CHARACTERIZATION OF SOLID WASTES AT THE KADUNA POLYTECHNIC, KADUNA

BY

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DECLARATION

I hereby declare that this thesis has been composed by myself and it is an authentic record of my own research work. It has not been accepted in any previous application for a higher degree. All sources of information are specifically acknowledged by means of references.

Aikulola 14-03-96

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CERTIFICATION

This thesis titled "Characterization of Solid Waste at the Polytechnic, Kaduna", by A. O. Aikulola, meets the regulations governing the award of the degree of Master of Science (M.Sc) of Ahmadu Bello University, and is approved for its contribution to Scientific and literary presentation.

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ABSTRACT

The characteristics of the waste generated at the Kaduna Polytechnic was determined on the basis of weight, volume, density, moisture content, and ash content.Also, the composition, calorific value and possible biogas production potential were investigated over a period of six months.

The results show that wastes generated have average weight of 10.20 kg/block/week for the male hostel, 22.97 kg/block/week for the female hostel and 16.48 kg/block/week at the staff houses. The volumes were 0.08 m^3 for the male hostel, 0.11 m^3 for the female hostel and 0.09 m^3 at the staff houses. The per capita waste contribution obtained was 0.31 kg/day.

Other results obtained indicate that average moisture content was 62.2 percent, ash content 91.8 percent while the net calorific value of 1.53 kCal/kg. Generally there was 0.53 percent glass, 0.81 percent rubber and plastics, 2.04 percent metals an cans, 2.15 percent paper and cardboard, 89.55 percent garbage, and 4.86 percent of grass cuttings, leather, textile and others.

A digester charged with garbage, operated for a period of one month, produced an average of 0.08 l/kg/day gas, which was found to be predominantly methane mixed with hydrogen sulphide.

The solid waste collection faacilities at the Polytechnic are grossly inadequate. The operation were ineffective because of manpower and equipment shortages.

CHAPTER ONE

INTRODUCTION

There is a growing solid waste disposal problem world wide, which is gradually approaching crises levels. This trend has gone unchecked for so many years that now, the situation appears to be untractable.

In Nigeria, the solid waste disposal problem is typified by overflowing dust bins, open refuse dumps at virtually every street corner with their attendant odour problems, (especially where burning also occur); and the existence of improperly operated landfills which are often rodent infested and with great potential for ground water pollution.

So far, most of the solutions proffered to solve the problem have at best been short-term in scope and have tended to view the problem as a localised household or institutional problem rather than a regional one.

Nature is endowed with the capacity to dispense, degrade, absorb or otherwise, dispose of wastes in the atmosphere, waterways, oceans, seas and soil. However, according to Eliassen (1969), there is concern (and rightly too), about those residues that may poison ,or damage the environment, or adversely affect species in the biosphere, destabilizing the ecological balance.

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Solutions aimed at addressing the solid waste problem must be based on sound analyses of available information in accordance with set standards which, in Nigeria, are still lacking. Nonetheless, it is important not to base solid waste management decisions on cost-benefit analyses alone, but to consider overall benefits to health, conservation, aesthetics and recreation as well.

The modern Nigerian urban solid waste in characterized by junked cars, electrical appliances, empty cans and bottles and paper or foil wrappings of all sorts. The volumes of these wastes is increasing at a rapid rate because of the desire of consumers to discard old and acquire new items, completely disregarding the concept of recycling. It is necessary to tackle this problem through regional plans for waste management that will provide adequately for collection, processing, recycling, reusing and disposal of solid wastes. Such an integrated plan will go a long way in maximising the scarce resources and, on the long run, stimulate the development of operational organisation in the field of solid waste management. To achieve this, much information is required based on sound research.

1.1 SOLID WASTE MANAGEMENT, THE NIGERIAN SITUATION

In Nigeria, under the Environmental Sanitation edict of 1983 concerning refuse disposal and the recovery of materials, the local government authority is responsible for the collection, transportation, treatment and disposal of solid waste.

Before this, solid waste management had been the responsibility of state establishments, like the Lagos State Waste Disposal Board and the present Public Health Unit of Kaduna State Environmental Protection Agency. On the national scale, this responsibility is vested on the Federal Environmental Protection Agency, which was established on the 30th of December 1988.

According to the French Ministry of Environment (1984), a number of possible service solutions are available to these authorities. These include;

(i) operation under direct supervision

(ii) operation by a company

(iii) contracting the service to private companies.

In Nigeria, a combination of these service options are employed in a bid to solve the solid waste problem. Most of the time, these options have proved inadequate. This is reflected in the unattended heaps of solid waste that litter virtually every street corner, particularly in the urban centres.

1.2 OBJECTIVES AND JUSTIFICATION

The objectives of this study is as follows:

(i) To determine the quantities and compositions of solid wastes generated at the Kaduna Polytechnic.

(ii) To assess the effectiveness of the colection process.

(iii) To recommend an appropriate method of disposing such wastes.

The age of high-tech disposables, which is the current trend in Nigeria drives home the necessity to find a long term solution to an already existing problem. For instance, it is more common to find paper towels, disposable diapers, plastic knives, forks and spoons.(The list is endless), of throwaway conveniences. Nigeria is fast cultivating West European habits that culminate in a throwaway syndrome.

In recent years, developing countries have become the dumping ground for thousands of tons of unwanted wastes. The dumping of toxic waste at Koko in 1988 in Nigeria is a case in point. Also, Awake magazine of September of 1990, reported that Zurich, Switzerland is exporting its surplus garbage to France. Canada, U.S.A., Japan and Australia had found dumping grounds in the "back-yard" of Eastern Europe. Today, barges loaded with thousands of tons of toxic wastes roam the seas looking for a "back-yard" on foreign shores. Therefore it is important to formulate adequate long term measures to manage the solid waste generated today in Nigeria before it reaches a crisis situation like in the developed countries.

SCOPE AND PLAN OF STUDY

This study is confined to the Kaduna Polytechnic within Kaduna Metropolis in Kaduna State, Nigeria. The institution has all the attributes of a community that is ideal for study, towards long term provisions of solutions for solid waste management.

Data was collected at the main campus: College of Science and Technology, Tudun-wada Kaduna. The college consist of the administrative establishment, schools, departments, laboratories, workshops, library, student hostels, staff residences, health centre, cafeteria, kiosks, a chapel, mosques and a sports complex.

The following parameters are to be studied:

i Weight of collected wastes.

ii Volume of collected wastes.

iii Density of collected wastes.

iv The composition of the waste (%)

v Moisture content (%)

vi Volatile solids (%)

vii Biogas volume (l)

The Kaduna Polytechnic main campus was studied by categorizing representative populations based on land use. The following representative sampling populations were used.

i. Main campus: this comprises of students' hostels (male and female), and the surrounding facilities like kiosks, cafeteria, class rooms, offices, library and the health clinic.

ii Staff residences: this comprises of the Panteka-lemu road, and the crescent road complex. The Panteka-lemu road complex is made up of a mixture of two bedroom flats (for junior staff), three bedroom flats (for senior staff) with a detached boys quarters, and four bedroom flats (for

senior staff) also with a detached boys quarters. The crescent road complex is made up of only four bedroom flats (for senior staff) with detached boys quarters.

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL

Public attention has recently been focused on the subject of solid waste,and its associated problems. The issues raised however extend far beyond purely aesthetic concerns. solid waste disposal practice further raises serious issues concerning health and environmental risks.

The American solid waste disposal act of 1965 defines solid wastes as "garbage, refuse and other discarded materials including solid materials resulting from industrial and commercial activities". The term "Solid waste" describes that material which is solid, and arises from animal or human life activities;which is usually discarded as unwanted or useless.The act also defines solid wastes as the heterogenous mass of throwaways from urban communities, as well as the more homogenous accumulations of agricultural, industrial and mineral waste.

Tchobanoglous et. al (1977), identified the following categories of sources:

- Residential
- Commercial
- Municipal
- Industrial
- Open areas

- Treatment plants

Further typical waste generation facilities, activities or locations associated with each of these sources have been presented and are shown in Appendix 1(a)

2.2 DEFINITIONS

The definitions of different solid waste items and classification vary greatly in literature. Consequently, the following definitions are intended to serve only as a guide.

2.2.1 FOOD WASTES

Food wastes, also called garbage are animal, fruit or vegetable residues resulting from the handling, preparation cooking and eating of foods. The most important characteristic of these waste is that they are highly putrescible and will decompose rapidly, especially in warm weather. Often, decomposition will lead to the development of offensive odours. In addition to the amounts of food waste generated at cafeterias and restaurants, large institutional facilities such as hospitals, prisons and facilities associated with the marketing of foods,also contribute to these wastes.

2.2.2 RUBBISH

These consist of combustible and non-combustible solid wastes of house-holds, institutions, commercial activities, etc, excluding food wastes or other highly putrescible materials. Typically, combustible rubbish consist of materials such as paper, cardboard, plastics, textiles, rubber, leather, wood, furniture and garden trimmings. Non-combustible rubbish consist of items like glass crockery, tin cans, aluminium foils, ferrous and other non-ferrous metals and dirt.

2.2.3 ASHES AND RESIDUES

These are materials remaining from the burning of wood, coal, coke and other combustible materials in homes, stores, institutions, industrial and municipal facilities for any purpose. They are normally composed of fine powdery materials, cinders, clinker, and small amounts of burned and partially burned materials.

2.2.4 DEMOLITION AND CONSTRUCTION WASTES.

Wastes deriving from razed buildings and other structures are classified as demolition wastes. That from the construction, remodelling and repairing of individual homes, commercial buildings and other structures are classified as construction wastes. These wastes are often classified as rubbish. The quantities and varieties produced are difficult to estimate, but

they may include dirt, stones, concrete bricks, plaster, lumber, shingles, plumbing and electrical parts.

2.2.5 SPECIAL WASTES

Wastes such as street sweepings, roadside litter, litter from litter containers, catch basin debris, dead animals and abandoned vehicles are classified under this category. Because it is impossible to predict where dead animals and abandoned automobiles will be found, these wastes are often identified as originating from non-specific diffuse sources. This is in contrast to residential sources which also are diffuse, but specific in that the generation of the wastes is a recurring event

2.2.6 TREATMENT PLANT WASTES

The solid and semi-solid wastes from water, waste water and industrial waste treatment facilities are included in this category. The specific characteristics of these materials vary depending on the nature of the treatment process.

2.2.7 AGRICULTURAL WASTES

Wastes and residues resulting from diverse agricultural activities such as planting, harvesting, production of animals for slaughter and operation of feedlots are collectively called agricultural wastes.

2.2.8 HAZARDOUS WASTES

Bass et. al (1990) defined hazardous wastes in terms of ignitability, corrosivity, reactivity and toxicity. Certain house hold products can be considered hazardous because of their toxicity to humans, or because of the harm they can cause to the environment. Chemical, biological, flammable, explosive or radioactive wastes that pose a substantial immediate or potential danger to human, plant or animal life are classified as hazardous. Typically these wastes occur as liquids, but they are often found in the form of gases solids or sludge.

2.3 CHARACTERISTICS OF SOLID WASTES

In order to evaluate alternative equipment needs, systems management programs and plans, it is important to have adequate information on the characteristics of solid wastes.

Tchobanoglous et. al (1977), classified solid wastes according to physical and chemical characteristics. They were of the view that information and data on physical characteristics of solid wastes are important in the selection and operation of equipment and facilities. This is in order to assess the feasibility of resource and energy recovery, and in the analyses and design of disposal facilities.

2.3.1 COMPOSITION

The vairability of solid waste composition with location, the seasons, economic conditions and many other factors are well documented by Shanklin (1991), Omorodion (1990), Brown et. al (1988), Tchobanoglous et. al (1977), Mantel (1975), Klee and Carruth (1970), Bordner et. al (1970) and Shuval (1962). Tchobanoglous et. al presented as shown in appendix 1b, compositions that typically make up most of municipal solid wastes and their relative distribution.

Klee and Carruth (1970) and Swiss Federal Institute for Water Supply,Sewage purification and Water Pollution Control, (EAWAG) (1970) evolved a generalized field method of determining the composition of solid waste. The method is based on common sense and random sampling. It involves the unloading of a representative sample, obtained from a typical daily collection within the study area, in a controlled area of the disposal site. Their study indicated that sample weights of about 100kg will yield good results, when doing a composition study.

2.3.2 MOISTURE CONTENT AND DENSITY

The moisture content of solid wastes is usually expressed as weight of moisture per unit weight of wet or dry materials in percentage. Tchobanoglous et. al (1977) presented typical moisture content data for waste components. This is shown in Appendix 1c.

Also presented, are typical densities of solid wastes in its uncompacted form as discarded. This is shown in Appendix 1d. It was further stressed that moisture content and density date are needed to assess the total mass and volume of water that must be managed.

2.3.3 VOLATILE SOLIDS AND ENERGY VALUE.

In order to evaluate alternative processing and recovery options, Mantel (1975) established the importance of a knowledge of the chemical composition of solid wastes, and stated that solid wastes that are to be used as fuel, needed to be analysed as follows;

(i) Proximate analysis; which include moisture content, volatile matter, ash and fixed carbon.
(ii) Fusing point of ash.
(iii) Ultimate analysis; which include the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur.
(iv) Heating value.

Further more, data on the ultimate analyses could be used to determine the calorific values of the wastes.

Wasmer (1969), described a method that established a relationship between moisture content and volatile solids in a waste with the calorific value. This method is simple and fast because only the moisture content and volatile solids of a waste need be

determined in order to establish the calorific value of such waste.

2.3.4 BIOGAS

Biogas is a relatively high value fuel, formed during anaerobic degradation of organic matter. The production and use of biogas has been known for centuries, and it provides a convenient source of energy that has found successful application in many parts of the world.

Extensive work has been carried out by Taiganides (1980), Yanson and Edewor (1980), Polprasert (1979), Reynolds (1975) and Trevelyan (1975). Most of these studies are centered around animal, forestry and agricultural wastes.

National Engineering Reaserch and Development Centre (1991) and Polprasert (1979) suggested low cost methods of constructing biogas digesters. Barker (1936), Mah et al (1977) and Zehnder and Brick (1979) carried out studies on methane formation, methane oxidation and methane producing bacteria respectively

An important point highlighted by all these studies is that anaerobic digesters must be completely air-tight for the process to proceed. Two basic designs of digesters exist. These are the Indian floating cover digester and Chinese fixed-dome digester.

Notwithstanding the design of the digester, Mah et al (1977) in their study in biogenesis of methane are of the view that gas yield is a function of moisture, volatile solids, fixed solids and the carbon to nitrogen ratio.

Muxi et al (1992) in their study, emphasized the importance of the selection of good inocula to start off anaerobic digesters. They suggested that digested sewage sludge could be very useful.

NERDC (1991) found that a biogas generator with 1000kg feed capacity could produce at $1m^3$ at a pressure slightly over atmospheric pressure. the gas would be sufficient for the cooking requirements of a family of five, and would also produce approximately 1000kg fertilizer.

The French Ministry of Environment (1984) reported that, fermented refuse would yield gas at a rate of 200 m^3 per ton ($0.2m^3/kg$), and that the gas would be composed of methane (40 - 60 %).

Taiganides (1980) observed that animal waste would yield gas at rate of 126 l/kg for poultry waste, 32 l/kg for swine and 161 l/kg for cow dung.

2.4 COLLECTION

The collection of solid wastes in any community is a difficult and complex endeavour. This is because the generation of wastes

vary between residential, commercial and recreational facilities.

According to Mantel (1975), as the generation pattern vary, and the quantity of wastes increases, the logistics associated with collection become more complex.

Quon et. al (1970) reported that collection of solid wastes constitutes about 80% of the total cost of handling solid wastes.

Tchobanoglous et. al (1977) discussed collection of solid wastes under the following

- The type of collection services that are provided.
- The types of collection systems and some of the equipment now in use, as well as associated labour requirements.
- An analysis of collection systems including the component relationship that can be used to quantify collection operations.
- The general methodology involved in setting up of routes
- Some of the more advanced techniques of analysis that can be used to evaluate collection operations.

Quon et. al (1970) in their study, observed that the collection efficiency depends on haul operation, characteristics of equipment used. Some parameters that may affect the collection work efficiency were identified as follows: Age of equipment, number of loaders on a truck, rank of head and population density. The age of truck and rank of load were found to strongly

influence work efficiency. The number of loaders on the truck and population density of the area serviced have little effect.

2.4.1 COLLECTION ROUTES

According to Bordner et al (1970), the layout of collection routes is generally a trial and error process, and there are no fixed rules that can be applied to all situations. Therefore, once equipment and labour requirements have been determined, collection routes may be laid out, so that both workforce and equipment are used effectively. Tchobanoglous et al (1977) and Bordner et al (1970), enumerated some factors that need to be considered when laying out routes. These factors include:

1. Existing policies and regulations related to such items as the point and frequency of collection must be identified.
2. Existing system condition such as crew size and vehicle types must be coordinated
3. Whenever possible, routes should be laid out so that they begin and end near arterial streets, using topographical and physical barriers as routes boundaries.
4. In hilly areas, routes should start at the top of the grade and proceed downhill as the vehicle becomes loaded.
5. Routes should be laid out so that the last container to be collected is located nearest to the disposal site.
6. Wastes generated at traffic-congested locations should be collected as early in the day as possible.

7. Sources at which extremely large quantity of wastes are generated should be serviced during the first part of the day.

8. Scattered pick-up points where small quantities of wastes are generated that receive the same collection frequency should, if possible, be serviced during one trip or on the same day.

2.4.2 LAYOUT OF ROUTES

Steps involved in establishing collection routes, in the view of Tchobanoglous et al (1977), are: Preparation of location maps showing pertinent data and information concerning waste generation sources; data analysis; preliminary layout of routes and the comparison of preliminary routes and subsequent development of balanced routes by trial and error.

2.4.3 OPTIMAL ROUTING

The studies of Quon et al (1970) and Bordner et al (1970), applied the techniques of mathematical simulation to the macro-scale analysis of refuse collection systems. These define the relationship between servicing cost variables and the collection process.

Quon et al used simulation to discriminate between these variables of primary and secondary importance to the collection

system. The effect of the variability of refuse production on overall pick-up and haul efficiencies were investigated.

Bordner et al on the other hand related refuse collection cost and quality of service to crew size, vehicle size, pick-up time, labour and equipment usage. In addition various operational policies like overtime allowance, incentive time, vehicular capacity utilization and crew assignments were investigated.

2.4.4 COLLECTION SYSTEM

Solid waste collection systems could be classified according to the mode of operation, equipment used and the types of wastes collected.

Tchobanoglous et al (1977) classified collection systems into two categories

1. The hauled container systems:- These are collection systems in which containers used for the storage of wastes are hauled to disposal sites, emptied, and returned to either their original location or some other location.
2. The stationary container system:- In these systems, the containers used for storage of wastes remain at the point of generation. Except for occasional short trips to the collection vehicle.

Solid waste collection may be performed by municipal agencies or by private companies under contract. The advantages and

disadvantages of both are documented in Tchobanoglous et al (1977) and Mantel (1975).

Bartone et al (1991) studied private sector provision of solid waste services in four Latin American cities. Their findings substantiate the view that private service provision can be successful in terms of cost containment and quality of service.

2.5 SOLID WASTE DISPOSAL

The problem of waste disposal has always existed for growing and established communities.

Bass et al (1990) reported that the first modern sewage treatment plants were built in the 1880's, it was only in the early 1900's, systems were developed to handle solid wastes. The first sanitary landfill was built in 1916, in an attempt to alleviate the problems that previous disposal methods were fraught with. These problems included problems of rodents, odour, fires, flies and ground and surface water pollution.

According to Testin and Drobny (1970), solid waste is fast assuming the role of a major pollutant. This is because of a number of problem areas associated with traditional methods of disposal, and with an ever increasing amount of wastes being generated.

Open dumping has been stopped in most areas for a variety of reasons like aesthetic considerations and conditions that lead to insect proliferation and water pollution. While properly operated sanitary landfills can overcome these objectionable aspects, lands suitable for landfill near urban areas where most solid waste is generated, is becoming increasingly scarce and costly to obtain. Open dumping, as a traditional disposal method is almost universally outlawed because of the substantial contribution to air pollution involved. Incineration as traditionally practiced is increasing in cost, and pollution effects. As a result it has been prohibited in certain localities due to stringent emission regulations.

The disposal problems is accentuated by, the increasing use of throwaway items and packaging materials and the general increase in affluence that leads to the discard of many items.

Anon (1967) reported that production of solid wastes would reach 231.54 billion kg in 1979.

Tchobanoglous et al (1977) observed that there are only two alternatives for long term handling of solid wastes and residual matter. Disposal on or in the earth's mantle, and disposal at the bottom of the ocean. Disposal by land is by far the most common method in use today. Morgan et al (1962) support this view, but warned that radioactive wastes cannot be indiscriminately cast into open seas; hap-hazardly buried, or partly incinerated the same way as municipal wastes.

Gunnerson et al (1970) reported that present trends indicate that there is an increasing investigation of possibilities of waste disposal at sea.

Tchobanoglous et al (1977) recommended alternative disposal methods. These methods are hog-feeding of garbage; open dumps, sanitary landfills, composting, incineration and recycling or resource recovery and reuse. They stressed that these methods could be useful as an integrated solid waste management method. Few of these would be discussed.

2.5.1 OPEN DUMPS

Because it is simple to just carry wastes to the edge of town and dump them there, open dumps became a common method of disposal for urban communities especially in Nigeria.

Vincenz et al (1970) and Morgan et al (1970) observed that the burning of these dumps was a practice which caused a variety of difficulties. Also the proliferation of rodents mosquitoes, flies, odours and pollution of nearby streams have been persistent problems.

2.5.2 SANITARY LANDFILLS AND CONTROLLED TIPPING

Sanitary landfills are a waste disposal method in which wastes to be disposed of are compacted and covered with a layer of soil

at the end of each day's operation. Mantel (1975) described it as "the engineering burial of solid waste."

Stone and Gupta (1970) reported that the technology of sanitary landfill has been improved by research to determine factors such as: The depth of compacted earth cover required to prevent insects, rodents and other vector infestations; the dangers of leachaetes reaching the ground water; the type and amount of gas production and movement within the soil; the rate of settlement, and many other features have been researched.

Vincenz et al (1970) found that the costs of most landfill disposal operations are lower than that recorded for incineration, and other competing refuse disposal systems. With incineration, for example, the residue must eventually have to be buried in a fill.

Most of the aspects of planning, analysis, design and operation of sanitary landfills are documented in Mantel (1975) and Tchobanoglous et al (1977)

2.5.3 INCINERATION.

This is the burning of solid wastes. One of its advantages, is that it can be carried out relatively close to the centre of a city, thus saving cost. However, efficient incineration requires sufficiently combustible solid wastes and a fairly expensive incineration plant which is reliably operated.

Lisk (1988) found that the environment was contaminated by particulate and gaseous emission containing a variety of chemical pollutants especially heavy metals, and other compounds from incinerators. Scott and Jones (1990) reported the presence of viable bacteria in the exhaust flue of incinerator.

Denison and Silbegeld (1988) studied the risk of municipal waste incineration and found that the central focus of the debate over incineration has shifted from its apparent management advantages to unresolved risk issues. The shift according to them is due to a lack of comprehensive consideration of risk associated with incineration. These authors concluded that incineration is a waste processing, and not a waste disposal technology. Therefore, its products pose substantial management and disposal problems of their own. Consideration of the nature of these products suggests that incineration is ill-suited for the management of municipal waste stream in its entirety.

Scott and Jones (1990) in particular stated that incineration greatly enhances the mobility and the bio-availability of toxic metals present in wastes. They therefore suggested that incineration be viewed as only one component in an integrated solid waste management system.

2.5.4 COMPOSTING

The major alternative to tipping and incineration is composting. Composting converts the organic content of solid waste into

compost. This serves as a soil conditioner to improve the fertility and structure of agricultural soil. Its agricultural value is greater if solid waste is composted together with suitable quantities of night soil or sludge.

Stone (1962) and Shuval (1962) reported that if a market for sale of compost can be developed, composting might eventually prove to be an economic alternative to incineration. also, composting plants would become common when the process and demand for compost become stable.

2.5.5 RECYCLING AND RESOURCE RECOVERY.

The whole process of reclamation, refining or processing redundant products and materials, and converting them into new, perhaps quite different products once more is called recycling and resource recovery.

Omorodion (1990) noted that the sources of reclaimed materials include; old industrial plants; consumer products ranging from old cars to tin cans which have ended their useful life; as well as industrial process scrap, such as metals and plastic cut-offs and chips.

Omorodion (1990), Tchobanoglous et al (1977) and Mantel (1975) noted that paper, plastics, rubber, textiles, glass, ferrous metals, precious metals, organic and inorganic materials are principal recoverable materials contained in municipal solid

wastes. They also stressed the critical consideration of the economics of materials recovery, since it may be possible to separate various components. But there may be no market for them if they do not meet necessary specifications. Omorodion (1990) then observed that to assess the economic or financial viability of any recycling scheme, certain factors that should be considered include:

- Availability of recyclable materials
- End uses for recovered materials
- The cost of other disposal methods.

Finally, recycling schemes should not be viewed in isolation. Instead, they should form part of an integrated waste management programme which should combine two basic policies; waste reduction and resource recovery.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS AND EQUIPTMENT

Materials and equipment used during the study include;

(a) an Elber index-convex steel measuring tape, 3.5m in length. The tape was used for the determination of the dimensions of waste collection containers.

(b) A 12mm diameter mild steel rod, 1.5m long was used to determine the depth of wastes in the container in order to determine volume of wastes collected.

(c) Flat steel and ceramic plates were used for spreading wastes to dry during moisture content determinations, while porcelain petri-dishes were used to ignite the wastes during the determination for volatile solids.

(d) Bagco woven sacks (50 kg capacity) and polythene bags were used for weighing collected wastes, and for storing crude samples. Rubber tubing with 5mm bore were used for connecting the digester and gas chamber during biogas experiments.

(e) Physical balances used to determine weights. A top loading Griffin Model G-25 to weigh up to 100 kg, a Griffin Model

G-500K to weigh up to 2.0 kg and a spring balance model 0-20v for weighing up to 5.0 kg

Small weights were determined by an analytical balance, Mettler PC180, a digital balance with accuracy up to two decimal places.

(f) A Genlab Model OW2-400-010X drying oven was used for drying samples, while ignition of samples was achieved with an Ogawa Seiki Muffled furnace (Model PR-612).

(g) A Phillips Model HR2811 blender was used for size reduction.

(h) Glassware used include the following:

i. Beakers; 1000ml, 500ml and 250ml capacities
ii. Measuring cylinders; 1000ml and 100ml capacities
iii. Burettes (100ml)
iv. Conical flasks (250ml)
v. Pipettes (10ml) and
vi. Glass aspirators.

3.2 METHODS

3.2.1 Method of Sampling

All samples were collected in accordance with the methods of sampling and analysis of solid wastes suggested by the Swiss

Federal Institute forwater supply, sewage purification and Water pollution Control EAWAG (1970). Grab samples were collected from all the students hostels and two staff residential complexes. The students hostels are located in Rima, Shere and Mambilla villages for male students, and in Dalla village for female students. The staff residential complexes are those located at Panteka-lemu road and the Crescent road.

Samples were collected once a week or daily depending on the amount of waste available. This was carried out between the period of January to June 1992. The size of the collected wastes was reduced using a blender. 1.0 to 2.0 kg. Small individual portions of the well mixed and reduced wastes are poured into air-tight polythene bags. These are then used as raw samples for analyses.

3.2.2 WEIGHT VOLUME AND DENSITY DETERMINATIONS

The weights and volumes were determined on site. Weights were determined by emptying contents of waste containers into a pre-weighed fibre-woven sack. This was then hooked on to a spring balance and the weight determined.

Volumes on the other hand were determined by inserting a steel rod into the waste containers to determine the average depth of the wastes, thereby computing the volume of the refuse knowing the cross-sectional area of the containers.

Consequently, the densities of measured waste were computed using the weight-volume-density relationship of Archimedes principle.

3.2.3 MOISTURE CONTENT DETERMINATION

Moisture contents were determined in accordance with methods stipulated by EAWAG (1970). The entire crude sample was weighed, spread thinly on pre-weighed ceramic and/or steel plates. The sample was then dried at 105^{0}C in a ventilated drying oven until the weight was constant. The dried sample was then left to cool for 4 hours, and weighed immediately afterwards.

The moisture content (%) was then computed as follows

$$w(\%) = \frac{N_w - N_d}{N_w} \times 100$$

where W(%) is moisture content of crude sample in weight percent. N_w is Net weight wet and N_d is Net weight dry.

3.2.4 CHARACTERIZATION OF WASTE

The characterization of collected wastes was carried out at the disposal site, where the Kaduna Polytechnic refuse service crew dispose their waste. To determine composition, a typical truck load of waste collected from the institution was off loaded in an isolated area at the disposal site. The load was first quartered, one part was selected for additional quartering until a sample size of about 100 kg was obtained. From this, all components were sorted into six categories as follows:

i. Glass

ii Rubber, plastics, and polythene materials

iii Metal, tins, cans, foil wrappings and associated materials.

iv Paper, cardboard and other related materials.

v Garbage

vi Grass cuttings, leather, textiles and others.

The compositions were then determined as percentages.

3.2.5 VOLATILE SOLIDS DETERMINATION

Volatile solids in the crude samples were determined in accordance with the methods of sampling and analysis of solid wastes EAWAG (1970). 4.0 g of the sample was placed in a porcelain dish that had been pre-weighed; ignited in a muffled furnace and left in the furnace for three hours at a temperature of 600^0C.

The volatile solids (%) was then computed as follows:

$$V_s\,(\%) = \frac{4.0 - N_w}{4.0} \times 100$$

where Vs (%) is volatile solids,

Nw is Net weight and this is equal to; Gross weight ignited - weight of crucible.

3.2.6 CALORIFIC VALUE COMPUTATION

The empirical relation of Wasmer (1969) as sited in EAWAG (1970) was used to compute calorific value. The calorific value (CPn) is given by

$$CPn = Vs(100 - W) \times 44.4 - 6.0W$$

Where Vs is the volatile solids in percentage,
CPn is the calorific value in kCal/kg
W(%) is moiture content of crude samples in weight percent.

3.2.7 BIOGAS GENERATION AND MEASUREMENT

An attempt to generate biogas from the putrecible portion of the sampled solid was made. The digester was the Chinese fixed dome type, in which aspirators were used as digesters and gas chambers. Determination of biogas yield was achieved by using the acid(H_2SO_4 0.1N)displacement method after Fry and Merril (1973) as illustrated in Fig. 3.1

The digestion chamber was charged with moistened garbage of between 1.5 kg and 2.0 kg weight. The charge was innoculated with sewage sludge according to Muxi et. al. (1992) to start off methane production. The charge of garbage was composed in a 40:1 carbon to nitrogen ratio as suggested by Hagerty et. al. (1973).

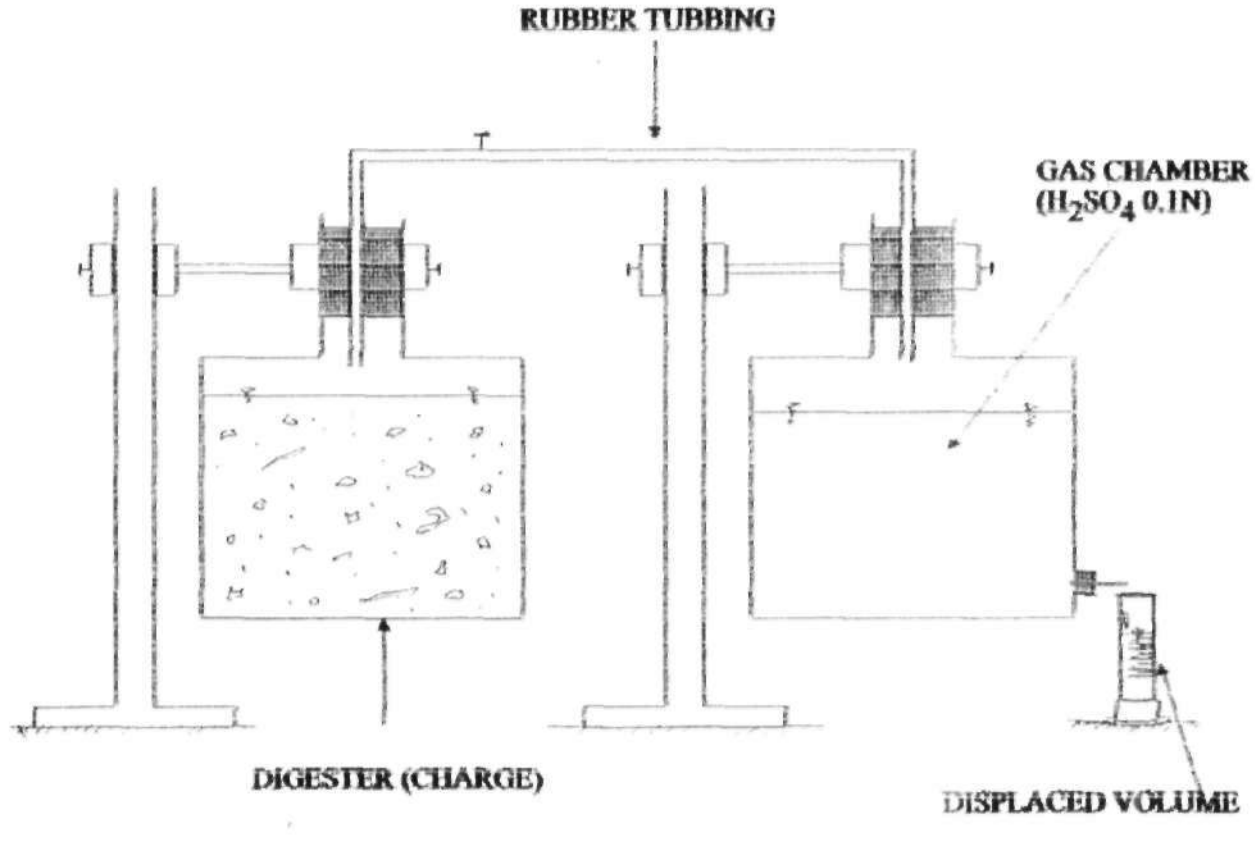


Fig. 3.1: Acid displacement method: Fry and Merril (1973)

3.2.8 BIOGAS TEST PROCEDURE

Institution of Civil Engineers (ICE) (1972) presented a method for testing the presence of methane gas in an environment. The method involves the use of a flame safety lamp of an approved design. This could not be used as the lamp was not available. Alternatively, a simple though crude method was employed. This method involved passing the gas produced through a bunsen burner, and a burning match stick was applied to the emerging gas to verify if the produced gas is flammable. According to ICE (1972) and the French Ministry of Environment (1984), out of the gases that could be produced on the fermentation of refuse, only methane gas is flammable with a blue flame.

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3.3 METHODS OF ANALYZING RESULTS

3.3.1 MASS DIAGRAMS

Mass diagrams, which are plots of total commulative mean weights/volumes of wastes measured against time would be obtained.

According to Nelson (1974) as sited in Tchobanoglous et al (1977) this plot should yield the rate of waste disposal from the slope of the graph. Also the maximum vertical distance between turning points along the plot should yield the amount of waste that need to be handled in weight/volume, i.e. the storage capacity.

3.3.2 STATISTICAL ANALYSES

In order to analyze the data obtained, range, means and 95 percent confidence intervals were computed for these data. Also, analytical empirical expression relating weights of measured wastes to their varying components, using regressional analysis. These are in accordance with the methods of statistical analysis as suggested by Loveday (1977).

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CHAPTER FOUR

RESULTS

4.1 WASTE QUANTITIES IN STUDENTS HOSTELS

4.1.1 Rima village (male)

Table 4.1 shows the weights, volumes and densities of waste for the male hostels at Benue and Gongola halls of Rima village in the Kaduna Polytechnic.

Wastes from Benue hall have weights that ranged between 0.29 kg and 29.5 kg, with an average of 10.7 kg. Corresponding volumes ranged between 0.03 m^3 and 0.25 m^3 with an average of 0.10 m^3. In Gongola hall, the weights ranged between 0.20 kg and 21.30 kg, with an average of 10.30 kg. Volumes ranged between 0.01 and 0.17 m^3 with an average of 0.08 m^3.

Average weight of waste measured for Rima village was therefore 10.50 kg/hall/week, with a corresponding average volume of 0.09 m^3/hall/week.

Densities of the wastes in Benue hall ranged between 6.7 kg/m^3 and 118.0 kg/m^3 with an average of 107 kg/m^3. In Gongola hall, densities of the wastes ranged between 20.0 kg/m^3 and 406.7 kg/m^3 with an average of 128.75 kg/m^3.

Average density of wastes measured in Rima village was therefore 117.9 kg/m^3.

Table 4.1: Weights and volumes of wastes for Rima village - male hostel

Date	Benue Hall			Gongola Hall		
	weight (kg)	volume (m^3)	density (kg/m^3)	weight (kg)	volume (m^3)	density (kg/m^3)
07-01-92	18.00	0.19	94.7	15.70	0.17	92.4
14-01-92	6.80	0.05	136.0	5.10	0.05	102.0
21-01-92	4.60	0.08	57.5	9.10	0.07	130.0
27-01-92	3.60	0.08	45.0	5.90	0.09	65.6
04-02-92	9.70	0.10	97.0	10.20	0.09	113.3
11-02-92	8.90	0.10	89.0	4.10	0.05	82.0
18-02-92	14.50	0.16	90.6	12.80	0.12	106.7
25-02-92	4.00	0.05	80.0	11.20	0.07	160.0
03-03-92	29.50	0.25	118.0	13.80	0.10	138.0
10-03-92	12.50	0.10	125.0	16.10	0.09	178.9
17-03-92	17.00	0.21	81.0	17.80	0.12	148.3
24-03-92	15.70	0.10	157.0	19.70	0.10	197.0
31-03-92	4.80	0.05	96.0	12.20	0.03	406.7
07-04-92	18.90	0.08	236.3	9.10	0.06	151.7
14-04-92	2.20	0.03	73.3	0.60	0.01	60.0
21-04-92	0.20	0.03	6.7	0.20	0.01	20.0
28-04-92	24.40	0.13	187.7	12.10	0.10	121.0
04-05-92	9.50	0.07	135.7	14.70	0.11	133.6
12-05-92	12.80	0.07	182.9	21.30	0.10	213.0
19-05-92	4.30	0.04	107.5	7.90	0.07	112.8
26-05-92	7.20	0.07	102.9	2.50	0.02	125.0
02-06-92	5.30	0.04	132.5	5.40	0.05	108.0
Mean	10.70	0.10	107.0	10.30	0.08	128.8
Range	0.20-29.50	0.03-0.25	6.7-118	0.20-21.30	0.01-0.17	20-406.7

Measured mean waste quantities for Rima village
- weight = 10.50 kg/hall/week
- volume = 0.09 m^3/hall/week
- density = 117.9 kg/m^3/hall/week

4.1.2 Shere village (male)

Table 4.2 shows the weights, volumes and densities of wastes at the male hostels at Abuja and Sokoto halls of Shere village in the Kaduna Polytechnic.

Table 4. 2: Weights and volumes of wastes for Shere village - male hostel

Date	Abuja Hall			Sokoto Hall		
	weight (kg)	volume (m^3)	density (kg/m^3)	weight (kg)	volume (m^3)	density (kg/m^3)
07-01-92	18.70	0.09	207.8	23.70	0.13	182.3
14-01-92	14.60	0.05	292.0	4.70	0.04	117.5
21-01-92	9.20	0.04	230.0	11.90	0.07	170.0
27-01-92	9.30	0.06	155.0	7.70	0.05	154.0
04-02-92	26.70	0.14	190.7	22.10	0.14	157.9
11-02-92	10.20	0.07	145.7	4.90	0.02	245.0
18-02-92	26.90	0.13	206.9	7.90	0.10	79.0
25-02-92	–	–	–	–	–	–
03-03-92	13.80	0.14	98.5	12.80	0.16	80.0
10-03-92	9.10	0.04	227.5	12.40	0.04	310.0
17-03-92	–	–	–	–	–	–
24-03-92	6.30	0.07	90.0	12.10	0.10	121.0
31-03-92	11.70	0.04	292.5	9.30	0.06	155.0
07-04-92	10.70	0.09	118.9	15.10	0.09	167.8
14-04-92	0.70	0.03	23.3	0.60	0.04	15.0
21-04-92	0.30	0.01	30.0	0.20	0.03	6.7
28-04-92	17.10	0.12	142.5	17.20	0.10	172.0
04-05-92	21.10	0.11	191.0	14.80	0.09	164.4
12-05-92	9.00	0.09	100.0	9.30	0.08	116.3
19-05-92	5.90	0.05	118.0	7.10	0.05	142.0
26-05-92	4.90	0.06	81.7	3.30	0.02	165.0
02-06-92	4.80	0.06	80.5	5.90	0.05	118.0
Mean	10.50	0.07	150.0	9.20	0.07	131.4
Range	0.70-26.50	0.01-0.14	23.3-292.5	0.60-23.10	0.02-0.16	6.7-310.0

Measured mean waste quantities for Shere village
- weight = 9.85 kg/hall/week
- volume = 0.07 m^3/hall/week
- density = 104.7 kg/m^3/hall/week

The wastes from Abuja hall have weights that ranged between 0.70 kg and 26.9 kg, with an average of 10.5 kg. Corresponding volumes ranging between 0.01 m^3 and 0.14 m^3 with an average of 0.07 m^3, are shown. In Sokoto hall, the weights ranged between 0.60 kg and 23.70 kg, with an average of 9.20 kg. Volumes ranged between 0.02 and 0.16 m^3 with an average of 0.07 m^3.

Average weight of waste measured for Shere village was therefore 9.85 kg/hall/week, with a corresponding average volume of 0.07 m^3/hall/week.

Densities in Abuja hall ranged between 23.3 kg/m^3 and 292.5 kg/m^3 with an average of 150.0 kg/m^3. In Sokoto hall, densities ranged between 6.7 kg/m^3 and 310.0 kg/m^3 with an average of 131.4 kg/m^3. Average density of wastes measured in Shere village was therefore 140.7 kg/m^3.

4.1.3 Mambilla village (male)

Table 4.3 shows the weights, volumes and densities of wastes at the male hostels (Bendel and Rivers halls) of Mambilla village in the Kaduna Polytechnic.

The wastes from Bendel hall have weights that ranged between 0.20 kg and 32.40 kg, with an average of 9.80 kg. Corresponding volumes ranged between 0.02 m^3 and 0.28 m^3 with an average of 0.07 m^3. In Rivers hall, the weights ranged between 0.20 kg and 32.20 kg, with an average of 10.40 kg. Volumes ranged between 0.01 and 0.19 m^3 with an average of 0.08 m^3.

Average weight of waste measured for Mambilla village was therefore 10.10 kg/hall/week, with a corresponding average volume of 0.08 m^3/hall/week.

Densities in Bendel hall ranged between 20.0 kg/m^3 and 263.0 kg/m^3 with an average of 140.0 kg/m^3. In Rivers hall, densities ranged between 5.0 kg/m^3 and 306.7 kg/m^3 with an average of 130.0 kg/m^3. Average density of wastes measured in Mambilla village was therefore 135.0 kg/m^3.

Table 4.3: Weights and volumes of wastes for Mambilla village - male hostel

Date	Bendel Hall			Rivers Hall		
	weight (kg)	volume (m^3)	density (kg/m^3)	weight (kg)	volume (m^3)	density (kg/m^3)
07-01-92	32.40	0.28	115.7	32.20	0.19	169.5
14-01-92	3.60	0.07	51.4	3.90	0.12	32.5
21-01-92	2.80	0.05	56.0	14.10	0.06	235.0
27-01-92	14.90	0.08	186.3	11.80	0.10	118.0
04-02-92	12.70	0.08	158.8	9.50	0.07	135.7
11-02-92	6.90	0.03	230.0	3.40	0.02	170.0
18-02-92	10.50	0.16	65.6	19.6	0.17	115.3
03-03-92	1.00	0.04	25.0	14.7	0.13	113.1
10-03-92	3.10	0.02	155.0	19.20	0.12	160.0
17-03-92	7.60	0.07	108.6	14.30	0.11	130.0
24-03-92	28.30	0.15	188.7	15.50	0.08	193.8
31-03-92	17.00	0.09	188.8	8.50	0.03	283.3
07-04-92	5.80	0.04	145.0	5.80	0.07	82.9
14-04-92	15.80	0.06	263.0	9.20	0.03	306.7
21-04-92	2.60	0.02	130.0	1.80	0.04	45.0
28-04-92	0.20	0.01	20.0	0.20	0.04	5.0
04-05-92	16.9	0.10	169.0	15.80	0.13	121.5
12-05-92	12.80	0.05	256.0	9.10	0.04	227.5
19-05-92	11.10	0.07	158.5	10.10	0.07	144.3
26-05-92	4.50	0.03	150.0	3.20	0.02	160.0
02-06-92	3.30	0.07	42.8	2.20	0.08	220.0
Mean	9.80	0.07	140.0	10.40	0.08	130.0
Range	0.20-32.40	0.02-0.28	20.0-263.0	0.20-32.20	0.01-0.19	5.0-306.7

Measured mean waste quantities for Mambilla village
- weight = 10.10 kg/hall/week
- volume = 0.08 m^3/hall/week
- density = 135.0 kg/m^3/hall/week

4.1.4 Dalla village (female)

Table 4.4 shows the weights, volumes and densities of wastes at the female hostels at Kwara and Kaduna halls of Dalla village in the Kaduna Polytechnic.

Table 4.4: Weights and volumes of wastes for Dalla village - female hostel

Date	Kwara Hall			Kaduna Hall		
	weights (Kg)	volume (m^3)	density (Kg/m^3)	weight (Kg)	volume (m^3)	density (Kg/m^3)
04-02-92	23.60	0.11	214.5	31.70	0.16	198.1
11-02-92	19.40	0.14	138.6	28.60	0.12	238.3
18-02-92	12.60	0.08	157.5	17.30	0.09	192.2
25-02-92	18.90	0.09	210.0	20.10	0.11	182.7
03-03-92	11.30	0.06	188.3	8.60	0.04	215.0
17-03-92	32.60	0.17	191.8	16.3	0.05	326.0
24-03-92	54.20	0.17	318.8	43.70	0.20	218.5
31-03-92	28.00	0.13	215.4	-	-	-
07-04-92	19.10	0.09	212.2	21.90	0.12	182.5
14-04-92	15.30	0.10	153.0	18.30	0.11	166.4
21-04-92	8.50	0.03	288.3	6.90	0.03	230.0
04-05-92	48.60	0.16	303.8	33.60	0.18	186.7
12-05-92	24.20	0.10	242.0	31.70	0.15	211.3
19-05-92	16.10	0.12	134.2	25.50	0.14	182.1
26-05-92	9.30	0.07	132.9	15.20	0.10	152.0
Mean	22.78	0.11	207.1	21.29	0.11	193.6
Range	8.50-54.20	0.03-0.17	132.9-318.8	6.90-43.70	0.03-0.20	152.0-326.0

Measured mean waste quantities for Rima village
- weight = 22.04 kg/hall/week
- volume = 0.11 m^3/hall/week
- density ≈200 kg/m^3/hall/week

The wastes from Kwara hall have weights that ranged between 8.5 kg and 54.2 kg, with an average of 22.78 kg. Corresponding volumes ranged between 0.03 m^3 and 0.17 m^3 with an average of 0.10 m^3. In Kaduna hall, the weights ranged between 6.7 kg and 43.7 kg, with an average of 21.3 kg. Volumes ranged between 0.03 and 0.20 m^3 with an average of 0.11 m^3. Average weight of waste measured for Dalla village was therefore 22.0 kg/hall/week, with a corresponding average volume of 0.11 m^3/hall/week.

Densities in Kwara hall ranged between 132.9 kg/m^3 and 318.8 kg/m^3 with an average of 207.1 kg/m^3. In Kaduna hall, densities ranged between 152.0 kg/m^3 and 326.0 kg/m^3 with an average of 193.6 kg/m^3. Average density of wastes measured in Dalla village was therefore 200.0 kg/m^3.

4.2.1 STAFF RESIDENCES AT PANTEKA-LEMU ROAD COMPLEX

Table 4.5 shows the weights and volumes of wastes at staff residences at blocks A_3, A_4, B_{13} and B_{20}, at the panteka-lemu road complex in the Kaduna Polytechnic. The quantities of wastes were between 2.8 kg and 43.6 kg with an average of 16.48 kg/block/week. The corresponding volumes for these blocks were between 0.01 m^3 and 0.25 m^3, with an average of 0.9 m^3/block/week.

The densities of wastes from these blocks were between 76.0 kg/m^3 and 925.0 kg/m^3 with an average of 209.9 kg/m^3 (Table 4.6).

Table 4.5: Weights and volumes of wastes for staff residence - (Panteka-Lemu road complex)

Date	A_5		A_1		B_{11}		B_{20}	
	wt (kg)	vol. (m^3)	wt (kg)	vol. (m^3)	wt (kg)	vol. (m^3)	wt (kg)	vol. (m^3)
08-01-92	10.80	0.05	7.60	0.01	12.50	0.07	16.20	0.16
15-01-92	17.20	0.16	10.30	0.01	15.10	0.11	12.60	0.09
22-01-92	7.80	0.05	15.70	0.01	18.20	0.20	18.70	0.23
28-01-92	23.60	0.14	30.10	0.16	21.20	0.16	32.60	0.21
05-02-92	20.10	0.15	22.60	0.05	15.30	0.08	17.40	0.08
12-02-92	15.20	0.09	12.80	0.02	17.70	0.11	11.20	0.06
19-02-92	11.50	0.06	5.60	0.01	13.20	0.07	12.40	0.05
26-02-92	10.60	0.04	6.30	0.01	9.80	0.03	13.10	0.04
04-03-92	28.60	0.24	33.90	0.28	26.50	0.20	28.20	0.16
11-03-92	19.20	0.07	16.50	0.02	14.30	0.06	12.80	0.06
18-03-92	12.50	0.06	8.60	0.01	-	-	15.30	0.08
25-03-92	31.60	0.25	21.80	0.06	17.60	0.08	11.90	0.04
04-04-92	28.10	0.20	17.90	0.04	14.30	0.04	29.30	0.18
08-04-92	16.40	0.07	8.30	0.01	11.40	0.04	19.90	0.11
15-04-92	7.60	0.04	19.70	0.02	16.70	0.06	4.80	0.01
22-04-92	10.30	0.03	15.10	0.04	11.50	0.04	26.40	0.14
29-04-92	43.60	0.29	28.90	0.09	10.80	0.05	18.60	0.07
05-05-92	11.80	0.05	17.60	0.02	27.60	0.14	21.80	0.11
13-05-92	18.20	0.09	8.50	0.01	2.80	0.01	11.50	0.05
MEAN	18.14	0.11	16.20	0.05	13.97	0.08	17.62	0.10
RANGE	7.60-43.60	0.03-0.25	5.60-33.90	0.01-0.09	2.80-27.60	0.01-0.20	4.80-28.20	0.01-0.23

Measured mean waste quantities for Panteka-Lemu road
- weight = 16.48 kg/block/week
- volume = 0.09 m^3/block/week

Table 4.6: Densities of wastes for Staff Residence (Panteka-Lemu Road complex)

Date	A_1 ρ (kg/m^3)	A_4 ρ (kg/m^3)	B_{13} ρ (kg/m^3)	B_{20} ρ (kg/m^3)
08-10-92	216.0	76.0	178.6	101.3
15-01-92	107.5	103.0	137.3	140.0
22-01-92	156.0	157.0	91.0	81.3
28-01-92	168.6	188.1	132.5	155.2
05-02-92	134.0	452.0	191.3	217.5
12-02-92	168.9	640.0	160.9	186.7
19-02-92	191.7	560.0	188.6	248.0
26-02-92	265.0	630.0	326.7	327.5
04-03-92	119.2	121.1	132.5	176.3
11-03-92	274.3	825.0	238.3	213.3
18-03-92	208.3	860.0	-	191.3
25-03-92	126.4	363.3	220.0	297.5
04-04-92	140.5	447.5	357.5	162.8
08-04-92	234.3	830.0	285.0	180.9
15-04-92	190.0	925.0	278.3	480.0
22-04-92	343.3	377.5	287.5	188.6
29-04-92	150.3	321.0	216.0	265.7
05-05-92	236.0	860.0	197.1	198.2
13-05-92	202.0	850.0	280.0	230.0
MEAN	164.9	324.0	174.6	176.2
RANGE	107.5 - 343.3	76.0 - 925.0	91.0 - 357.5	81.3 - 480.0

Measured mean waste quantities for Panteka-Lemu road
- density = 209.9 kg/m^3/block/week

4.2.2 Crescent road complex

At the crescent road complex, waste quantities for blocks 12, 18, 20, 21, 26 and 38 were between 2.10 kg and 38.50 kg, with an average of 17.48 kg/block/week (Table 4.7). The corresponding volumes for these blocks were between 0.01 m^3 and 0.33 m^3, with an average of 0.07 m^3/block/week.

Table 4.7: Weights and volumes of wastes for staff residence (Crescent road complex)

Date	12CR		26CR		18CR		20CR		21CR		38CR	
	wt(kg)	vol.(m^3)	wt(kg)	vol.(m^3)	wt(kg)	vol.(m^3)	wt(kg)	vol.(m^3)	wt(kg)	vol.(m^3)	wt(kg)	vol.(m^3)
08-01-92	5.70	0.01	11.30	0.02	12.00	0.04	18.60	0.12	9.70	0.05	21.20	0.04
15-01-92	11.80	0.02	18.10	0.02	17.10	0.14	21.50	0.07	11.60	0.07	24.50	0.07
22-01-92	15.60	0.01	11.70	0.01	12.20	0.06	16.50	0.11	15.20	0.11	20.60	0.05
28-01-92	28.90	0.05	25.60	0.08	23.20	0.06	35.60	0.16	27.80	0.23	38.30	0.11
05-02-92	19.40	0.06	16.70	0.02	15.10	0.08	11.30	0.03	18.20	0.08	22.30	0.05
12-02-92	10.50	0.02	15.00	0.03	14.60	0.06	16.20	0.04	11.40	0.06	18.80	0.05
19-02-92	11.10	0.04	7.60	0.01	4.20	0.01	15.40	0.04	12.20	0.04	15.20	0.01
26-02-92	8.30	0.03	10.30	0.01	8.90	0.01	12.20	0.04	15.70	0.06	17.30	0.01
04-03-92	31.40	0.33	27.20	0.04	28.30	0.16	35.10	0.31	22.80	0.07	31.60	0.07
11-03-92	17.60	0.05	20.41	0.05	22.10	0.17	15.70	0.05	18.50	0.06	21.40	0.03
18-03-92	10.10	0.03	4.10	0.02	12.80	0.06	17.90	0.07	11.60	0.04	-	-
25-03-92	7.30	0.03	9.20	0.01	10.20	0.04	11.30	0.04	10.50	0.04	17.60	0.04
04-04-92	18.90	0.10	12.80	0.02	15.60	0.07	31.70	0.25	27.50	0.24	24.50	0.05
08-04-92	26.70	0.21	18.91	0.04	21.90	0.09	26.40	0.21	23.00	0.18	19.80	0.02
15-04-92	11.10	0.02	22.40	0.06	28.20	0.14	18.20	0.07	15.40	0.04	11.40	0.04
22-04-92	13.70	0.05	17.60	0.03	19.80	0.09	12.90	0.04	17.80	0.08	29.90	0.10
29-04-92	14.30	0.10	26.70	0.07	23.10	0.12	27.70	0.19	21.90	0.16	38.50	0.11
05-05-92	17.60	0.07	12.10	0.02	16.20	0.05	15.50	0.08	12.70	0.04	19.78	0.02
13-05-92	18.20	0.07	2.10	0.00	12.40	0.04	11.70	0.06	5.40	0.01	15.60	0.04
MEAN	15.90	0.07	15.40	0.03	16.70	0.08	19.50	0.10	16.30	0.09	21.10	0.05
RANGE	5.70 - 31.40	0.01 - 0.33	2.10 - 27.20	0.01 - 0.08	4.20 - 28.30	0.01 - 0.17	11.30 - 35.60	0.03 - 0.31	5.40 - 27.80	0.01 - 0.24	11.40 - 38.50	0.01 - 0.11

Measured mean waste quantities for Crescent road
- weight = 17.48 kg/block/week
- volume = 0.07 m^3/block/week

Table 4.8: shows the densities of wastes from the blocks at the crescent road complex. These were between 21.0 kg/m^3 and 920.0 kg/m^3 with an average of 249.7 kg/m^3

Table 4.8: Densities of wastes for staff residence (Crescent road complex)

Date	12CR (kg/m^3)	18CR (kg/m^3)	20CR (kg/m^3)	21CR (kg/m^3)	26CR (kg/m^3)	38CR (kg/m^3)
08-01-92	570.0	300.0	155.0	194.0	565.0	530.0
15-01-92	590.0	122.1	307.1	165.7	905.0	350.0
22-01-92	156.0	203.0	150.0	138.2	117.0	412.0
28-01-92	578.0	386.7	222.5	120.9	320.0	348.2
05-02-92	323.3	188.8	376.7	227.5	835.0	446.0
12-02-92	525.0	243.3	405.0	190.0	500.0	376.0
19-02-92	277.5	420.0	385.0	305.0	760.0	380.0
26-02-92	276.7	890.0	305.0	261.7	103.0	432.0
04-03-92	95.2	176.9	113.2	325.7	680.0	451.4
11-03-92	352.0	130.0	314.0	308.3	408.0	713.3
18-03-92	336.7	213.3	255.7	290.0	205.0	-
25-03-92	243.3	255.0	282.5	262.5	920.0	440.0
04-04-92	189.0	222.9	126.8	114.6	640.0	490.0
08-04-92	127.4	243.3	125.7	127.8	472.5	660.0
15-04-92	555.0	201.4	260.0	385.0	373.0	285.0
22-04-92	274.0	220.0	322.5	222.5	586.7	299.0
29-04-92	143.0	192.5	145.8	136.9	381.4	350.0
05-05-92	251.4	324.0	193.8	317.5	605.0	659.0
13-05-92	260.0	310.0	195.0	540.0	21.0	390.0
MEAN	227.0	208.8	195.0	181.1	513.3	422.0
RANGE	95.2-590.0	122.1-890.0	113.2-405.0	120.9-385.0	21.0-920.0	285.0-713.3

Measured mean waste quantities for Crescent road density =249 kg/m^3/block/week

4.3 COMPOSITION OF WASTES

Table 4.9 shows the compositions of wastes that were determined from sample weights that ranged between 114.8 kg and 327.4 kg, with an average of 209.5 kg. These wastes averagely consist of; glass 0.53 percent, rubber, plastics and polythene materials 0.81 percent, metals, tins and cans 2.04 percent, paper, cardboard and other related materials 2.15 percent, garbage 89.65 percent, grass cuttings, leather, textile and others 4.86 percent.

Table 4.9: Percentage composition of wastes by weight

No	Glass (%)	Rubber plastic & Polythene (%)	Metals Tins & Cans (%)	Paper & Cardboard (%)	Gabbage (%)	Grass cuttings & others (%)	Total (%)
1	0.91	0.43	1.01	2.40	91.79	3.47	100
2	0.22	0.45	6.99	1.05	80.60	10.69	100
3	0.13	0.39	1.76	0.85	93.75	3.13	100
4	0.00	1.20	2.39	3.72	87.22	5.48	100
5	0.86	2.02	0.58	2.47	90.62	3.45	100
6	0.09	0.26	0.96	1.66	93.73	3.31	100
7	1.48	0.74	1.09	2.96	86.29	7.44	100
8	0.63	0.71	1.10	2.51	93.03	2.04	100
9	0.44	1.13	2.48	2.15	89.55	4.86	100
M	0.53	0.81	2.04	2.15	89.55	4.86	100
R	0 - 1.481	0.26-2.02	0.58-6.99	0.85-3.72	80.60-93.75	2.04-10.69	

4.4 MOISTURE CONTENT, VOLATILE SOLIDS AND CALORIFIC VALUE OF WASTES

In the Kaduna Polytechnic, wastes had between 51.5 percent and 67.4 percent moisture content, with an average of 62.2 percent (Table 4.10).

Table 4.10: Moisture and calorific value of wastes

S.No.	Sample weight (g)			Water (%)	Vs (%)	Calorific Power (kCal/kg)
	wet	dry	ashed			
1	52.0	18.0	4.0	65.4	92.3	1.4
2	41.0	16.0	3.0	60.9	92.7	1.6
3	86.0	34.0	7.0	60.5	91.8	1.6
4	60.0	23.0	6.0	61.7	90.0	1.5
5	107.0	45.0	9.0	57.9	91.6	1.7
6	50.0	17.4	3.8	65.2	92.4	1.4
7	50.0	17.3	4.0	65.4	92.0	1.4
8	58.0	20.6	5.9	65.5	89.8	1.4
9	45.0	16.5	3.2	63.3	92.8	1.5
10	57.0	18.6	4.4	67.4	92.3	1.3
11	90.0	35.0	7.6	61.1	91.6	1.6
12	50.0	17.0	3.8	66.0	92.4	1.4
13	103.0	50.0	8.0	51.5	92.2	2.0
14	80.0	32.0	6.7	60.0	91.6	1.6
Mean	66.4	25.7	5.5	62.2	91.8	1.5
Range	41.0-107.0	16.0-45.0	3.0-9.0	51.5-67.4	89.8-92.8	1.3-2.0

Measured average water content (w) = 62.2%
Measured average volatile solids (Vs) = 91.8%
Measured average calorific power (CPn) = 1.5 kCal/kg.

The wastes also had volatile solids of between 89.8 percent and 92.8 percent, with an average of 91.8 percent (Table 4.10). From these, the calorific value of wastes obtained were between 1.3 kCal/kg and 2.0 kCal/kg, with an average of 1.5 kCal/kg.

4.5 BIOGAS YIELD

Table 4.11 shows the biogas yield from a garbage charged digester, whose composition is 2.0 kg of carbon based garbage like yam peelings and green vegetables, and 0.05 kg of nitrogenous compounds of garbage like beans, fish and meat. The table also shows the ambient temperatures at which the digester was operated.

The quantities of gas produced in a day range in volumes between 0.03 l and 0.28 l, with an average yield of 0.08 l. Corresponding temperatures are between 25^0C and 36.5^0C.

From the results obtained, it was observed that gas production rate was high at the on set. High gas yields of between 0.28 l and 0.1 l were recorded during the first week of starting the digester. The yield then progressively reduced, and subsequently stabilized at between 0.06 l and 0.03 l per day.

Also, the results show that the gas production rate bears a significant relationship to the ambient temperature at which the digester was operated. For instance, on days that high temperatures were recorded, higher rates of gas production were recorded as against days when lower temperatures were recorded.

The gas produced was tested by passing it over a flame. The flame turned blue with a yellow tinge for about three seconds and became extinguished.

Table 4.11: Biogas yield from a garbage charged digester

Date	Biogas (l)	Temperature (^{0}C)	Cumulative yield (l)
25-06-93	0.28	35.0	0.28
26-06-93	0.26	34.0	0.54
27-06-93	0.21	32.5	0.75
28-06-93	0.21	32.0	0.96
29-06-93	0.11	32.0	1.07
30-06-93	0.10	33.0	1.17
01-07-93	0.07	35.5	1.24
02-07-93	0.11	35.0	1.35
03-07-93	0.10	33.5	1.45
04-07-93	0.12	33.0	1.57
05-07-93	0.12	32.0	1.69
06-07-93	0.08	29.0	1.77
07-07-93	0.08	28.0	1.85
08-07-93	0.08	28.0	1.93
09-07-93	0.07	26.0	2.00
10-07-93	0.07	26.5	2.07
11-07-93	0.07	28.0	2.14
12-07-93	0.06	32.0	2.20
13-07-93	0.06	26.0	2.26
14-07-93	0.05	25.0	2.31
15-07-93	0.04	25.5	2.35
16-07-93	0.03	28.5	2.38
17-07-93	0.03	28.0	2.41
18-07-93	0.03	30.0	2.44
19-07-93	0.03	28.0	2.47
20-07-93	0.03	32.0	2.50
21-07-93	0.04	35.0	2.54
22-07-93	0.04	35.5	2.58
23-07-93	0.04	33.5	2.62
24-07-93	0.04	35.0	2.66
25-07-93	0.04	36.5	2.70
26-07-93	0.05	34.0	2.75
27-07-93	0.05	32.0	2.80
28-07-93	0.05	28.0	2.85
29-07-93	0.05	28.5	2.90
30-07-93	0.05	30.5	2.95
31-07-93	0.05	32.5	3.00
01-08-93	0.06	35.5	3.06
02-08-93	0.05	33.0	3.11
03-08-93	0.05	32.0	3.16
04-08-93	0.05	28.0	3.21
05-08-93	0.05	29.5	3.26
Mean	0.08	30.4	

4.5.1 Characteristics of gas produced

Initially, on starting the digester, the gas produced was observed to be predominantly hydrogen sulphide by reason of its

characteristic smell of rotten eggs. This was observed to have reduced significantly after the first week because of the absence of the characteristic smell of hydrogen sulphide.

4.5.2 Test of the produced gas

The gas produced was passed through a bunsen burner, and a burning match stick was applied to the emerging gas. The yellow flame of the burning match stick immediately turned blue, increased in size for about two seconds and was extinguished. The behaviour of the flame suggests that the gas that initially emerged could likely be methane. This is because methane is lighter than the other gases (hydrogen sulphide and carbon dioxide) that could also be produced during bio-digestation of wastes. Also, since the system did not explode, it is safe to assume that the amount of gas produced contain less than five percent of methane, as suggested by ICE (1972) that as little as five percent of methane present in an atmosphere renders such an atmosphere potentially explosive.

4.6 ANALYSES OF RESULTS

4.6.1 Application of mass diagrams to results

4.6.1.1 Rima village - male hostel

Mass diagrams of cumulative weights and volumes of generated solid wastes against time were obtained for all the investigated sites. These are shown in Figures 4.1 to 4.13. From these figures, the maximum weight of wastes and the corresponding

volumes that would have to be considered for disposal, from each site are deduced and shown in Table 4.12.

Table 4.12: Quantities of wastes to considered for disposal

Sites	Maximum weights (Kg)	Maximum volume (m^3)
Rima village	32	0.24
Shere village	30	0.15
Mambilla village	26	0.22
Dalla village	35	0.17
Panteka-Lemu Road	25	0.14
Crescent Road	20	0.19
Mean	28.00	0.19

4.6.1.2 Shere village - male hostel

Similar mass diagrams of weight and volume of wastes against time was obtained for Shere village, as shown in Figures 4 and 5 respectively. From these figures, is deduced that maximum weight to be considered for the village is 30.0 kg. While the volume of waste is 0.15 m^3 from the same site. Also, each block in the village would require an average disposal rate of 8.0 kg/week in weight and a volume of 0.07 m^3/week.

4.6.1.3 Mambilla village - male hostel

Mass diagram of weight and volume against time was obtained for Mambilla village. These are shown in Figures 6 and 7 respectively. From these figures, it may be deduced that the maximum weight of waste that would have to be considered for

disposal, from the village is 26.0 kg. While the volume is 0.22 m^3 from the same site.Also, each block in the village would require an average disposal rate of 10.0 kg/week in weight, and 0.07 m^3/week in volume.

4.6.1.4 Dalla village - female hostel

Similar mass diagrams of weight and volume of wastes against time was obtained for Dalla village, as shown in Figures 8 and 9 respectively. From these figures, the maximum weight to be considered for the village is 35.0 kg, while the volume of waste is 0.17 m^3 from the same site. Also, each block in the village would require an average disposal rate of 25.0 kg/week in weight and a volume of 0.1 m^3/week.

4.6.1.5 Panteka - lemu road staff residential complex

For the staff residential complex at Panteka - Lemu road, mass diagrams of weight and volume of waste against time were also obtained. These are shown in Figures 10 and 11 From these figures, the maximum weight and volume of waste to be considered for disposal are, 25.0 kg and 0.14 m^3 respectively. Each block would also require an average disposal rate of 15.0 kg/week in weight and 0.09 m^3/week in volume.

4.6.1.6 Crescent road staff residential complex

Similarly, for the Crescent road staff residential complex, mass diagrams of weight and volume of waste against time were obtained. These are shown in Figures 4.12 and 4.13. From these figures, it may be deduced that the maximum weight and volume of waste to be considered for disposal are 20.0 kg and 0.19 m^3 respectively. Also, each block would require an average disposal rate of 7.0 kg/week in weight and 0.08 m^3/week in volume.

4.6.1.7 Storage required for produced gas

To determine the storage capacity required for the produced gas, a graph of cumulative daily gas yield produced against time was plotted as shown in Figure 4.13. From this graph, the storage that would be required for the gas produced is 1.0 l/d, for the composition of the charge used in the digester.

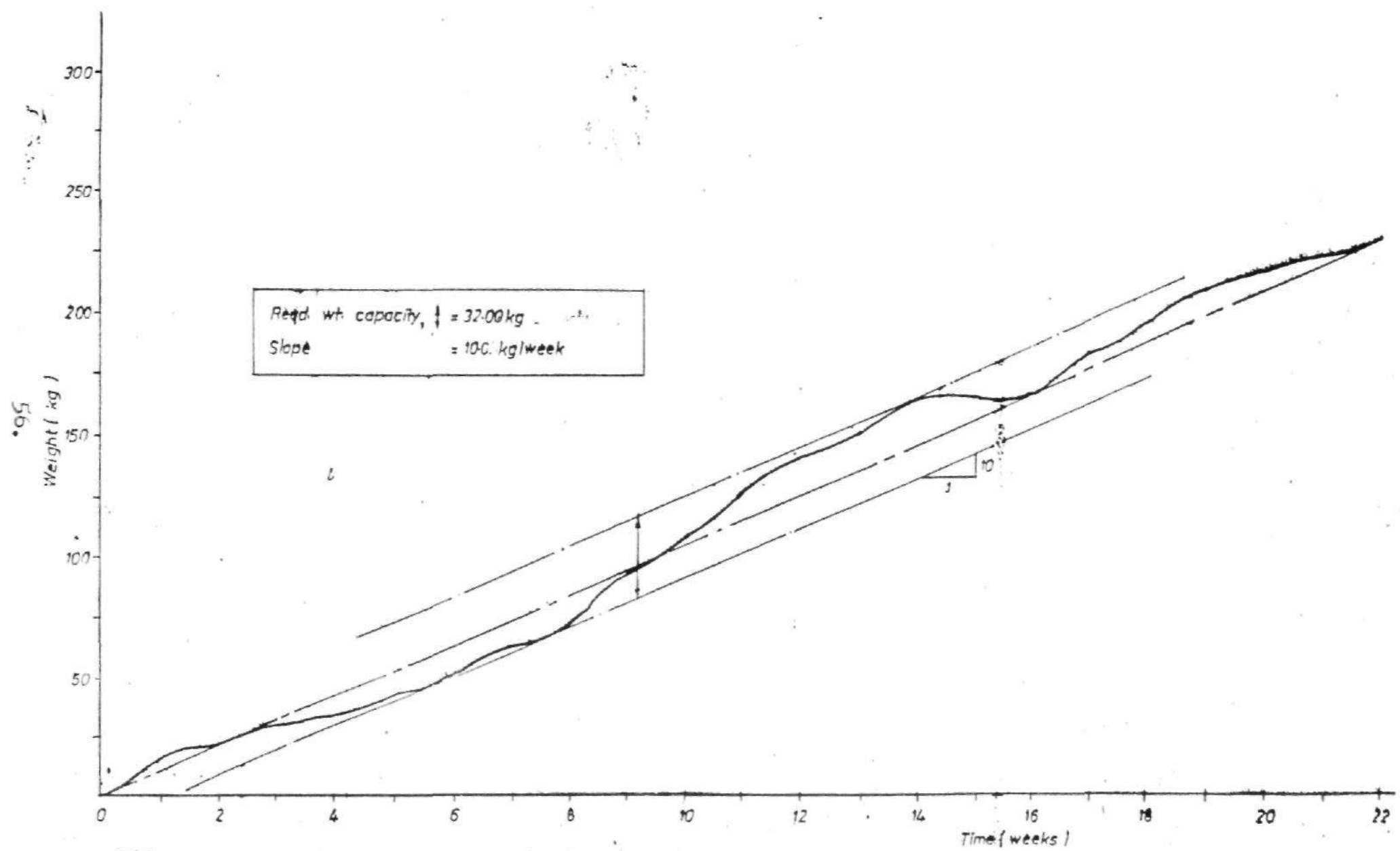


FIG. 4.1 RIMA VILLAGE – MALE HOSTELS MASS DIAGRAM OF CUMULATIVE WEIGHT (KG) VERSUS TIME (WEEKS)

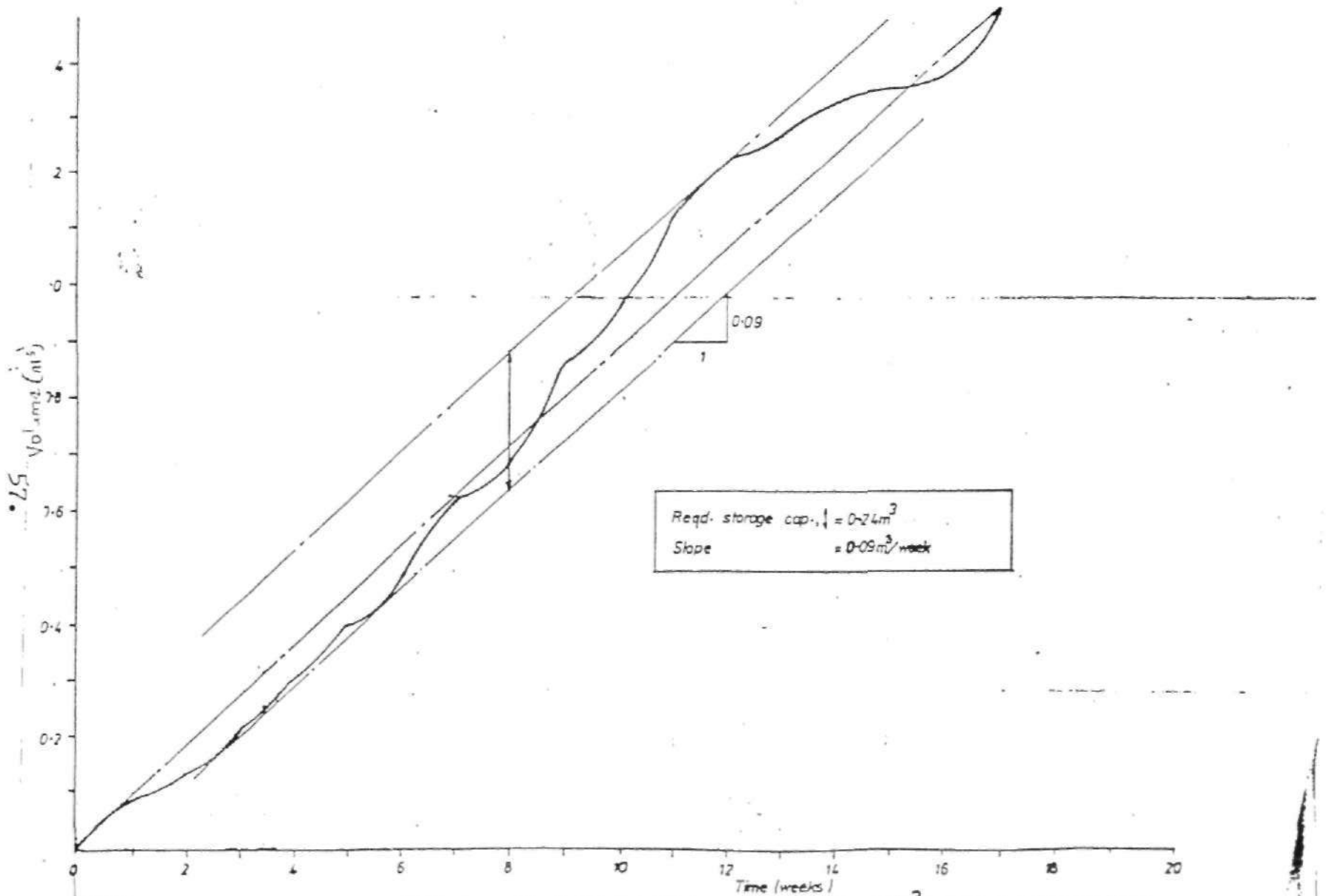


FIG. 4.2 RIMA VILLAGE - MALE HOSTELS MASS DIAGRAM OF CUMULATIVE VOLUME(M^3) VERSUS TIME(WEEKS)

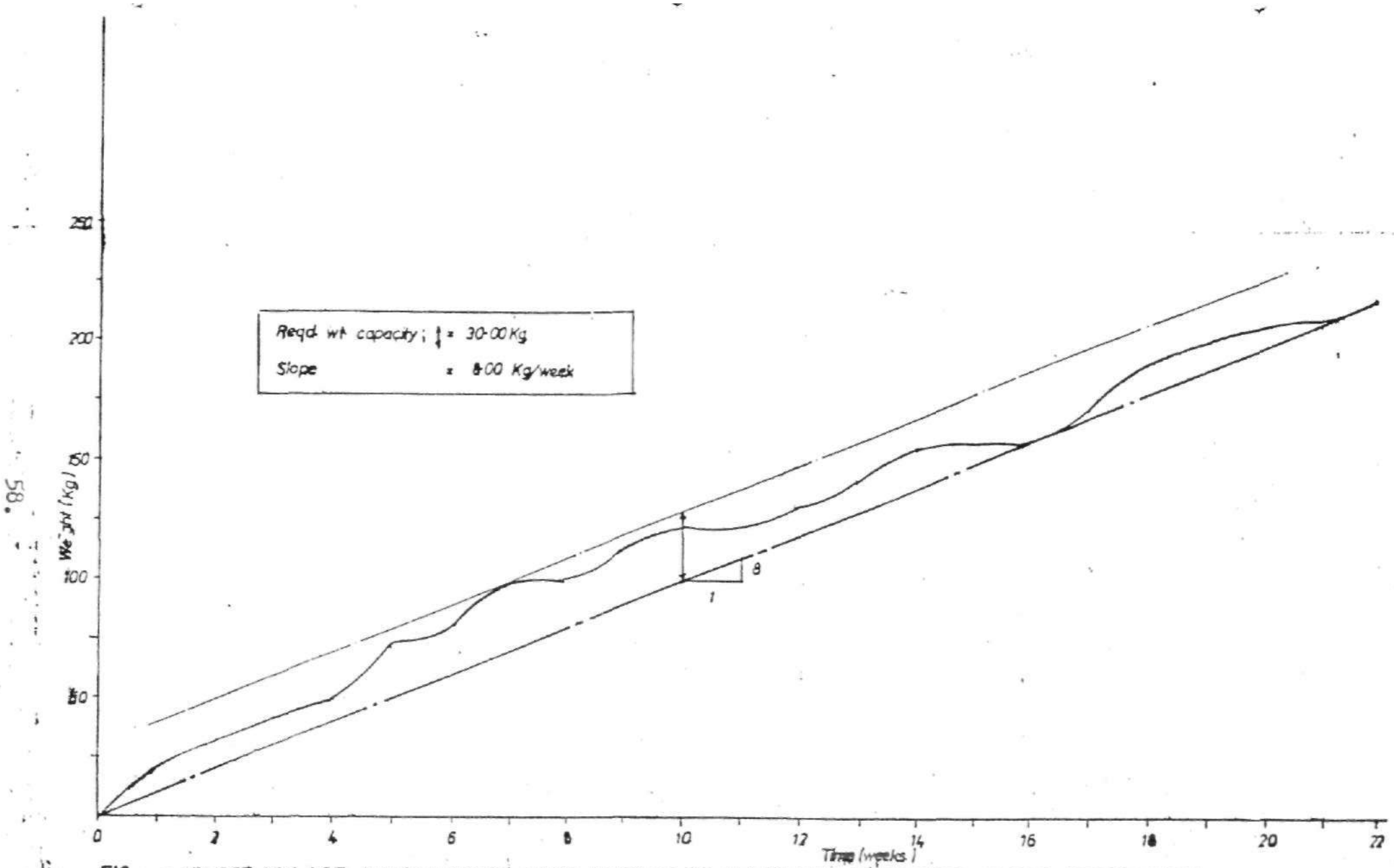


FIG 4.3 : SHERE VILLAGE - MALE HOSTELS MASS DIAGRAM OF CUMULATIVE WEIGHT (KG) VERSUS TIME (WEEKS)

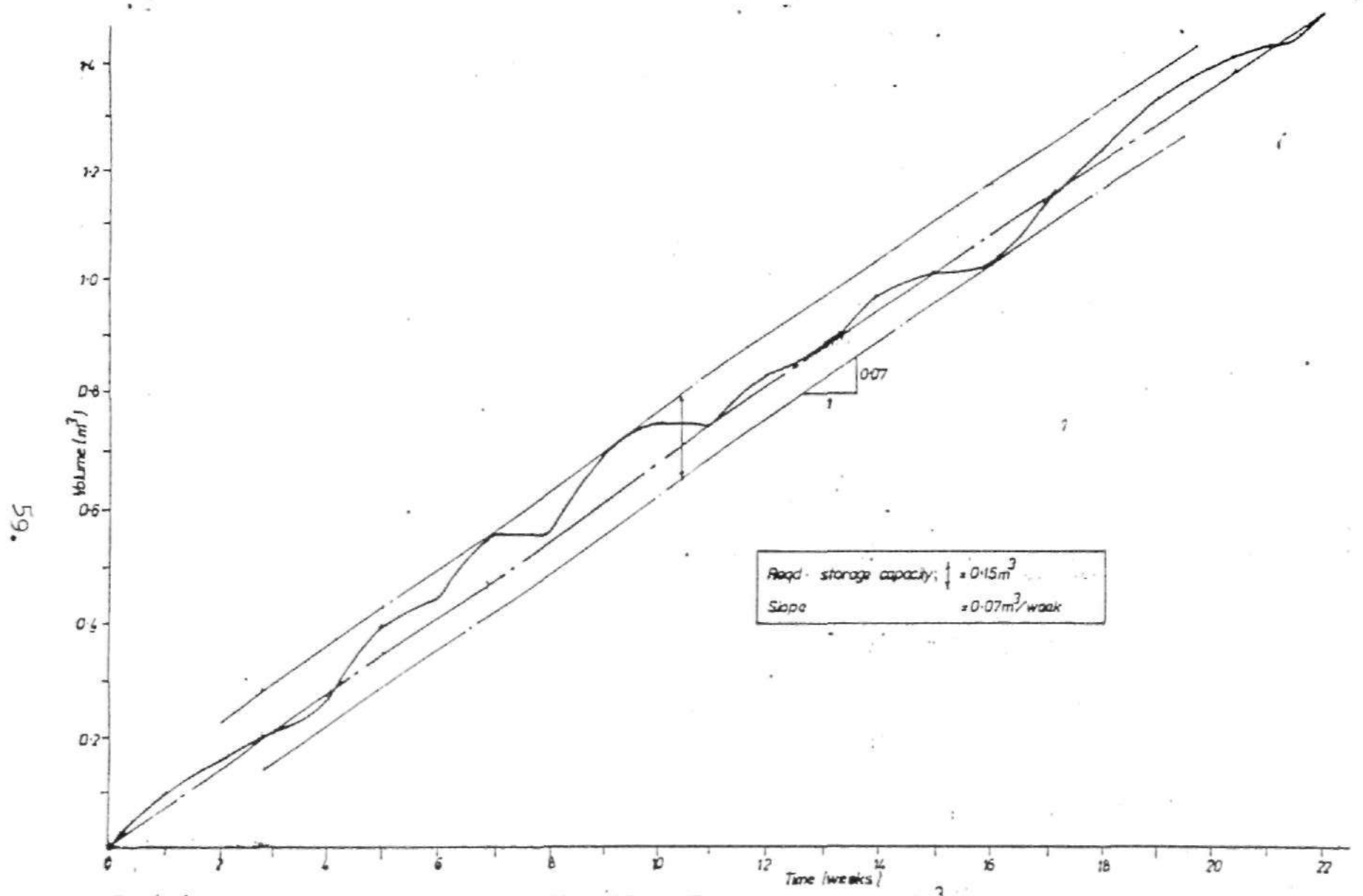


FIG 6.4 SHERE VILLAGE - MALE HOSTELS MASS DIAGRAM OF CUMULATIVE VOLUME (M^3) VERSUS TIME (WEEKS)

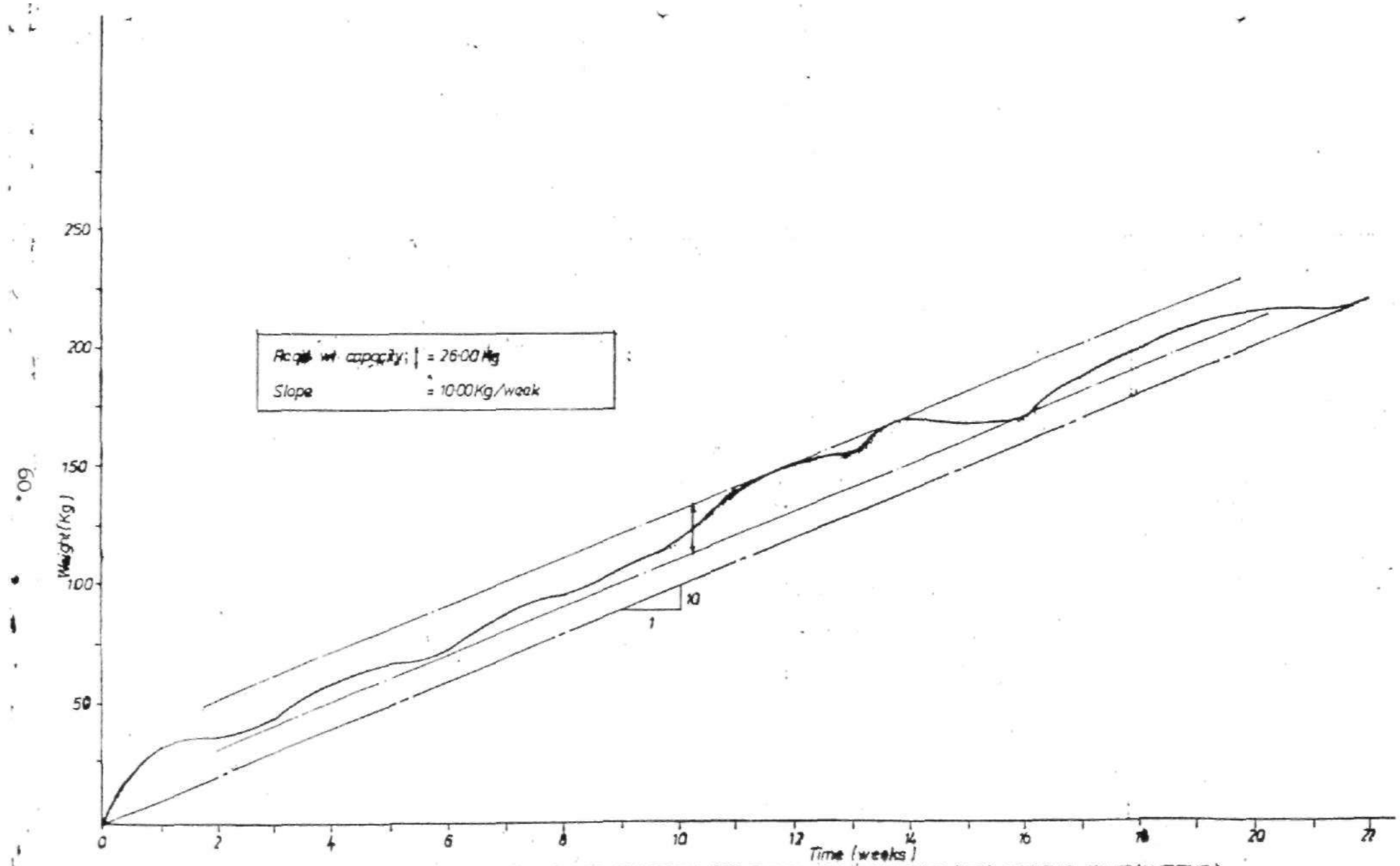


FIG. 4.5. MAMBILLA VILLAGE - MALE HOSTELS MASS DIAGRAM OF CUMULATIVE WEIGHT (KG) VERSUS TIME (WEEKS)

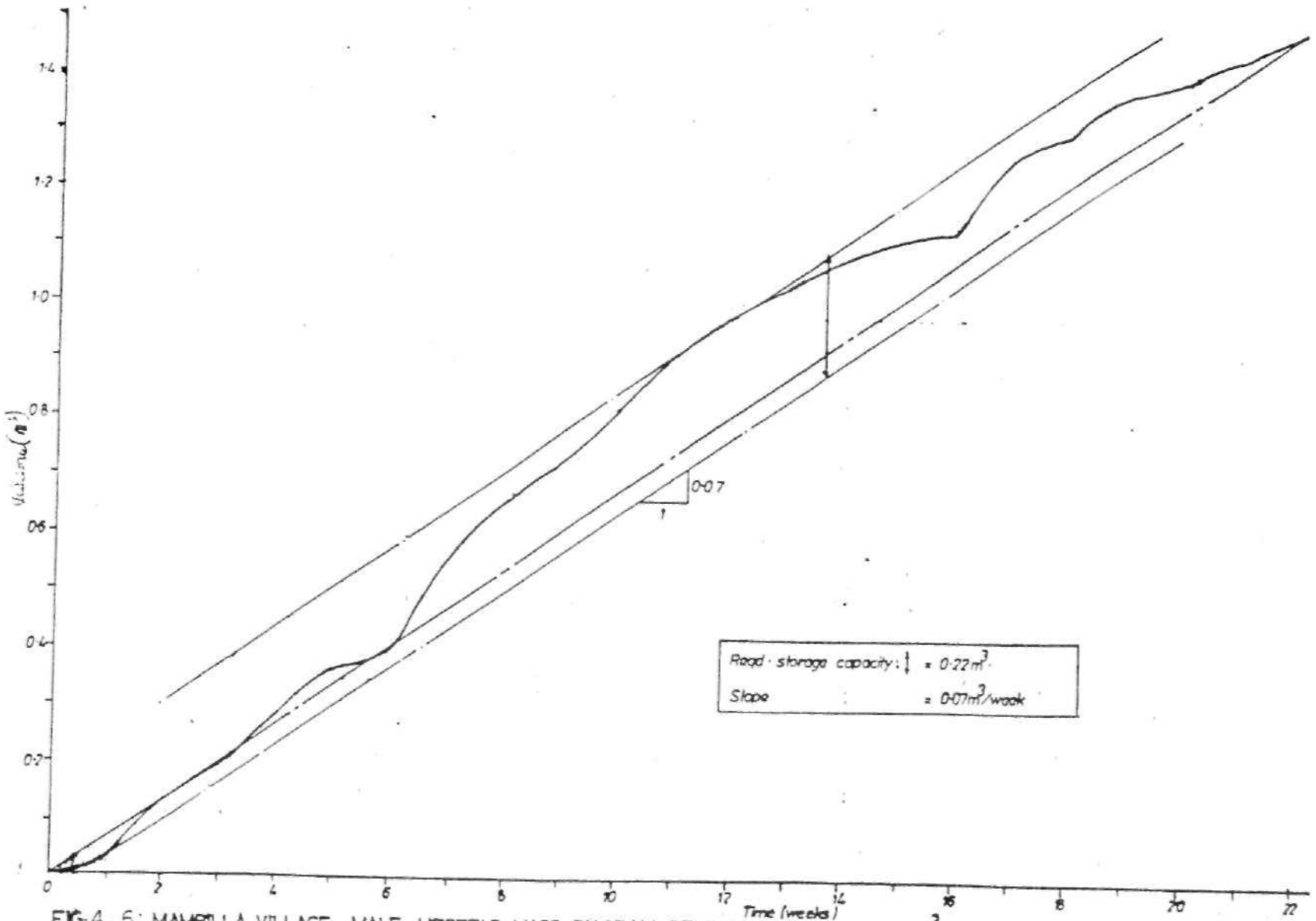


FIG-4.6: MAMBILLA VILLAGE - MALE HOSTELS MASS DIAGRAM OF CUMULATIVE VOLUME (M^3) VERSUS TIME (WEEKS)

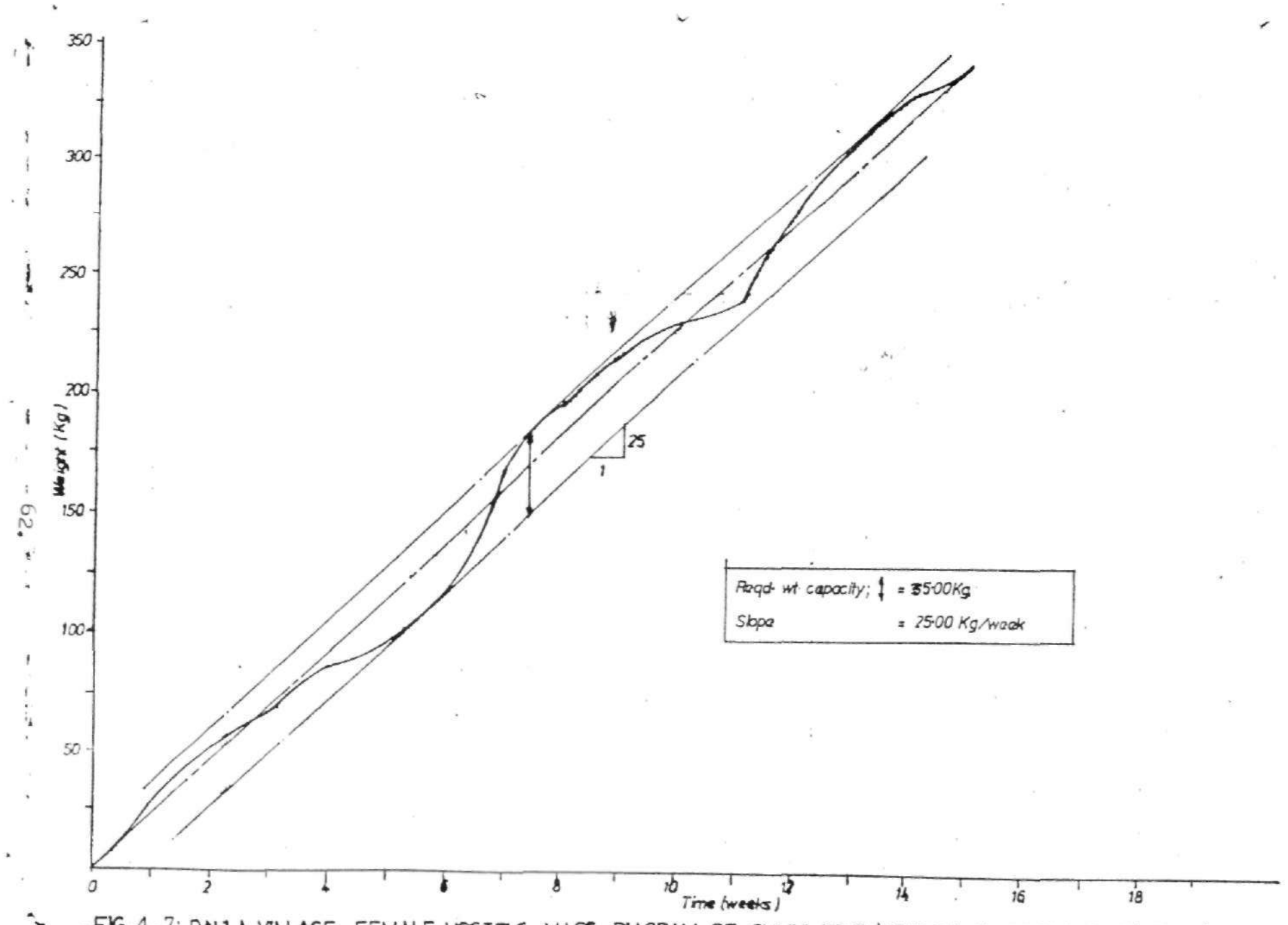


FIG. 4.7: DALLA VILLAGE - FEMALE HOSTELS MASS DIAGRAM OF CUMULATIVE WEIGHT (KG) VERSUS TIME (WEEKS).

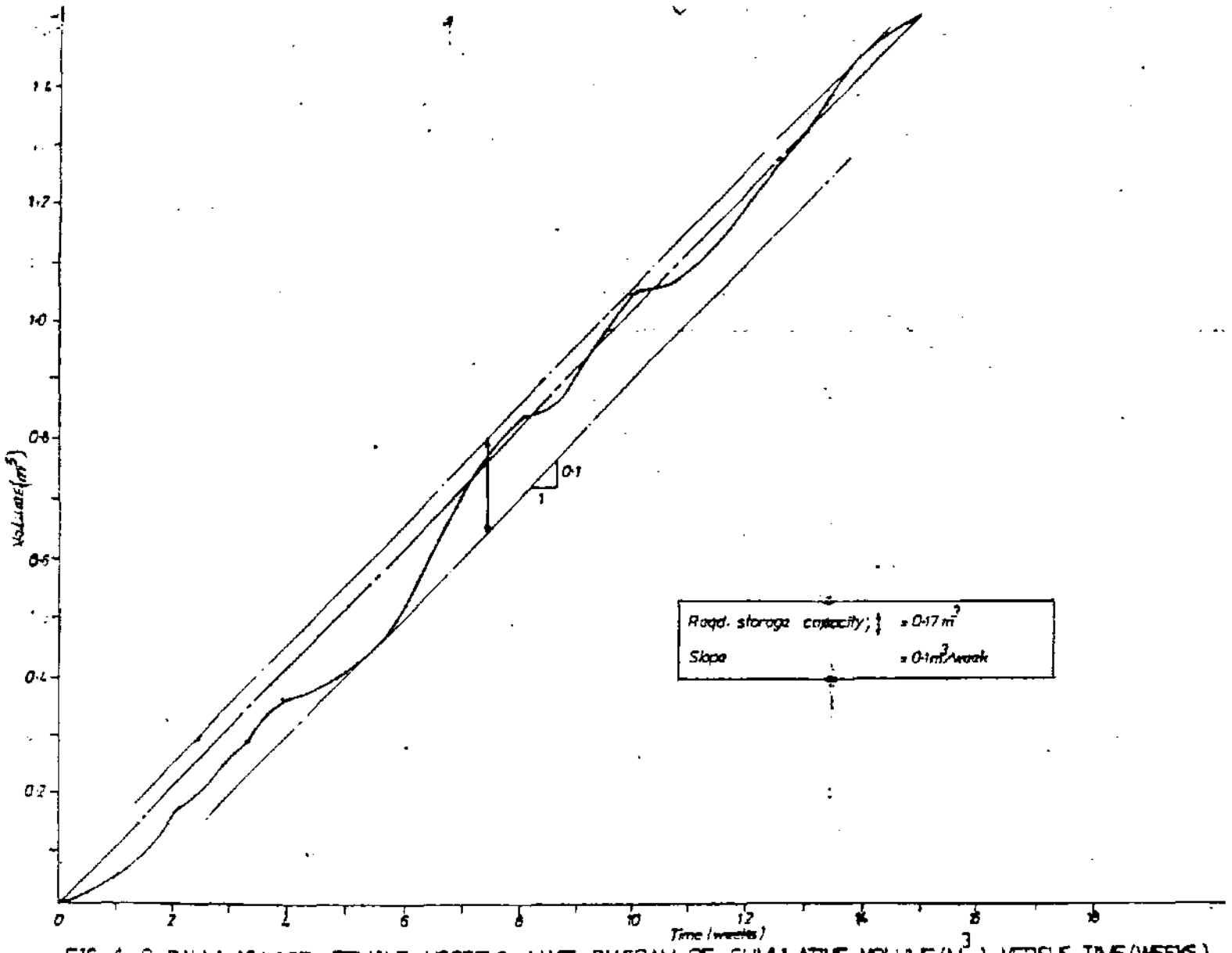


FIG 4.8 DALLA VILLAGE - FEMALE HOSTELS MASS DIAGRAM OF CUMULATIVE VOLUME (M^3) VERSUS TIME (WEEKS)

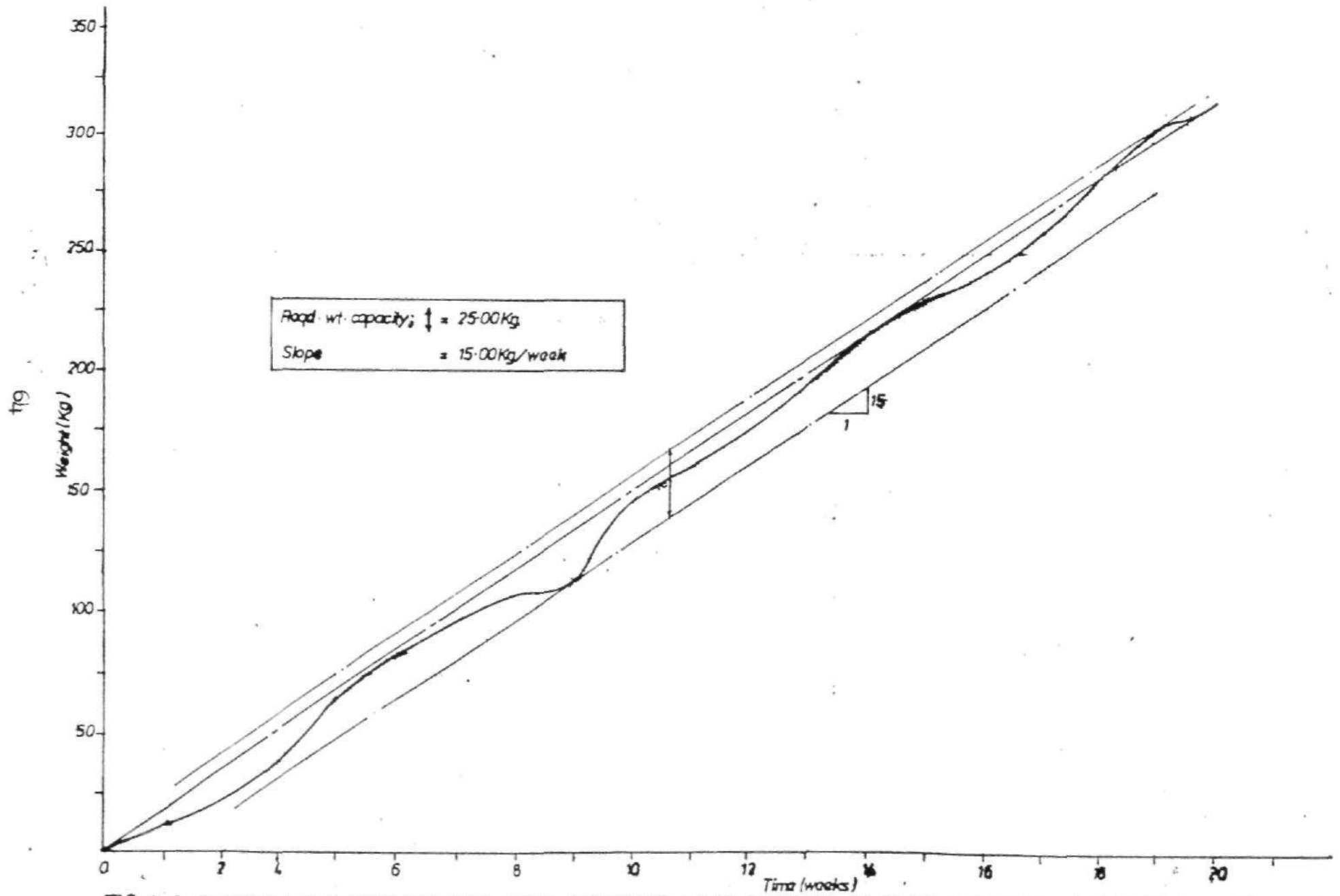


FIG 4.9 PANTEKA-LEMU ROAD COMPLEX-STAFF RESIDENCE MASS DIAGRAM OF CUMULATIVE WEIGHT (KG) VERSUS TIME (WEEKS)

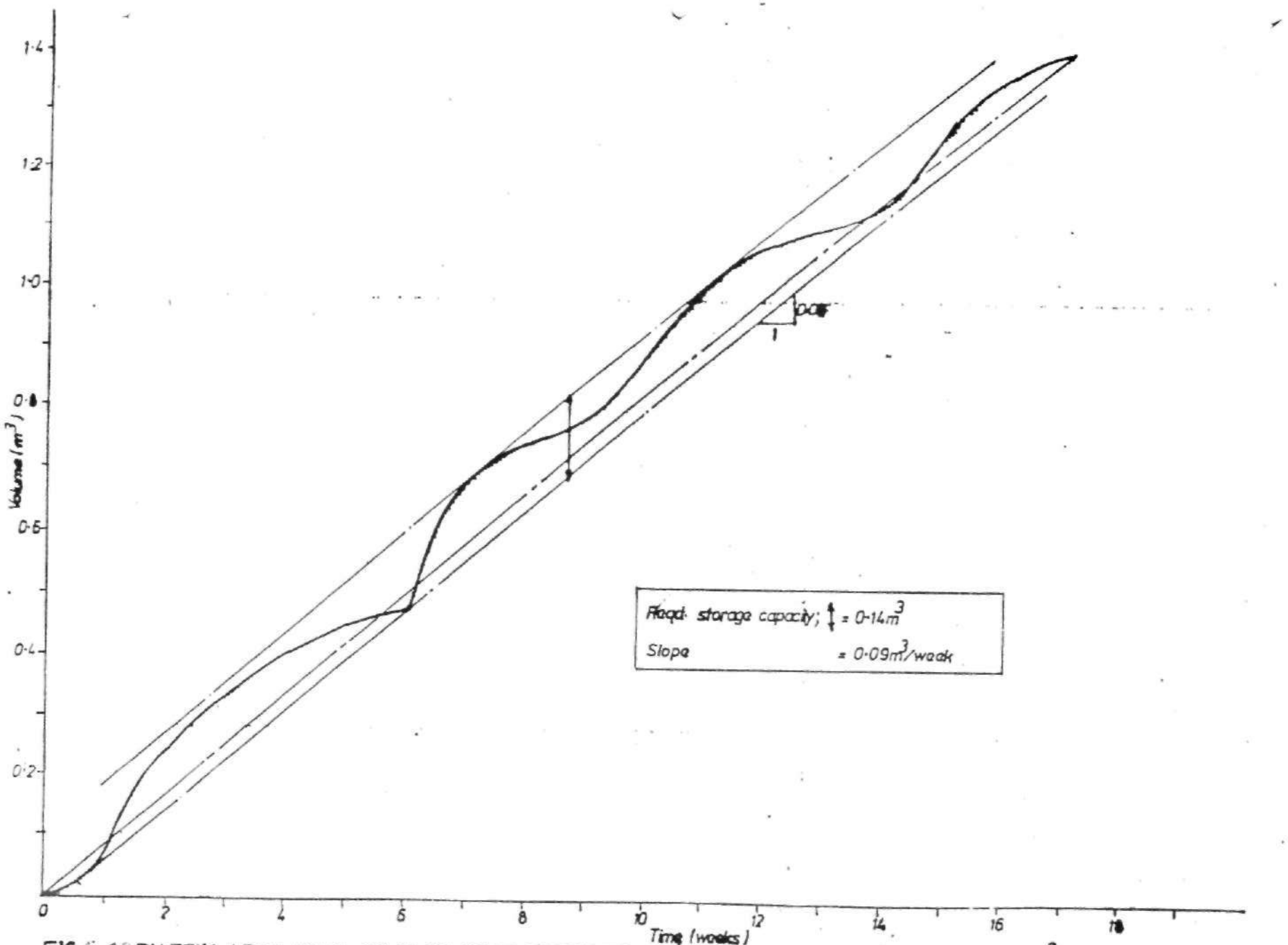
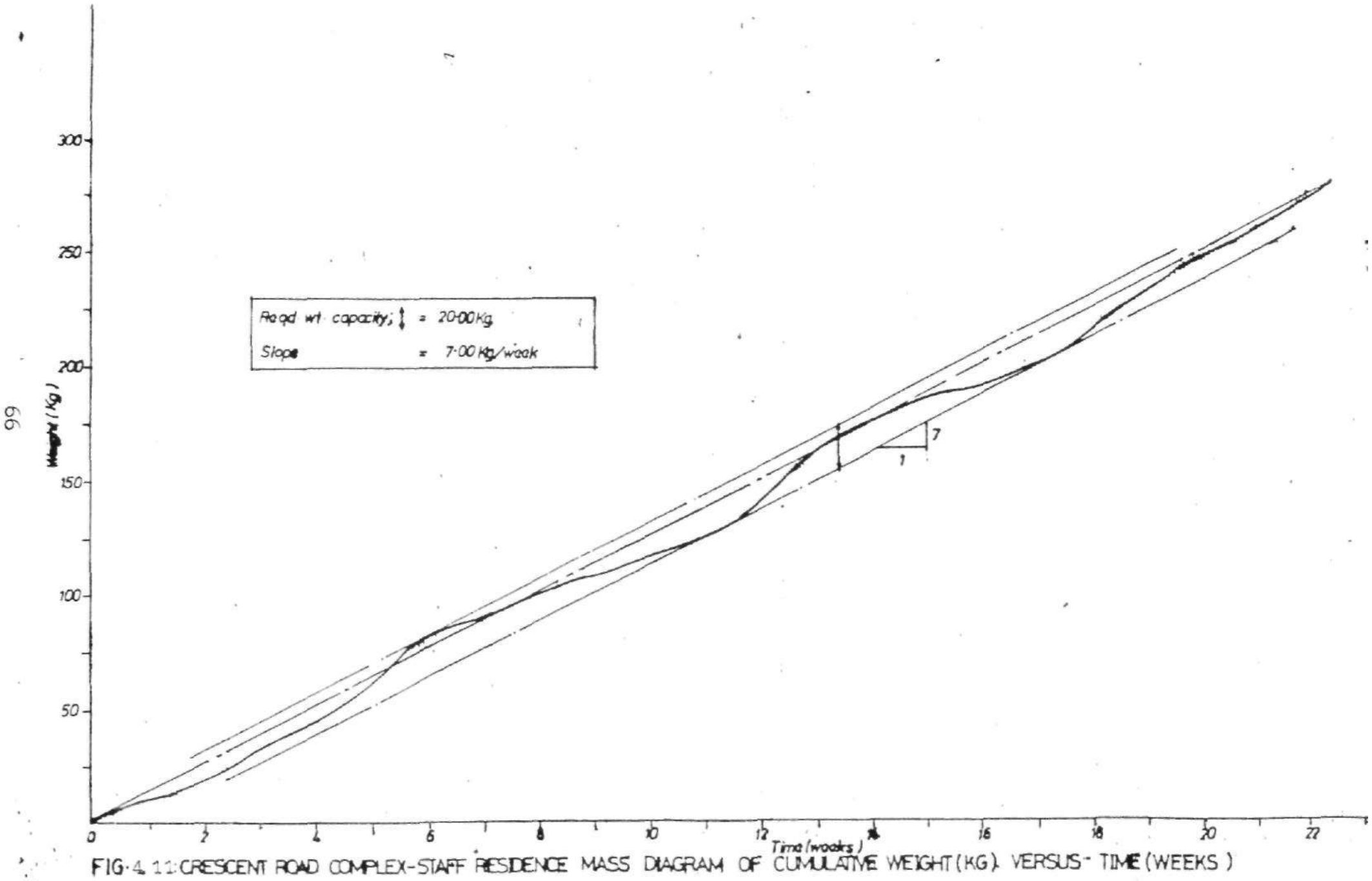


FIG 4.10 PANTEKA-LEMU ROAD COMPLEX-STAFF RESIDENCE MASS DIAGRAM OF CUMULATIVE VOLUME (M^3) VERSUS TIME (WEEKS)



FIG·4.11: CRESCENT ROAD COMPLEX-STAFF RESIDENCE MASS DIAGRAM OF CUMULATIVE WEIGHT (KG). VERSUS - TIME (WEEKS)

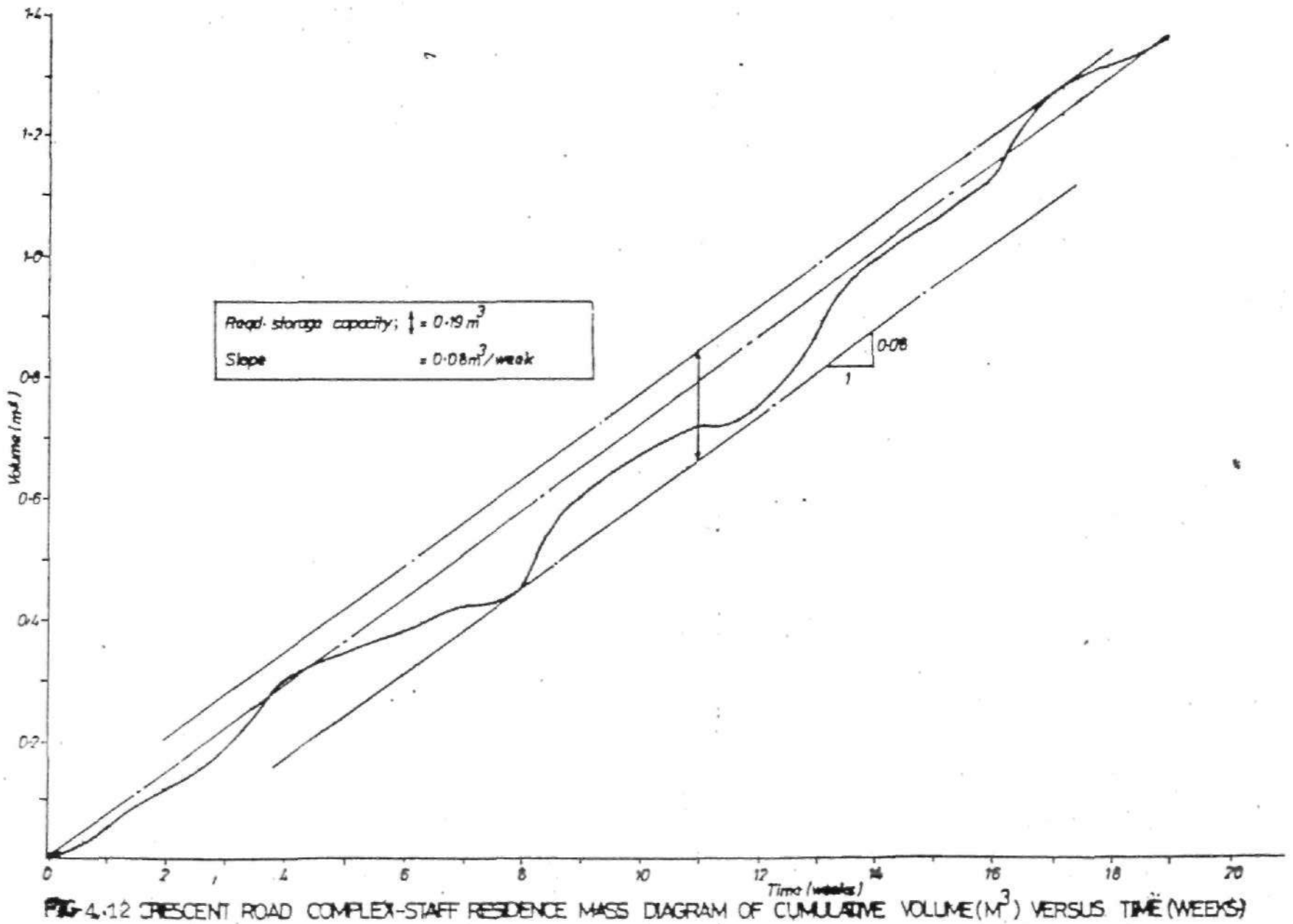


FIG 4.12 CRESCENT ROAD COMPLEX-STAFF RESIDENCE MASS DIAGRAM OF CUMULATIVE VOLUME(M^3) VERSUS TIME (WEEKS)

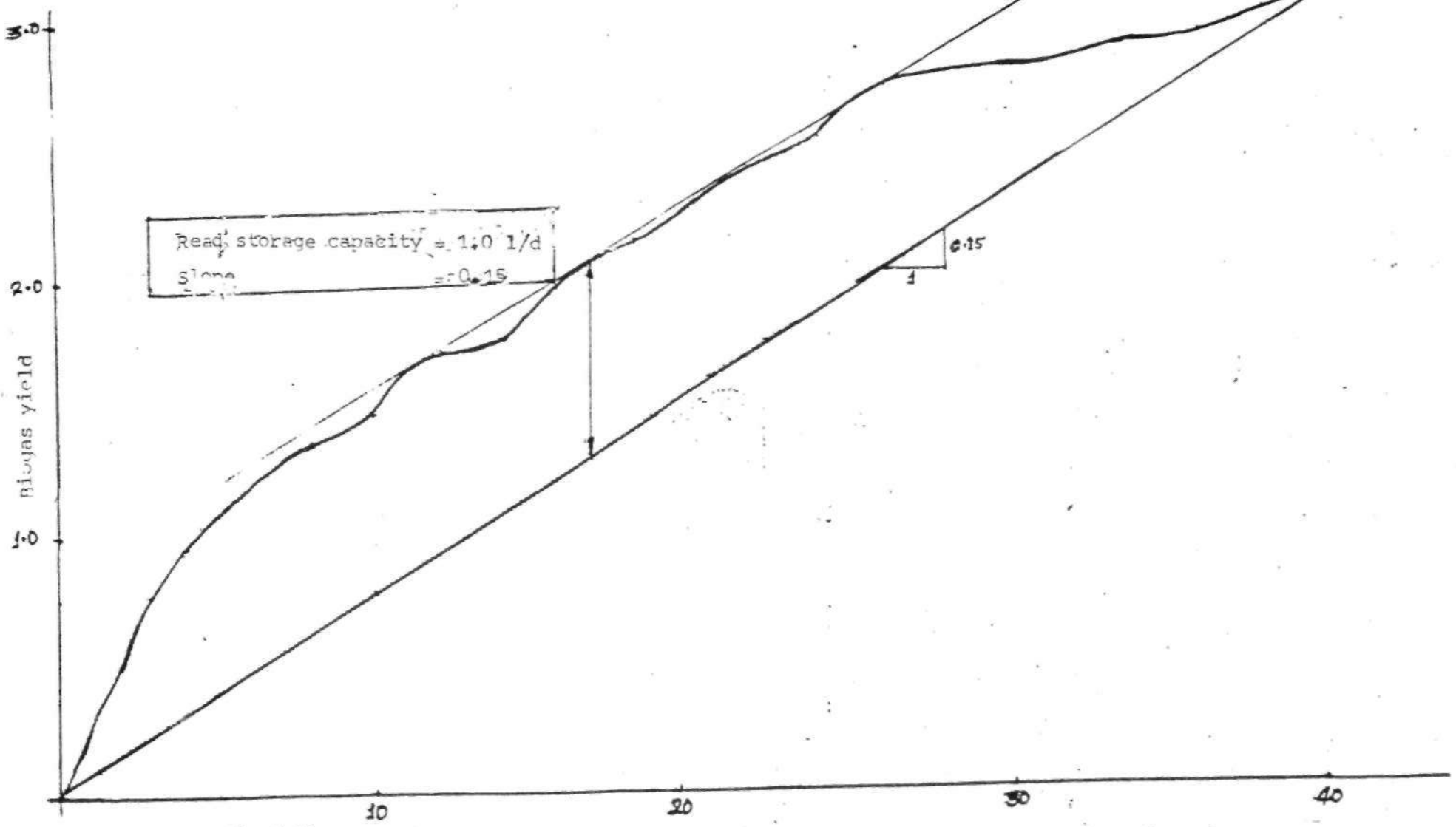


Fig.6.13 Mass diagram of Biogas yield

4.6.2 Application of Regression Analysis

Using the values in Table 4.9, regression analysis performed between composition and the weights of sampled wastes yielded regression parameters shown in Table 4.13 below.

Table 4.13: Regression parameters

Composition	Constant	X Coefficient(s)	R Squared
Gi	180.44	54.97	0.11
Ri	134.93	91.58	0.41
Mi	186.93	11.07	0.07
Pi	225.77	-7.56	0.01
GBi	1030.38	-9.17	0.24
GRi	153.10	11.62	0.15

Constant = Y intercept
X Coefficient = slope
R squared = correlation coefficient.

Where
Gi represents glass
Ri represents rubber, plastic and polythene materials
Mi represents metal, tins, cans, foil wrappings and associated materials
Pi represents paper, cardboard and related materials
GBi represents garbage
GRi represents grass cuttings, leather, textiles and others

4.7 GENERAL OBSERVATIONS

Study and research into solid waste management practice is not only capital intensive in terms of consumable materials and equipment, but also labour intensive, in terms of data collection. During this study, the refuse collection crew of the Kaduna Polytechnic was actively involved in the data collection.

The management of the wastes produced at the Kaduna Polytechnic is the responsibility of the Public Health unit of the Estate Department. This consists of an officer and a crew of seven, with a 6.0 m^3 refuse collection truck.

The crew service the Polytechnic's two campuses, collecting solid wastes from both residential and school areas on a daily basis, and transporting them to the open dump site operated by the Kaduna State government along Abuja road.

At small unit and household levels, the wastes are collected in dust-bins and trash cans strategically located in the offices, hostels, the library, kiosks, canteens, staff houses, workshops and others, the wastes are collected in dust bins and trash cans which are placed at strategic locations. There are central collection points located within complexes particularly at the colleges and the administrative complex. The refuse disposal crew collect solid wastes from these central collection centres, which are basically fenced open dumps as shown in Plate I, these also serve as burning sites occasional. At the staff houses, the crew collect from individual drums and dust-bins.



Plate I: Central Collection Point Showing Heap of Refuse and Residue in a Fenced Dump.

4.7.1.0 Characteristics of solid wastes

Generally, the nature of wastes generated in the Kaduna Polytechnic is associated with human activities. This is to be expected, because Morgan et. al. (1962) for instance, suggested that solid wastes generated, reflect the life style of the generating populace. Therefore, the character and amounts of various components is expected to vary from locality to locality.

At the colleges and administrative areas, the wastes are predominantly paper wastes, while at the hostels and staff houses, it is predominantly garbage.

4.7.1.1 Hostels

The variation in average weights, volumes, densities and composition of wastes generated at the student hostels is probably related to the financial status of the students, as well as the period of the semester. The pattern is that on the average the quantity of wastes produced by the inhabitants of Shere village is the lowest, while inhabitants of Rima village produced the highest value at the male hostel. This can be explained by the fact that students that inhabit Rima village are mainly foreign students whose cash liquidity is higher by virtue of the grants they enjoy. While Shere and Mambilla village is inhabited by indigenous students with less money. Therefore the financial status influenced the variation in weight, volume density and composition observed.

Solid wastes varied in quantity and composition depending on the period of the semester. At the early part of the semester, students were fresh from home and they tended to consume more packaged foods, take-away snacks and confectioneries etc., resulting in the generation of more paper wastes than garbage. Consequently wastes were lower in density. As the semester progresses, wastes from the hostels tended to become

predominantly garbage than paper, i.e. wastes of higher densities as reflected in Tables 4.1 to 4.4

This could be explained by the fact that during this period of the semester, students have spent a large proportion of their money. therefore they tend to be more economical by cooking their meals as against eating outside.

The large difference in average weights volumes and densities of wastes sampled at the female hostels compared to that of the male hostels could be associated with the financial status and living style of the female students. The female students generated more wastes because they consumed more packaged food, snacks and confectioneries; they also cook more thereby generating and disposing of more garbage (see Plate II.)



Plate II Garbage Dumped outside a Collection Point (Kaduna Hall)

4.7.1.2 Staff residences

The amount and composition of wastes generated at the staff houses is also related to the income status and pattern of living of the staff. The wastes were mainly garbage, sweepings garden trimmings and paper wastes. The quantity and composition also show a monthly rhythm. Between pay-day and the commencement of a new month, more packaged food wastes are generated with the usual garbage; the quantities decrease as the month progresses, and the cycle is repeated.

4.7.2 OPERATIONAL METHODS

4.7.2.1 Equipment and crew size

The facility at the Kaduna Polytechnic, which consists of only one 6.0 m^3 two tons capacity truck with a crew of seven is obviously inadequate, if one considers that 3,000 kg of solid wastes with a volume of 3.0 m^3 has to be collected and disposed daily.

The Kaduna Polytechnic truck is an old one, therefore the truck is plagued with regular break downs. This results in accumulation of wastes, with a consequent indiscriminate dumping as shown in Plates III, IV and V.



Plate III: Indiscriminate Dumping of Refuse (Male Hostel).



Plate IV: Indiscriminate Dumping of Refuse (Isa Kaita Library).



Plate V: Indiscriminate Dumping of Refuse and Faeces (Female Hostel).

The number of dust-bins provided at strategic places are also inadequate. This also encourages indiscriminate dumping. (See Plates III - V).

4.7.2.2 Waste handling and health related hazards

Gellin (1985) conducted an evaluation of the skin changes and injuries among waste collectors. He found that about 75 percent

of the population sampled had palmar calluses. A majority of waste collectors sustained work related injuries each year. These injuries according to Faust et. al. (1988) and Gollin (1985), are sprains, abrasions lacerations, fractures and eye injuries. Workers who protected their hands on the other hand had normal skins, with minor or complete absence of calluses.

The crew operating the Kaduna Polytechnic refuse disposal truck are not adequately protected. Nothing is provided to prevent skin infections and inhalation of obnoxious smells and dusts by workers. This results in the exposure of the crew to serious health hazards. The collection of solid waste, and the handling of these wastes is a hazardous occupation this is documented in Bass et. al. (1990).

4.7.2.3 Disposal of solid wastes

4.7.2.3.1 Open dumping

The final disposal site of solid wastes in Kaduna metropolis is at the outskirts of the town. There are many sites where mostly uncontrolled tipping is practiced. One of such sites is that located 5.0 km along Kaduna-Abuja road, and is the one used for dumping the wastes produced at the Kaduna Polytechnic. This site is basically an open dump, and is one of many such dumps operated by the Kaduna State Government Public Health Unit.

4.7.2.3.2 On-Site Incineration

At the Kaduna Polytechnic, there was a tendency to burn wastes (See Plate VI).



Plate VI: Burning of refuse at the hostel

This method in itself is not a complete operation. Incineration is a waste processing and not a waste disposal technology. Its products pose substantial management and disposal problems of their own. The focus of attention on incineration should now shift from its apparent management advantages to the associated and resolved risk issues.

4.7.3 Reuse and energy recovery

At the Kaduna Polytechnic, other than experimental reuse of glass from expired flourescent bulbs, there is no effort to recycle and reuse waste produced at the institution.

CHAPTER FIVE

DISCUSSION

The quantity of waste generated is generally a function of the population. A survey revealed that on the average, eight persons live in one house. The per Capita waste contribution was found to be 0.31 kg per day of weight and 0.001 m^3 per day of volume. This is comparable with the average value of 0.49 kg per capita per day observed by the Federal Ministry of Housing and Environment (1982), in a field survey of solid waste generation rates in Nigerian urban centres.

According to the French Ministry of Environment (1984), Hagerty et. al. (1973) and Quon et. al. (1970), discrepancies would exist in solid waste generation rates and composition, because of several factors such as the varying standard of living of the population under study, and most importantly, the duration of the study. The French Ministry (1984) also stated that a generation rate of 0.8 kg per capita per day for urban centres in France is usual.

Morgan et. al. (1962) and Quon et. al. (1970) are also of the view that because of the discrepancies observed in data on wastes generation rates, such published data are often only of partial benefit to a designer and planner. Shanklin (1991), Omorodion (1990) and Brown et. al. (1988) however advised that if the generation rate and distribution of components are critical factors in a particular management decision process, a special

study should be undertaken, if possible, to assess the actual distribution.

In order to put the problem of waste management in perspective, Hagerty et. al. (1973) postulated that, it is necessary to present some basic data regarding the quantities and the characteristics of wastes. These data are necessary for a variety of reasons like; (1) the collection and disposal systems have to be geared to the total amount and quantity of the materials produced. (2) the overall management of the developed system will rely heavily on the preliminary data concerning the quantities and character of the waste.

5.2 ASSESSMENT OF OPERATIONAL METHODS

5.2.1 Equipment and crew size

Quon et. al. (1970) studied the efficiency of refuse collection crews and observed that number of truck, age of truck and size of collection crew strongly influenced work efficiency. The disposal truck at the Kaduna Polytechnic is an old one. The age renders it inefficient. This probably explains the accumulation of wastes at the various disposal sites in the polytechnic.

The crew of seven working with one truck is large. Quon et. al. (1970) recommends a crew of two. Since in their study, they observed that a crew of two is more efficient than that of three.

But if one compares the sophistication of equipment and trucks used by the crew as reported by Quon et. al. (1970), and that used by the crew at the Kaduna Polytechnic, then one can safely assert that the crew of seven may not be too large after all.

5.2.3 Disposal of solid wastes

5.2.3.1 Open dumping

Mantel (1975) suggested that nothing good can be said of crude tipping. It was further stressed that even its cheapness is more apparent than real. Rats and flies are attracted to the loosely tipped masses of waste and infect them; the lighter materials are scattered by the wind and the constituents at the dumps are disturbed by rats, birds and human agencies. Fire may start giving rise to large volumes of smoke. Crude open dumps Mantel (1975) concluded must unhesitatingly be condemned.

5.2.3.2 On-Site Incineration

Denison and Silbergeld (1988) studied the risk assessment of the incineration of municipal solid waste. They found that incineration greatly enhances the mobility of toxic metals present in the waste. Furthermore, cognisance should also be taken of other hazardous products of incineration like dioxins, routes of exposure, and their associated effects such as cancer. These findings suggest that incineration is ill-suited to management of solid waste in its entirety.

5.3.0 Energy recovery

The net calorific value observed (1.5 kCal/kg) is equivalent to 6.3 kJ/ton and differs significantly from the value reported (13 - 17 kJ/ton) by the French Ministry of Environment (1984). This discrepancy probably could be explained as the result of the difference in composition of the raw waste and the degree of size reduction. Furthermore, a biogas yield of 0.081/kg/d waste was obtained from the waste of the Kaduna Polytechnic. This yield is comparable to the 0.03/kg/d obtained for swine waste, 0.131/kg/d for poultry wastes and 0.161/kg/d for cow dung as documented by Mah et al (1971) and United Nations Environmental Programme (1981).

The charge used for the digester is by no means the best in terms of substrate composition. The 20-30:1 carbon to nitrogen ratio

used as suggested by McCallum (1978) and Hagerty et. al. (1973) may not have produced a situation of optimum gas yield.

National Academy of Sciences (1977) is of the view that the quantity of gas produced is strongly influenced by the composition of the substrate. Further more, Van Buren (1980) suggested that a combination of substrates tend to yield more gas when compared to single substrates. Therefore, in order to ascertain the best composition, other charges in combination with garbage like garbage/cow dung, garbage/poultry or garbage/swine wastes would have to be tried to determine which variation would yield the optimum in gas production.

The test conducted on the produced gas suggests that this gas is likely to be methane mixed with hydrogen sulphide and carbon dioxide.This is because Polprasert (1979), opined that methane mixed with hydrogen sulphide on ignition will yield a bluish flame with a yellowish tinge.

CONCLUSION

A lot of difficulties were encountered during this study in terms of research materials and equipment. However, the central point of interest in this investigation was to evaluate the existing system at the Kaduna Polytechnic, assess its effectiveness and recommend appropriate measures to enhance its operational and management efficiency.

Based on the observations and subsequent analyses of the findings in this study, the following conclusions are drawn.

1. The quantities of solid wastes disposed in terms of weight, volume, and compositions vary with the assumed financial status of the students, as well as the period of the semester at the students' hostels. At the staff houses, it shows a monthly rhythm starting with period of payment of salaries to few days before payment of salaries to the staff.
2. The collection frequency (once a week) in the institution is grossly inadequate.
3. The number of dust bins and refuse trucks provided are inadequate.
4. The refuse collection crew of seven , manning a single truck, is too large.
5. Biogas could be produced and subsequently used as an additional source of energy.

RECOMMENDATIONS

In the light of the findings and conclusions drawn in this study, the followings are being recommended.

1. The existing truck should be replaced with a better and more efficient one. This will enhance collection frequency and the effectiveness of collection operations.
2. The collection frequency should also be increased to prevent unnecessary accumulation of wastes.
3. Dust bins should be provided on every floor of buildings at the students' hostels, academic and administrative blocks as well as residential buildings to ensure proper collection of wastes.
4. Indiscriminate dumping and on-site incineration should be discouraged by enlightenment and proper monitoring of the refuse management board.
5. The crew size of seven, manning a single truck, being too large could be reduced to two groups of three each and a field supervisor.
6. The fenced open dumps, i.e. the collection points within the institution should be renovated and reconstructed in such a way that wastes would not be scattered by wind or animals.
7. The academic community should be further enlightened about the benefits of proper solid waste disposal.
8. Further studies into an integrated solid waste management practice, with particular focus on reuse and energy

recovery with its attendant cost implications should be undertaken.

9. Landfill is the most appropriate method of solid waste disposal recommended. Alternatively, the garbage component could be used to prepare compost for farming supplement, while the paper and plastic components could be recycled.

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APPENDICES

APPENDIX 1a

TYPICAL SOLID WASTE GENERATION FACILITIES, ACTIVITIES, AND LOCATIONS ASSOCIATED WITH VARIOUS SOURCE CLASSIFICATIONS.

Source	Typical facilities, activities, or locations where wastes are generated	Types of solid wastes.
Residential	*Single-family* and multifamily dwellings, low-, medium-, and high-rise apartments, etc.	*Food wastes, rubbish,* ashes, special wastes.
Commercial	Stores, *restaurants,* markets, office buildings, hotels, motels, print shops, auto repair shops, medical facilities and institutions	*Food wastes, rubbish,* ashes, demolition and construction wastes, occassionally hazardous wastes.
Municipal	As in residential and commercial.	Same as in residential and commercial.
Industrial	Construction, fabrication, light and heavy manufacturing, refineries, chemical plants and demolition.	Food wastes, rubbish, ashes, demolition and construction wastes.
Open areas	Streets, alleys, parks, vacant lots, playgrounds, beaches, highways.	Special wastes and rubbish.
Treatment plant sites	Water, wastewater, and industrial treatment processes.	Treatment plant wastes and residual sludges.
Agricultural	Field and row crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes and agricultural wastes.

Source: Tchobanoglous et. al. (1977)

APPENDIX 1b

TYPICAL PHYSICAL COMMPOSITION OF MUNICIPAL SOLID WASTES.

COMPONENT	PERCENT BY WEIGHT	
	RANGE	TYPICAL
Food wastes	6 - 26	15
Paper	25 - 45	40
Cardboard	3 - 15	4
Plastics	2 - 8	3
Textiles	0 - 4	2
Rubber	0 - 2	0.5
Leather	0 - 2	0.5
Garden trimmings	0 - 20	12
Wood	1 - 4	2
Glass	4 - 16	8
Tin cans	2 - 8	6
None ferrous metals	0 - 1	1
Ferrous metals	1 - 4	2
Dirt, ashes, brick, e.t.c.	0 - 10	4

Source: Tchobanoglous et. al. (1977)

APPENDIX 1c

TYPICAL MOISTURE CONTENT DATA FOR MUNICIPAL WASTE COMPONENTS

COMPONENT	PERCENT BY WEIGHT	
	RANGE	TYPICAL
Food wastes	50 -80	70
Paper	4 - 10	6
Cardboard	4 - 8	5
Plastics	1 - 4	2
Textiles	6 - 15	10
Rubber	1 - 4	2
Leather	8 - 12	10
Garden trimmings	30 - 80	60
Wood	15 - 40	20
Glass	1 - 4	2
Tin cans	2 - 4	3
None ferrous metals	2 - 4	2
Ferrous metals	2 - 6	3
Dirt, ashes, brick, e.t.c.	6 - 12	8
MUNICIPAL SOLID WASTES	15 - 40	20

Source: Tchobanoglous et. al. (1977)

APPENDIX 1d

TYPICAL DENSITIES OF MUNICIPAL SOLID WASTES BY SOURCE

SOURCE	DENSITY, kg/m^3	
	RANGE	TYPICAL
Residential (uncompacted)		
Rubbish	90 - 180	130
Garden trimmings	60 - 150	105
Ashes	650 - 830	740
Residential (compacted)		
In compactor truck	180 - 445	300
In landfill (normally compact)	360 - 505	445
In landfills (well compacted)	600 - 740	600
Residential (after processing)		
Baled	600 - 1070	710
Shredded, uncompacted	120 - 265	215
Shredded compacted	650 - 1070	770
Commercial - industrial (uncompacted)		
Food waste (wet)	475 - 950	535
Combustible rubbish	50 - 180	120
Non combustible rubbish	180 - 360	300

Source: Tchobanoglous et. al. (1977)

APPENDIX 1e

TYPICAL DENSITIES OF MUNICIPAL SOLID WASTE COMPONENTS AS DISCARDED (UNCOMPACTED).

COMPONENTS	DENSITY kg/m ^{3}	
	RANGE	TYPICAL
Food wastes	128 -480	288
Paper	32 - 128	81
Cardboard	32 - 80	50
Plastics	32 - 128	64
Textiles	32 - 96	64
Rubber	96 - 192	128
Leather	96 - 256	160
Garden trimmings	64 - 224	104
Wood	128 - 320	240
Glass	160 - 480	194
Tin cans	48 - 160	88
None ferrous metals	64 - 240	160
Ferrous metals	128 - 1120	320
Dirt, ashes, brick, e.t.c.	320 - 960	480

Source: Tchobanoglous et. al. (1977)