Nil
	Cowpea	Animal feed

Source: Author's Field Work, 2014

4.5 TYPES OF AGRICULTURAL CROP RESIDUES CATEGORIZED IN THE UNEP STANDARD TOOLKIT

Based on the UNEP standard toolkit 2005 edition, it can be seen that the emission factor of 30µg is for agricultural crop residues that has higher chlorine content selected in the category six (6) of open burning of agricultural crop residues, the 30µg is for crop that impacted with either fertilizer or chemicals during farming. These crops include Maize, Millet, Sorghum, Rice, Sugarcane, Cowpea and Cotton. These residues when burnt, sufficient quantity of potential emissions of pollutant from the combustion process include, nitrogen oxides (NO_x), carbon oxides (CO_x), sulphur dioxide (SO_2), volatile organic compounds (primarily hydro- carbons), nitrogen oxides (NO_x) and dioxins in an uncontrolled condition and low temperature will be released into air when these crop residue are subjected to a burning management regime.

The farmer association visited and focus group conducted attributed that they used chemicals to destroy pest and kill unwanted weed in their farms while the fertilizer are used to enhance soil nutrient which will increase their yield production, but this will also increase the chlorine content of those plant because most of the chemical and fertilizer used are organochlorine. Therefore the crop residues will further become more chlorinated if chemicals are used during planting season and emission factor of 30µg is applied because these agricultural waste are impacted and 4µg for sugarcane as assigned in the UNEP standard toolkit which they belong to category six (6) of open burning of agricultural crops residues.

4.5 QUANTITY OF DIOXIN EMITTED

The main source of dioxins and furans in the environment is combustion of agricultural waste healthcare waste and combustion-related processes (open burning, different kinds of incineration, gasification, rotary kiln furnaces, plasma pyrolysis, etc.). Dioxin releases are estimated in terms of µg I-TEQ per year (micrograms International-Toxic Equivalent per year). The amount of dioxin and furan emitted in each community in the study area is assessed below.

4.5.1 Miringa Community

In Miringa community, the total quantity of potential emissions of dioxin and furan released into air when subjected to burning management regime is 1410µg TEQ/a as shown in table 4.4 below. Maize and rice generated the highest amount of dioxin and furan with the estimated emission value of Maize 480µg TEQ/a, Rice 330µg TEQ/a, Millet have an emission value of 270µg TEQ/a, Sorghum 240µg TEQ/a and Cotton 90µg TEQ/a in the area cultivated. The farmers produced maize and rice in large quantity for commercials and as such more waste also will be generated which are mostly burnt after harvest the target crops to clear the land in preparation for the next planting season.

Table 4.4: Quantity of Potential Dioxin and Furan Emitted in Miringa Community

Crop Type	Estimated Quantity of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furan Emitted (µg TEQ/a)
Maize	19	16	480
Millet	13	9	270
Sorghum	11	8	240
Rice	13	11	330
Cotton	3	3	90
Total	**59**	**47**	**1410**

Source: Author's Field Work, 2014

4.5.2 Tum Community

Estimates of crop residues generated in Tum community, emission factor of 30µg toxicity equivalent in the UNEP standard toolkit was used for agricultural crop, it can be seen from the table below that Rice has potential emission of dioxin and furan of about 390µg TEQ/a, Maize and Sorghum 270µg TEQ/a each, Millet 210µg TEQ/a and Cotton having 60µg TEQ/a of emission when subjected to burning in the study area as shown below in Table 4.5. The total emission potential estimated for the period is 1200µg TEQ/a in the year under study.

Table 4.5: Quantity of Potential Dioxin and Furan Emitted in Tum Community

Crop Type	Estimated Quantity of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furan Emitted (µg TEQ/a)
Maize	13	9	270
Millet	15	7	210
Sorghum	9	9	270
Rice	17	13	390
Cotton	2	2	60
Total	**47**	**40**	**1200**

Source: Author's Field Work, 2014

4.5.3 Mandafuma Community

Table 4.6 shows that in Mandafuma community, Millet has the highest potential of generating dioxin and furan with an emission potential of 300µg TEQ/a, Sorghum is next with 270µg TEQ/a, Maize 150µg TEQ/a and Rice 120µg TEQ/a in the area cultivated. The study indicates that the quantity of Dioxin and Furan released into air was 840µg TEQ/a using the toolkit's emission factor of 30µg TEQ/t, when this results were compared with the work of Alvarado and Gutiérrez (2003) which used the U.S. emission factor of 2ng TEQ/Kg with respect to Dioxin release from burning Agricultural residues a total emission of 442.98g TEQ/year was generated thus, a variation was observed due to the difference in the emission factors used in the two studies.

Table 4.6: Quantity of Dioxin and Furan Emitted in Mandafuma Community

Crop Type	Estimated Quantity Of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	9	5	150
Millet	16	10	300
Sorghum	12	9	270
Rice	14	4	120
Total	**51**	**28**	**840**

Source: Author's Field Work, 2014

4.5.4 Maina Hari Community

The results on table 4.7 below shows the quantity of residues disposed by burning annually and the potential emission of dioxin and furan released into air (µg TEQ/a). Maize has 330µg TEQ/a, Sorghum 240µg TEQ/a, Millet and Rice have 180µg TEQ/a each and sugarcane bagasse 360µg TEQ/a. The potential emission that was released is estimated to be 1290µg TEQ/a when the agricultural crop residues were burnt in Maina Hari community. The communities believed that this burning add more value to the land which by increasing the soil nutrient which also enhance their yield production in some areas than the inorganic fertilizer and it does not require any cost in terms of monetary aspect and they also regard said it is easier to handle than inorganic fertilizer.

Table 4.7: Quantity of Dioxin and Furan Emitted in Maina Hari Community

Crop Type	Estimated Quantity of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	15	11	330
Millet	10	6	180
Sorghum	11	8	240
Rice	10	6	180
Sugarcane Bagasse	16	12	360
Total	**62**	**43**	**1290**

Source: Author's Field Work, 2014

4.5.5 Buratai Community

Table 4.8 below shows the crop type, emission factor of 30µg toxicity equivalent as assigned in the UNEP standard toolkit was used to calculate the quantity of dioxin and furan released annually and the quantity of potential emission released within the study period. Rice has 270µg TEQ/a, Cowpea 240µg TEQ/a, Maize 180µg TEQ/a, Millet 120µg TEQ/a, and Sorghum 90µg TEQ/a of the total emission generated. The total estimate of Dioxin and Furan emission in the area applying the UNEP toolkit emission factor of 30µg was 1290µg TEQ/a, this shares close similarity with the work of Alvarado, Fiedler and Gutiérrez, (2005) where an estimate of 1,163µg TEQ/year of Dioxin release was given using the U.S emission factor of 2ng TEQ/Kg thus, the difference is as a result of the difference in the value assigned to the emission factor used which was 2ng for U.S and 30µg for the value assigned to Nigerian emission factor if the crops are impacted with fertilizer or chemicals during cultivation period.

Table 4.8: Quantity of Dioxin and Furan Emitted in Buratai Community

Crop Type	Estimated Quantity Of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	10	6	180
Millet	9	4	120
Sorghum	7	3	90
Rice	11	9	270
Cowpea	10	8	240
Total	**47**	**30**	**900**

Source: Author's Field Work, 2014

4.5.6 Mandaragirau Community

The total potential emission of dioxin and furan was estimated in year under study from Mandaragirau community, results of table 4.9 below shows the emission factor 30µg toxicity equivalent for the crop types as assigned in the UNEP standard toolkit in category six (6) of open

burning of agricultural crop residues and the potential emission released into air (µg TEQ/a). the crop variation shows that Maize has 540g TEQ/a, Cowpea 360µg TEQ/a, Sorghum 330µg TEQ/a, Millet 270µg TEQ/a, and Rice 210µg TEQ/a. the maize emission is high because most farmers cultivate it in large quantity and this makes it to generate large quantity of crop residues compare with the rest of the crops. This condition was found to be as a result of the use of excessive fertilizers or chemical applications of pesticide during farming have contributed in increasing the concentration of chlorine in the crop residue even after harvesting the target crops, thus, the application of chemicals and fertilizer serve as precursors capable of enhancing the production of dioxin and furan in the selected crop types categorized in the UNEP standard toolkit should the feedstock be burnt at a low temperature of below 250^0C.

Table 4.9: Quantity of Potential Dioxin and Furan Emitted in Mandaragirau Community

Crop Type	Estimated Quantity of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	22	18	540
Millet	15	9	270
Sorghum	13	11	330
Rice	12	7	210
Cowpea	14	12	360
Total	**76**	**57**	**1710**

Source: Author's Field Work, 2014

4.5.7 Mangada Community

Table 4.10 below shows the quantity of potential Dioxin and Furan emitted in Mangada community for the period under study, Sorghum has 330µg TEQ/a, Maize 240µg TEQ/a, Rice 210µg TEQ/a, Cowpea 180µg TEQ/a, and Millet 150µg TEQ/a. From the table, Sorghum generated the highest quantity of dioxin and furan followed by Maize while Millet has the lowest quantity of emission because these crops are produced in large commercial quantity since the community is a major supply point for grains to neighboring villages, city centers and other states

such as Gombe State. Another reason attributed to the high emissions produced is the excessive application of chemical fertilizers with high chlorine content during farming, which implies that large amount of agricultural crop residues were generated. These crop residues constitute a major source of pollution when subjected to a burnt management regime under low temperature.

Table 4.10: Quantity of Potential Dioxin and Furan Emitted in Mangada Community

Crop Type	Estimated Quantity Of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	12	8	240
Millet	8	5	150
Sorghum	15	11	330
Rice	13	7	210
Cowpea	9	6	180
Total	**57**	**37**	**1110**

Source: Author's Field Work, 2014

4.5.8 Kimba Community

Table 4.11 below shows the quantity of crop residue generated in a year and the estimated amount of residues disposed by burning. Emission factor 30µg toxicity equivalent for primary crop types grown in Kimba, were selected in the UNEP standard toolkit of category six of open burning of agricultural residues and the potential emissions of dioxin and furan released into air in (µg TEQ/a), Maize has highest emission of the pollutant which is 390µg TEQ/a, Sorghum 330µg TEQ/a, Millet 270µg TEQ/a, and Rice 210µg TEQ/a. The dioxin and furan generated is due to burning activities in the community where most farmers confirm that burning was the predominant method of clearing their farms before the beginning of rainy season and its cheaper in terms of financial aspect. While others farmer gave their reason as the place were hilly which are very difficult to clear their farm without burning as being the common practice in the community for long time.

Table 4.11: Quantity of Potential Dioxin and Furan Emitted in Kimba Community

Crop Type	Estimated Quantity Of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	17	13	390
Millet	12	9	270
Sorghum	14	11	330
Rice	11	7	210
Total	**54**	**40**	**1200**

Source: Author's Field Work, 2014

4.5.9 Yamarkumi Community

Table 4.12 below shows the emission factor of 30µg toxicity equivalent for primary crop types grown in Yamarkumi, which were selected in the UNEP standard toolkit in category six (6) of open burning of agricultural crop residues and the potential emissions of dioxin and furan released into air in (µg TEQ/a), Maize has 180µg TEQ/a, Millet 150µg TEQ/a, Sorghum 240µg TEQ/a, Rice 210µg TEQ/a, and Cowpea 120µg TEQ/a. The dioxins and furans generated is as a result of inputs of chemicals, fertilizer used that contains chlorine and were used during farming activities, in the selected crop type categorized in UNEP standard toolkit, they save as a precursor capable of enhancing the generation of dioxin and furan emissions in the study area when these residues are burnt under low temperature under uncontrolled condition.

Table 4.12: Quantity of Potential Dioxin and Furan Emitted in Yamarkumi Community

Crop Type	Estimated Quantity Of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	11	6	180
Millet	8	5	150
Sorghum	12	8	240
Rice	10	7	210
Cowpea	9	4	120
Total	**50**	**30**	**900**

Source: Author's Field Work, 2011

4.5.10 Garundana Community

Table 4.13 shows the crop type and crop residues that are generated in community and about 46 tons of agricultural crop residues was generated in the year under study, it further revealed that about 26 tons of these crop residues are disposed to burning in preparation for the next planting season. Agricultural crop residues that has more chlorine contents as assigned in the UNEP standard toolkit in category six (6) of open burning of agricultural residues are generated and the potential emissions of dioxin and furan released into air when subjected to burning management regime generated, with Maize having 300µg TEQ/a, Sorghum 240µg TEQ/a, Millet 180µg TEQ/a and Cowpea 150µg TEQ/a in the total area cultivated whereas rice was not cultivated within the study period. The study revealed that about 870µg TEQ/a estimated emissions of dioxin and furan is generated in Garundana community. Burning of agricultural crop residues in an uncontrolled condition under low temperature of less than 250^{o}C was major method adopted after harvesting and processing of crops in the community surveyed and these will further increase the generation of dioxin and furan.

Table 4.13: Quantity of Potential Dioxin and Furan Emitted in Garundana Community

Crop Type	Estimated Quantity Of Crop Residue (tons)	Estimated Quantity of Waste Disposed by Burning (tons)	Quantity of Dioxin and Furans Emitted (µg TEQ/a)
Maize	12	10	300
Millet	9	6	180
Sorghum	14	8	240
Cowpea	11	5	150
Total	**46**	**29**	**870**

Source: Author's Field Work, 2014

The findings of this study revealed that Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) which are environmental contaminants have potentials to

be emitted in all the communities under study. For alone maize generate 300µg, Sorghum 240µg and Millet 180µg generate the highest emission potential when these residues were burnt. Maize has the highest emission potential because it being grown as the major staple food in all the communities surveyed followed by sorghum and millet. Also all the visited confirm the use pesticide and inorganic fertilizer which increases the chlorine content of these plant and it will also enhance the emission potential of dioxin and furan in the study area. However for clarity of expression and simplicity of data presentation, the crop types and estimated annual emissions of dioxin and furan in the communities are summarized in Fig 4.3 below

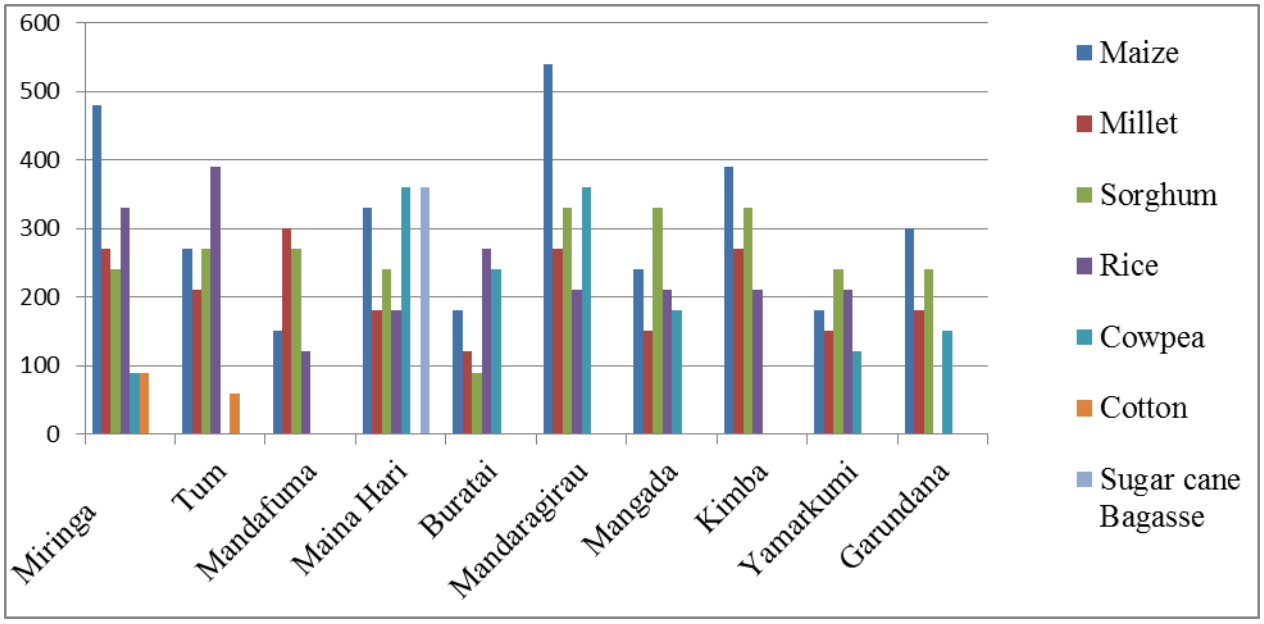


Fig 4.3: Estimated annual emissions of dioxin and furan in the communities
Source: Author's Field Work, 2014

The amounts of agricultural crop residues disposed by burning was calculated from the annual crop residue harvest figures by applying the emission factors of 30µg and 4µg for sugarcane assigned in UNEP standard toolkit that gives the estimate of potential emission of dioxin and furan released from the crop residue available for burning after harvesting the crops and the proportion of cultivated crop areas subjected to burning management regime. For maize the emission potential was 3060µg, Sorghum 2580µg, rice 2130µg and millet 2100µg, TEQ/per

was generated in all the communities surveyed. This showed that maize has highest emission potential followed by sorghum and rice, because they are the predominantly cultivated crops that also exported to some part of the neighbouring state as a source of income to the farmers. Data collected through the field survey also indicated that agricultural waste (residue) burning is one of the major strategy used to get rid of agricultural waste after harvest before the beginning of the raining season. Some farmers also revealed that the residues have multiple uses such as building roofs and walls in their houses; however, as a result of increasing demand of these crop residues for animals fodder it is difficult for some of the villagers to utilize these wastes for other uses.

The focus group discussion, (FGD) conducted revealed that the air around the area is contaminated with the emissions of dioxin and furan released as a result of burning agricultural crop residues in the field, the reason for this is that some of the communities have difficult environmental terrains and poor motorable roads for effective transportation of agricultural products and crop residues from the farmlands where they are cultivated to areas where they are either consumed or put into further use. Hence, it is economically profitable to burn such crop residues after harvest at the farmland as a better alternative of disposal than to attempt moving them out. The farmers in this area believe that with the burning still being practiced, the soil fertility will be improved in preparation for a better crop yield in the next planting season as well as help to destroy or reduce the presence of harmful organisms that might affect crop yield during the farming season. The FGD conducted with the farmers associations showed that most of these associations in the communities are not functional except for a few managed by the communities themselves without any form of support or intervention from government and other non-governmental organizations which was the common practice in the past. The annual quantity of agricultural crop residues generated in these communities is estimated to be 564 generated and

also about 381 tons were the estimated burnt crop residues. All the communities cultivate the crop of interest with the exception of few communities that are not producing some of the crops.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter was based on the summary of the findings, conclusion and recommendations of the study which was carried out during the assessment of potential emissions of dioxin and furan from open burning of agricultural waste in the study area. The summary of the findings, conclusion and recommendations are presented below.

5.2 Summary

The findings of this study shows that agricultural crop residues as selected in the UNEP standard toolkit in category six (6) of open burning of agricultural crop residues are generated in the study area. Maize, Rice, Sorghum, Millet Cotton and Cowpea are the major crops cultivated in the study area, hence these served as the major source of agricultural crop residues in the study area producing a total of about 564 tons, while 381 tons of crop residue are subjected burning in the year under study. The survey also showed a high rate of dioxin and furan emission of about 11,088µg TEQ/a generated from the total 1450 hectares of land, which also affects the health status of the host communities and it will also increase environmental contamination by emitting other harmful gaseous pollutants into the environment due to frequent and uncontrolled activities of burning being practiced in the study area. Although, all the farmers associations contacted through the focused group discussion confirmed that farmers still engaged in poor practice method of managing agricultural crop residues such as open burning, dumping, and sometimes left in the farm to decay without being processed. The farmers reported that lack of awareness on human health hazard and environmental pollution is one of the major challenges facing the study area. They also asserted an increased risk of birth defects and respiratory diseases which were not

known before in these communities are now emerging. The study showed that Maize, Rice and Sorghum were the major contributors to dioxin and furan emissions in the host communities.

5.3 Conclusion

The study has provided a basis for which post-harvest waste in selected farms can be estimated and the type of crops residue on these farms generated can also be utilized. Various management adopted by these farms have been studied and possible suggestions have been proffered on how to curb the menace of these wastes. It is therefore necessary that these wastes are taken care of in view of their increasing magnitude on these farms as the desire for increased agricultural production is achieved through farm mechanization. An inventory of agricultural practices can provide valuable information on the magnitude of agricultural crop residues generated quantity of residues disposed by burning as well as the estimated quantity of emissions from harmful pollutants released into the environment annually.

The selected communities in the study area cultivate the same type of crop except for some few communities that do not grow Cotton and Cowpea. Only one community grows Sugarcane out of the selected communities, most of the agricultural crop residues are left in the farm after harvest and this is either burnt or left to decompose before the raining seasons begins. Finally, this project work only focused on organic agricultural crops residues as selected in the UNEP standard toolkit (2005 edition).

The findings of this research agrees with that contained in most of the literatures consulted, which showed that most farmers still practice open burning of agricultural crop residues generated due to farming activities as a fast, cheap and economically viable means of waste disposal.

The research also conform to the literatures consulted that significant quantity of Dioxin and Furan are generated in the areas where agricultural crop residues are disposed by burning under uncontrolled conditions.

5.4 Recommendations

1. Waste recycling techniques can be used such as biogas production, composting, animal fodder and other recycling methods for agricultural crop residues.
2. Converting agricultural crop residues into animal foodstuff can help a great deal in overcoming some observed cases of deficiency in animal foodstuff in the host communities. Soil conditioner or fertilizer produced from composting and biogas production units can enrich the soil, increase crop yield, decrease the amounts of chemical fertilizer used and close the natural loop that exist.
3. Regulatory agency should focus on the identification and control of environmental airborne sources of pollution resulting from burning activities, which are currently the major origin of food chain contamination.
4. Research on converting agricultural crop residues into energy source such as briquettes (solid fuel) and/or biogas (gaseous fuel) will save a considerable amount of money and to avoid negative environmental impacts and health hazards as a result of the field burning.
5. More research should be carried out especially in collaboration with the United Nation development programme (UNDP) to investigate the effect of dioxins and furans emission in our environment.
6. This type of study should be carried out in all the Nigerian cities in order to thoroughly identify the sources of dioxin and furan emission from open burning and other source that can have adverse effects on the human health and the environment.

7. This type of study in all Nigerian cities will form a basis for the national inventory of UPOPs released into the Nigerian environment in line with Stockholm convention.

5.4.1 Recommendations for Policy Makers

1. Promote public education program, trainings and workshops, revise school curriculum by introducing the 3R concepts in general and agricultural waste management in particular, and reinforce social values for all children and citizens in the society. Initiate education and training program in fostering technical and administrative capabilities to local government and private personnel.
2. Government should monitor State Agricultural Development Programme – State ADP is located in every state, their responsibility is to provide extension services to farmers. A joint Federal and State Government collaborative effort should be encourage, the ADP is a nationwide, unified and all-inclusive extension delivery system in the agricultural field.
3. State and local government Farmers associations should be utilized to serve as the local level institutions through which government aid and assistance is channelled to farmers.
4. Develop regulations and related laws to set up mechanisms for implementing 3R concepts – Reduce, Reuse and Recycle.
5. Improve enforcement capacity of police and judicial stakeholders with respect to UPOPs regulations and by-laws are to be used. Under this activity, magistrates, law enforcement officers, agricultural development programme, NESREA and Federal Ministry of Environment (FMoE), and agricultural extension officers should be trained in UPOPs and the danger they pose to human and ecosystem health. Training will also focus on UPOPs regulations and by-laws developed in activities. Training will focus upon enforcement

capacity and waste management practices that are specific to UPOPs reduction, including how to assess agricultural (waste) residues.

6. This type of research should form part of the basis for agricultural residue reuse planning in our communities in order to minimize the negative perception agricultural crop residues.
7. Encourage research and development projects for suitable technology in coping with the mounting agricultural waste management problems and enhance management efficiency through established academic and research institutes; and the coordination between stakeholders is important.

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AHMADU BELLO UNIVERSITY ZARIA, DEPARTMENT OF GEOGRAPHY
An MSc RESEARCH GUIDE
FOCUS GROUP DISCUSSION: ILLUSTRATIVE GUIDE AND PROBE

Score questions	**Related probe questions**
General questions 1) Do you have any farmers associations? 2) In what ways does the association assist the farmers? 3) How does the farmers benefit? 4) Is there any awareness on the utilization of crop residue? 5) What is your reason for planting this type of crops? 6) Is the government aware of the any association or non-governmental organisations in your community?	Probe for farmers associations. Probe for association assistance Probe for the impact of benefit Probe for residue utilization Probe for planting this type of crop. Probe for government and non-governmental organisations
Farmers questions 1) What type of crops do you plant? 2) How many hectares of land do you cultivate? 3) How do you dispose off your on-site crops residue? 4) Do you know any environmental hazard or pollution cause by crops residue? 5) What are your reasons for disposing these residues in the farm? 6) Do farmers use fertilizer or pesticide?	Probe for planting this crops types. Probe for hectares of land cultivate Probe for how to dispose crops residue Probe for environmental pollution Probe reason for disposing crop residue in the farm Probe for using fertilizer and pesticide