# Organo-mineral Fertilizers from Urban Wastes: Developments in Nigeria

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Waste disposal hitherto has been considered simply as removing waste from human settlements. With increasing urbanization, declining land availability, and the demand for resources this concept is being reexamined globally. However, waste is also to be seen as a resource that should benefit the community. The waste generated in a community is the reflection of their way of life, their wealth and culture (UNCHS, 1989).

In plant nutrition, sixteen elements play a vital role. Carbon, hydrogen and oxygen are supplied by air and water. Nitrogen, phosphorus and potassium are usually referred to as primary elements and calcium, magnesium and sulphur as secondary elements. In addition to these macronutrients, plants require seven other elements, zinc, iron, copper, manganese, boron, molybdenum and chloride in micro levels. These are called micronutrients or trace elements. However, sodium, silicon, cobalt and selenium are also required in small amounts to improve the yield and quality of crops. Compost provides all of these nutrients judiciously. The composting process is a great equalizer, balancing excesses of any one substance that might cause harm if applied to growing plants. Sobulo and Aduayi (1990) stated that "the future of agriculture in fertilizer use will lie on the development of organic based fertilizers". The composting process is a forgotten traditional practice. Population growth, rapid urbanization and fast economic growth due to petroleum resources have established inappropriate priorities among Nigerian farmers particularly after Independence. This paper describes developments in organic waste utilization for farming purposes in Nigeria.

## History of Organic Matter Utilization

The use of organic manures, compost, bio-fertilizer, farmyard manure, crop residues, and the dung of domestic animals is an age-old practice among the agricultural communities in West Africa, including Nigeria. It was also recorded that 20 to 30 tons /Ha of green manure were being used traditionally to maintain the organic matter in soils. Sullage and sewage farms are also common in various parts of the country, taking advantage of the polluted streams and sediments as sources of manure and irrigation water (Sridhar, 1995).

In Kano, refuse, stable manure and market sweepings were disposed of by burning in incinerators, or mixed with nightsoil and converted into compost. Wastes arising from cattle, donkey, horse, sheep and goat rearing were carefully conserved by the Kano farmers and put

back on their farms. A recent nation-wide survey by us revealed that some composting had been done in the Kaduna, Kano, and Maiduguri areas in the past, but that it is no longer practised on a large scale. The only large scale composting plant was operated in Kano between 1936 and 1942 under the supervision of Dr. Gilles, using nightsoil and city wastes (Gilles, 1946). The survey further revealed that stalks of various crops (corn, guineacorn, sorghum), rice husks, wheat, straw, vegetable peelings, cotton stalks, grasses, cocoa and banana leaves, excreta from poultry, cows, pigs, sheep and goats, ashes, wastes from slaughterhouses, breweries and other industries which process organically rich material, as well as other matter, were being used in various parts of the country (Sridhar et al, 1992; Sridhar et al, 1993). However, these methods were followed empirically and in practice, the increase in crop yields was marginal and there were long waiting periods between crops. The potential resources of these organic manures in Nigeria, surprisingly, are not explored to the fullest extent (Sridhar et al, 1992; Sridhar and Adeoye, 1995).

After Independence and particularly after the start of the oil economy, farmers abandoned the practice of waste utilization and and concentrated on chemical fertilizers. Nevertheless, an average Nigerian farmer is unable to procure and apply the recommended quantity of fertilizer and is satisfied with about 1 bag per hectare as against 4 to 5 bags by his counterpart in neighbouring countries. Currently, fertilizer use in Nigeria is on the increase with about 5 to 10 per cent increase annually between 1990 and 1995. Governmental policies on fertilizer imports and supply vary depending on priorities and there has been no continuity in policies. The domestic supply is limited and the farmers are handicapped by the shortage of imported fertilizers. This situation has helped the farmers to look inward. Some of the farmers in Kano go to neighbouring Chad to get poultry droppings to manure their garlic farms. Traders from the neighbouring Republic of Niger barter their resource potash against some of their food needs from Kano and Jigawa farmers from northern Nigeria (Sridhar, 1999 Unpublished Field survey).

A series of discussions with various scientists, engineers and managers in the waste disposal and agricultural fields during 1990 produced mixed reactions about the successful introduction of composting in Nigeria. Some of the basic questions raised are: the nature of raw materials available (particularly in certain areas), availability or adaptability of technology, financial implications for installations and operations, preparedness of the farmers to prefer compost over fertilizers, and the effect of distance for transportation on total cost. However, in recent years, there has been a tremendous change in their attitude. The historical development of various efforts on organic matter utilization are given in Tables 1 to 3.

## Waste Resources and their Nature

One of the major wastes in urban centres is municipal solid waste. It is produced at the rate of 0.43 kg/head per day and 60 to 80 per cent of it is organic in nature. The generation of waste also varies depending on the season, social activities, and socio-economic level of the area.

Market and food producing areas are the worst places where a large quantity of solid waste is generated. In addition to organic matter, the wastes contain iron, aluminum and other metals, glass, plastics and polythene, bones, ash, dust and other inorganic components. In addition to these common wastes, others arise from livestock, farm harvesting, plantations, industries, aquatic weeds and others. A detailed list of wastes and their composition is given in Table 4.

## Composting process

Compost is organic manure artificially prepared from plant residues and animal waste products using natural principles. The process is biological in nature. There are several methods of making compost. The most popular methods are the "Indore Process" devised by Howard and Ward at the Indian Institute of Plant Industry, Indore, and the other is the "Bangalore Process" developed by C.N. Acharya at the Indian Institute of Science, Bangalore, both in India. The former method makes use of an anaerobic system and the latter an aerobic system. The Bangalore method is faster and was preferred in composting development in Nigeria (Sridhar et al, 1985; Tchobanoglous et al, 1993; Onibokun et al, 2000; Das, 2002). The materials that can be used for successful composting and their composition are given in Table 4. The various operations involved and a flow chart is given in Fig. 1.

## Organo-Mineral Fertilizer Production – The Ibadan Experience

**Human and Machinery Requirements.** Waste management has two major components: technical and human. The development of the Organo-Mineral Fertlizer project in Bodija market is a clear example of an Environmental Planning and Management (EPM) process where these two aspects are blended. Ibadan has been enjoying the Sustainable Cities Programme initiated by the UNCHS. Thus at a City Consultative Forum in 1995, waste management was considered as a top priority for sustainable city growth. The Forum has formed a waste working group which has multidisciplinary stakeholders, viz. Market traders, Local Government, State Government, External Agencies, NGOs, Tertiary Institutions, Ibadan Waste Management Authority, and Community members. Each stakeholder has contributed to the success of the project in various forms, by giving land, materials, funds and other support. One of the authors has been a member of the Forum since its inception. For a good organo-mineral fertilizer plant, a variety of inputs are needed and these are given below (Flintoff, 1976).

**Land.** This should be unused municipal land, as extensive as possible, well drained, with a hard surface such as concrete or black-top; this hard surface provides sure footing for trucks and loaders and eliminates mixing of soil and gravel with trash; as much as possible, it should be far away from residential areas; there should be space for future expansion; the minimum areas required for the simpler systems are: 20 tonnes/day-0.5 Ha; 40 tonnes/day-0.75Ha; 80 tonnes/day-1.5 Ha; and 200 tonnes/day-3.00 Ha. A site area of 1 Ha would allow sufficient storage space for at least 4,000 $m^3$ of compost.

**Site characteristics.** The site should be level, dry and possess load-bearing qualities appropriate to the civil and mechanical installations; able to accommodate reception, storage and pre-treatment plant; windrowing area; post-treatment plants; compost storage area; mechanical maintenance facilities, administration, laboratory and welfare facilities.

**Water supply.** A steady water supply is required, whether it is a surface source or ground water source, to wet the material during processing.

**Electricity.** A regular supply of electricity with a minimum of 3 phases is required for various machine operations. A generating plant is also satisfactory if electricity is unstable. Manual operations may be limited to waste processing before sizing, blending and bagging.

**Access road network**. The siting should be as near as possible to the source of generation of wastes; otherwise the transportation cost will increase. Good roads are necessary for raw material supply and product delivery.

**Labour.** An average Nigerian labourer may be able to turn 1 ton of waste per day. An Asian labourer may be able to turn 1.5 tonnes / day (Flintoff, 1976).

**Machinery requirement.** The following are generally required but can be minimized if the process is made labour intensive. The machinery requirement depends on the type of design selected or recommended.

1. Weighbridge/ Weighing scale.
2. Storage area and required tools and machinery, e.g. grab crane for lifting, front end loader, etc.
3. Salvaging equipment: picking belts, magnetic extraction equipment.
4. Size reduction: hammermills, rasps, short- term drums, long-term drums, shears and cutters.
5. Windrow layout and management: conveyors, tractor, compost turning machines.
6. Screens: rotary, vibrating screens, ballistic separators.

The recycling process planned at Bodija Market, Ibadan, was composting the various wastes produced in the market, most significantly, the cow and vegetable wastes, along with others. Compost is made aerobically by mixing organic wastes and heaping in windrows for about three to four weeks with periodical wetting and turning (the frequency depends on the weather and degree of decomposition, but every 2 days initially and later, once in 5 days was found adequate). It is envisaged that a total of 20 to 25 tons of waste per day may be processed into compost. At completion, the waste material will be reduced to half of its original volume. The composting process essentially involves mixing a portion of cow waste and vegetable waste in the ratio, generally 1:3 (standardized with an optimal C: N ratio of 25 or 30: 1), keeping the mixture in windrows measuring 2 m wide, 1.5 m high and 20 m long for maturation for 21 days, storing for a further period of 3 to 6 months for complete stabilization after sieving to remove any non-biodegradables such as plastics, metals, gravel, etc. At periodic intervals during the maturation,

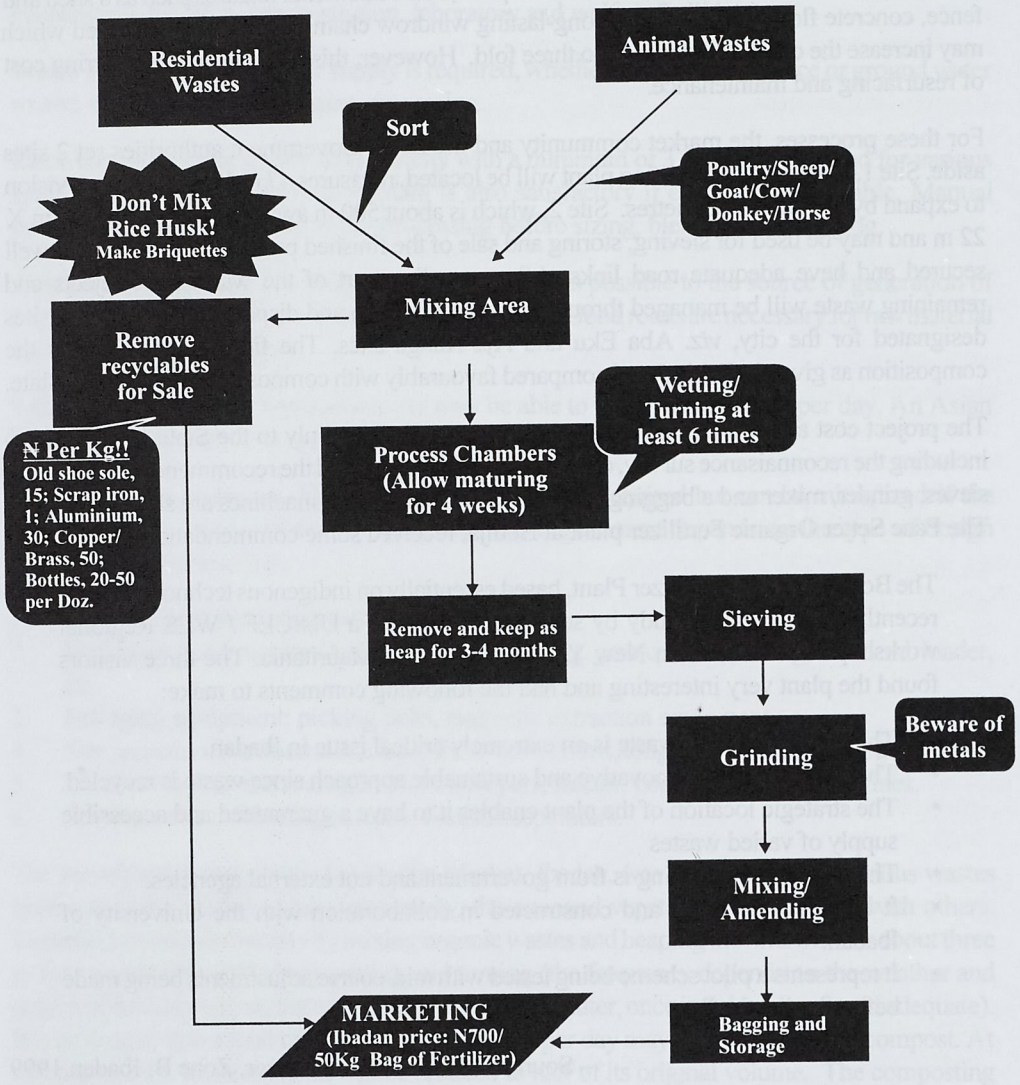
turning of windrows and maintenance of a certain level of moisture are essential. Even though the method is relatively inexpensive, due to the heavy rains in the region, and the intention to make the operations serve as a demonstration plant, some additional features such as a shed and fence, concrete flooring, and sturdy long-lasting windrow chambers were incorporated which may increase the capital cost by two to three fold. However, this will reduce the recurring cost of resurfacing and maintenance.

For these processes, the market community and the Local Government authorities set 2 sites aside. Site 1, where the composting plant will be located, measures 47 m X 36 m with provision to expand by another 6 to 8 metres. Site 2, which is about 500 m away from this site, is 52m X 22 m and may be used for sieving, storing and sale of the finished product. The sites were well secured and have adequate road links. After recycling part of the wastes, the rejects and remaining waste will be managed through regular collection and disposal at the disposal sites designated for the city, *viz.* Aba Eku and Aja Kanga sites. The finished product has the composition as given in Table 5 and compared favourably with composts available in the State.

The project cost about 7 million Naira (exact amount known only to the State Government) including the reconnaisance survey, construction of the sheds and the recommended machinery: sieves, grinder, mixer and a bagging machine. The shed and the machines are shown in Fig. 2. The Pace Setter Organic Fertilizer plant at Bodija, received some commendations:

> The Bodija Organic Fertilizer Plant, based essentially on indigenous technology, was, recently, the subject of study by some participants of a UNICEF / WES Regional workshop who came from New York, Abidjan and Mauritania. The three visitors found the plant very interesting and had the following comments to make:
>
> - The management of waste is an extremely critical issue in Ibadan.
> - The plant is a more innovative and sustainable approach since waste is recycled.
> - The strategic location of the plant enables it to have a guaranteed and accessible supply of varied wastes
> - The bulk part of funding is from government and not external agencies.
> - It is locally designed and constructed in collaboration with the University of Ibadan.
> - It represents a pilot scheme being tested with mid-course adjustments being made before replication".
>
> – Source: UNICEF/WES Officer, Zone B, Ibadan,1999

**Fig. 1. Flow Sheet for the Processing of Wastes into Organo-Mineral Fertilizer**



## Technology Transfer

The success of the Pace Setter Organic Fertilizer plant has encouraged others to adopt this technology.

A 5-ton per day capacity was built for a low income Ayeye community living in the inner core area of Ibadan. The design of this plant is an improvement over the one at Bodija in that the machinery is modified to operate horizontally. Some of the weak points were rectified. In the process a new local fabricator was trained. Segregation of wastes at source is incorporated into the scheme. It is community owned and managed with an income generation component (Fig. 3).

A composting plant was built for the Forcados terminal of Shell Petroleum Development Corporation in Delta State in the eastern part of Nigeria. This plant handles all the food waste generated from about 850 to 1000 people working for the oil company. Here food waste is mixed with grass cuttings produced from the lawns of the company (Fig. 4).

## Conversion of Compost into Organo-Mineral Fertilizer Pellets

Further elaborate studies conducted by our "Organo-Mineral Fertilizer Research and Development Group" at the University of Ibadan, have revealed that compost or organic manure may be supplemented with additional plant nutrients, and converted into pellets. The pellets can be handled easily by small scale farmers to carry and use on their farms. It is simple, cheap and has the added advantage of slow release of the nutrients when applied to the soil. The idea of pelletizing compost powder came from one of the discussions the authors had with the community. A farmer in Oyo State said "the compost is bulky and my car cannot carry it to my farm". This statement triggered ideas on how to make it into convenient pellets. Initially, a simple manually operated pelletizing machine was fabricated and used. It is designed for preparing 32 pellets with dimensions 6.4 cm long, 2.0 cm diameter with a volume of 20.11 $cm^3$ , each weighing 29.5 grams when dried. The freshly prepared pellets may be sun-dried and stored before use. The pellets were stable even after two years of storage under tropical humid conditions in Ibadan. The colour of the dried pellets was dark reddish brown and can vary depending on the binding agent used in the process. The advantage of pelletization is in the reduction of weight and volume of the original compost. The reduction in volume compared with freshly made and air dried compost used here was 70.5 and 54.5 per cent. The corresponding weight reduction for the same was 58.2 and 28.6 per cent. While this technology was being developed here, there were inquiries in an American journal, *Biocycle*, about the benefits of such pellets for farmers. This technology is unique and Nigeria has shown its value (John et al, 1995, 1996).

A larger pelletizer operated electrically and producing a greater quantity of pellets was further developed by Fadare, a member of our team through the support of RMRDC (Figs 5 and 6). The machine consists of four main parts: hopper, conveyor, compression chamber and prime mover.

The finished compost or organo-mineral fertilizer is mixed with a binder (usually clay), moistened with a certain level of water, sent to the compression chamber and extruded. For every revolution of the die, 850 pellets of 10 mm diameter are produced. Each pellet is 20 mm long and weighs10 g. The capacity of the machine is 10 tons per hour (Fadare, 2002 unpublished data). Talking about the pelletizer, the RMRDC said:

> The project has progressed well with the successful design, fabrication and test-running of the pelletizer which is the heart of the plant. The production of the pelletizer has stimulated great interest among the members of the National Commodity Farmers Association who witnessed its performance at the last 3rd Resources and Techno-Exposition held in December 1996 at Abuja (RMRDC, 1997).

**Organo-mineral Fertilizer Utilization**

The application of compost is a proven way of improving soil properties by supplying organic matter and micronutrients. Nigerian soils gain additional benefits: minimal nutrient losses due to erosion caused by heavy torrential rains and improvement of soils which are known for their low activity clay, low water holding capacity and low organic matter.

A variety of crops such as yams (Fig. 7), cassava, maize, green amaranth, sunflower, beans, and fruit crops were grown with the organo-mineral fertilizer both in green houses and on plots (Adeoye et al, 1993). The ornamental plant cultivators in all the major urban centres are the immediate users of the organic manure. The State Government has also used the manure on the flower garden in front of the Secretariat. The Northern States already know about the benefits of composting. They only need training in improved technology and mineral supplementation to suit the varying ecological zones and soil types. The rate of application was shown to be between 2.5 Tonnes /Ha and 7 Tonnes depending on the crop. This application rate has yielded better crops as compared to those grown on inorganic fertilizers such as N, P, K, formulations alone. Studies with N, P, and K fertilizers using maize indicated that optimum grain yield could be achieved at fertilizer application rates of between 100 - 200 N Kg/ha, 40 - 66 Kg P/ha and 20 - 90 Kg K/ha depending on the variety of the soil. The recommended manure application rates and the plant uptake of nutrients are given in Tables 6 and 7.

The "Task Force on Organo-mineral Fertilizer Testing in Kwara State" and other Farmers' Associations in the region have developed methods of propagating the use of organic fertilizers among the farmers. Small pamphlets were produced and circulated among their members. The messages indicated the soil problems, dosage of fertilizer, and benefits derivable for Nigerian soils.

Besides its fertilizing value for crop production, the organo-mineral fertilizer was also used to remedy soils contaminated with toxic chemicals. Sridhar, Adeoye and Etaghane (2001, unpublished data) showed that lead contaminated soils in Olodo village can be reclaimed

employing a phytoremediation technique using the organo-mineral fertilizer and cultivating a sunflower crop. The lead levels were brought down to permissible limits stipulated by the Federal Ministry of Environment. Application of organic fertilizers also helps in erosion control.

**The Way Forward**

Waste management involves three principal methods of disposal: sanitary landfill or land reclamation, incineration and composting. Nigeria faces environmental degradation and inadequate food supplies for the growing population. The solid wastes in the urban and rural communities are rich in organic matter amounting to 60 to 70 per cent which can be converted into compost which has an immediate market. Unlike the wastes from industrialized countries, these wastes do not contain high amounts of toxic and hazardous chemicals (Sridhar and Bammeke, 1986).

Composting is a viable option which may be practised among various settlements in the country. The settlements in Nigeria may be grouped under individual/household level, community level, Local Government level, State Government level, and Federal Government level. While the Federal Government is involved with policy issues, the other sectors may embark on composting developments. At the household level, small scale composting methods will be ideal. They may be called "Backyard composting systems". Government may give certain incentives to promote them in organized and willing communities.

At the LGA level, small-scale, semi-mechanical types may be encouraged involving various stake holders within the LGA set up. Movement of waste for composting may best be done by the LGA as an incentive and a Waste Management Committee may be set up to manage the plant with more community participation. At the State level, medium sized composting plants with a 20 to 50 tonne capacity may be ideal. These plants may at the same time serve as demonstration plants for others to replicate (Sridhar et al, 1991).

In the northern parts of Nigeria, animal power may be used effectively to defray the cost of moving raw materials and the finished products. In various developed countries, every county or the equivalent, owns a composting plant, an incineration plant, a sanitary landfill and a sewage treatment plant as communal basic infrastructure. While the county contributes to their maintenance, it derives benefits in the form of byproducts, better environment and sound health.

In areas affected by frequent and intensive rains, most of the operations have to be done under a suitable roof. Even if the rain wets the compost, it will dry up very soon as the heap generates heat while in storage. If the compost heap is prepared in the form of a cone, only

the peripheral areas may become wet, leaving the inside dry. More frequent turnings will then be needed.

Depending on the finances available, several alterations may be made to cut down the cost. Such changes may be in the modification of materials used in the structures, the size of the plant and sophistication of mechanical structures involved. One should not worry about the cost as a major factor in this context. A well-planned and managed composting plant may break even within 2 to 3 years of starting production. Material input, the quality of the finished product and a ready market will determine this. In Nigeria, the time is ripe and there is always a ready market under tropical conditions.

Maintaining quality control is very vital for acceptance by the farmers. Bags of commercial compost should carry clear and informative labels. The following information is mandatory: nutrient conent, C/N ratio (generally <20), organic matter content (generally >60 %, moisture content (generally set at <35 %, pH, Electrical Conductivity, and % inorganic materials (gravel, plastic, etc.). The following criteria should also be used by the producers (though not necessary to include on the label): heavy metals such as Zn, Pb, and Hg, germination tests and temperature stability. Because of the variable materials used in composting, all these criteria should be shown as within a particular range, rather than as a specific quantity (Quality Control of Organic Fertilizers, 1997).

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The authors would like to thank various people who assisted them in this project. Thanks are due to State Government officials particularly Mr. Ayodele Adigun, who translated the project from academic data to community project, members of Working Groups and the Sustainable Ibadan Project of the the Project Manager of Pace Setter Organic Fertilizer Project, various officials from UNICEF and UNDP and the communities at large.

**Table 1. Compost and organo-mineral fertilizer development and use in Nigeria (1936-1997)**

| | |
|---|---|
| 1936-1942 | Eric C. Gilles, a Medical Officer, introduced composting of night soil and town refuse in Kano; showed that waste can generate revenue (£ 480 per annum was generated) from the sale of compost referred as 'Black Gold'. |
| 1975 | A. Agbola and Obigbesan reported that a combined application of 20 Kg N and 5 tons Farm Yard Manure / Ha raised yields of tuber crops. |
| 1982 | Cooker concluded that Farm Yard Manure performed better than chemical fertilizers when applied to crops. |
| 1982 | M. K. C. Sridhar conducted experiments on the production of compost using the sewage sludge and city refuse of Zurich at Swiss Federal Institute of Technology, Dubendorf, Switzerland and assessed the nitrogen changes and amino acid composition. |
| 1983 | Sridhar made a country wide survey on the composting practices before and after Independence and collected valuable information from very senior community members from Yoruba, Igbo and Hausa areas. |
| 1983-86 | M. K. C. Sridhar and E. O. Ewenkhare studied the acceptability of composting as a means of solid waste disposal in Shasha market community; several small scale trials on composting with various raw materials from markets and communities conducted. |
| 1987 | An informal linkage was established between Department of Preventive and Social Medicine and Agronomy for collaborative work on compost development and agronomical applications through a team (Sridhar, Omueti and Adeoye); later it was enlarged into Organo-mineral Fertilizer Research Group. |
| 1987–1992 | Sridhar and Adeoye conducted composting experiments at Ajibode, University of Ibadan Estate, and University College Hospital; first harvested maize from Ajibode was sent to the then Vice-Chancellor (Professsor Ayo Banjo) on 28 July 1989 as a gift; composting in windrows and in pits was tested and windrows were found good; several crops such as maize, cassava, yam, okra, green amaranth, beans, ornamental plants were tried in green houses and on plots on exhausted soils and sand cultures; Professor A. B. O. Oyediran, a one time Vice Chancellor was a regular visitor to the field sites at the University and also was involved in project development. |
| 1992-94 | M.K.C. Sridhar, M. C. Asuzu and O. O. Egbewumi carried out a community based composting study at Elesu community in Oyo State and prepared a large quantity of compost from daily generated refuse and animal droppings. |
| 1993-94 | N. M. John, G. O. Adeoye and M. K. C. Sridhar developed conversion of compost into pellets; a simple manually operated pelletizer was designed and tested; Raw Materials Research and Development Council has shown interest in the technology and requested the team to submit a proposal. |
| 1994-97 | Joint venture between Ministry of Science and Technology and University of Ibadan in Organo-mineral Fertilizer pelletizer development and trials. |

**Table 2. Federal Ministry of Science and Technology –University of Ibadan Joint Venture on Organo-mineral Fertilizer Pellets (1994-1997)**

| | |
|---|---|
| 1994-95 | A proposal on "Production of bio-fertilizer through composting and pelletization of organic manures" was submitted (May 1994) to RMRDC by John; a panel chaired by Dr. Obio-Nelson critically examined this, kept the pelletizer in their offices and interviewed John; a grant was assured but not awarded; the pelletizer was kept for a long time. |
| 1995 | A formal joint venture between the University of Ibadan (Organo-mineral Fertilizer Research Group) and Federal Ministry of Science and Technology (Raw Materials Research and Development Council, RMRDC), was signed (January 2) by the CEO, RMRDC and the Vice Chancellor; O. Bamiro from the Mechanical Engineering Department who had some projects with the RMRDC was named as the Chairman of the joint venture by the RMRDC; J.A. I. Omueti was named as the Principal Consultant and M. K. C. Sridhar and G. O. Adeoye to be the Consultants to the project; funding to come from the RMRDC for development and the University to provide the infrastructure and technical input; no remuneration was fixed until project took off with returns; the project was to be executed in 9 phases over a 4 year period; An improved, electrically operated pelletizer was designed and fabricated (D. A.. Fadare, a Ph.D student of Bamiro); the trials of pellets in the country's 4 ecological zones were planned; 6 students were taken for their Ph.D programmes (John, Ogazi, Usman, Hassan, Ojo, and Sule) for field trials; a composting shed was built and RMRDC gave a vehicle for the project; several undergraduate students developed various minor projects to supplement the data; poultry droppings, city refuse, brewery waste, water hyacinth and saw dust were used as raw materials; several crops such as maize, rice, cassava, yam, okra, green amaranth, beans, ornamental plants were to be tried in green houses and on plots on exhausted soils and sand cultures; some work went on in the first phase; encouraging results were obtained. |
| 1996 | Federal Ministry of Science and Technology (RMRDC), awarded the University of Ibadan, a National Merit Award at the Techno-Expo '96 (December 9-14); the "golden" border around the plaque for the award "reflects the value placed by the Federal Ministry of Science and Technology on the project". |
| 1997 | Funds were not regular; Consultants were dropped without any formal notice; students were on their own without any funding forthcoming; no further information available since. |

**Table 3. Compost and organo-mineral fertilizer developments and use in Nigeria (1995 – 2003)**

1995 October 23-27, Sustainable Ibadan Project conducted City Consultation and M.K.C. Sridhar was invited where waste management was considered as a major problem needing immediate solutions; market waste management working group was formed and Sridhar was associated with the group; meetings were held at Bodija, Ibadan.

1997 Office of the Military Administrator, Project Coordination Department, Ibadan, by their letter dated December 18 appointed Sridhar as Consultant to design and set up the Pace Setter Organic Fertilizer Plant at Bodija, Ibadan; the Organo-mineral Fertilizer Research and Development Group of University of Ibadan has moved in for this task (Omueti opted out of the Group).

1998 On July 16, the Pace Setter Organic Fertilizer Plant (25 tons per day waste processing capacity) was formally commissioned by the then Military Administrator, Col. Usman; Grade A (high N) and Grade B (natural) types were produced and marketed; Mr Ayodele Adigun as Permanent Secretary has seen through the project successfully.

1998 Ibadan Waste Management Authority, and the Sustainable Ibadan Project separately received (October 4) "National Awards for Best Practices in Improving the Living Environment" for the Bodija Pace Setter Organic Fertilizer Plant and managing the waste.

1999 UNDP / UNCHS Sponsored M. K. C. Sridhar (as Lead National Consultant) and Soji Taiwo (Project Manager, Sustainable Ibadan Project) to sensitize all the Environmental Protection Agencies in the 36 States, Local Governments, NGOs, and FCT in the country on conversion of waste to wealth strategies using the Pace Setter Fertilizer plant as a model; the first meeting was held at Minna during October 19-21, and subsequently workshops were held in Kaduna (October 26-28), Owerri (November 9-11) and Sango-Ota (November 16-18) to cater to the States in the region.

2000 On June 30, SPDC Forcados terminal built and commissioned a composting plant (designed by M. K. C. Sridhar, G. O. Adeoye, and built by B. B. Ayade and O. T. Yusuf) to manage food waste produced from a canteen serving 250 staff and up to 750 to 1000 people altogether; segregation is practised effectively by the contractor using the facility.

2001 M. K. C. Sridhar, G. O. Adeoye and O. AdeOluwa successfully experimented on a natural plant commonly found in Nigeria which can supplement nitrogen up to 3.8% to normal compost; Adeoye, Sridhar and R. R. Ipinmoroti extracted potassium from cocoa pods on a commercial scale which can be mixed with compost.

2002 A community based waste sorting centre / organo-mineral fertilizer plant was designed and commissioned (November 28, 2002) for Ayeye Community, Ibadan to process about 5 tons of refuse per day; the facility can also take up recyclables (segregation of plastics, metal scrap, glass and paper were incorporated) along with kitchen and other organic wastes from the community; M. K. C. Sridhar, G. O. Adeoye, A. Ayorinde, T. T. Tairu and B. Wahab were the Consultants; UNDP funded the project.

2003 M. K. C. Sridhar, A. O. Coker, I. O. Akinjogbin and G. O. Adeoye used human urine for crop production which is comparable to organo-mineral and chemical fertilizers currently under use.

**Table 4. Nutrient composition of various organic wastes / manures available in Nigeria**

| Organic waste / Manure | N, % | $P_2O_5$, % | $K_2O$, % |
|---|---|---|---|
| Cow dung (Fresh) | 0.3 to 0.4 | 0.1 to 0.2 | 0.1 to 0.3 |
| Horse dung (Fresh) | 0.4 to 0.5 | 0.3 to 0.4 | 0.3 to 0.4 |
| Sheep / Goat dung (Fresh) | 0.5 to 0.7 | 0.4 to 0.6 | 0.3 to 1.0 |
| Poultry manure (Fresh) | 1.0 to 1.8 | 1.4 to 1.8 | 0.8 to 0.9 |
| Night soil (Fresh) | 1.0 to 1.6 | 0.8 to 1.2 | 0.2 to 0.6 |
| Sewage / Septic Sludge (dry) | 2.0 to 3.5 | 1.0 to 5.0 | 0.2 to 0.5 |
| Sewage Sludge, Activated (dry) | 4.0 to 7.0 | 2.1to 4.2 | 0.5 to 0.7 |
| Urine, Cattle | 0.9 to 1.2 | Trace | 0.5 to 1.0 |
| Urine, Horse | 1.2 to 1.5 | Trace | 1.3 to 1.5 |
| Urine, Sheep | 1.5 to 1.7 | Trace | 1.8 to 2.0 |
| Urine, Human | 0.5 to 1.0 | 0.1 to 0.2 | 0.2 to 0.3 |
| Farmyard manure | 0.5 to 1.5 | 0.4 to 0.8 | 0.5 to 1.9 |
| Green manures: | | | |
| Cowpea | 0.75 | 0.15 | 0.58 |
| *Gliricidia sepium* | 3.78 | 0.733 | 2.2 |
| *Chromolena odorata* | 2.50 | 0.70 | 4.3# |
| Water hyacinth | 4.50 | 0.49 | 5.17 |
| Dried blood | 10.0 to 12.0 | 1.0 to 1.5 | 1.0 |
| Fish manure | 4.0 to 10.0 | 3.0 to 9.0 | 0.3 to 1.5 |
| Bone meal (Raw) | 2.0 to 4.0 | 20.0 to 25.0 | Trace |
| Bone meal (Steamed) | 1.0 to 2.0 | 25.0 30.0 | Trace |
| Wood Ash | | | |
| Household | 0.5 to 1.9 | 1.6 to 4.2 | 2.3 to 12.0 |
| Coal | 0.73 | 0.45 | 0.53 |
| Crop Residues: | | | |
| Paddy husk | 0.3 to 0.5 | 0.2 to 0.3 | 0.3 to 0.5 |
| Straw | 0.36 | 0.08 | 0.71 |
| Groundnut shell / stem | 1.6 to 1.8 | 0.3 to 0.5 | 1.1 to 1.7 |
| Maize Stem | 1.1 | 0.16 | 1.45 |
| Maize cobs | 0.7 | 0.160 | 0.602 |
| Cocoa pod husk | 1.1 | 0.55 | 5.3 |
| Kola Pod husk | 1.12 | 0.24 | 3.9# |
| Plantain peelings | 0.8 | 0.16 | 2.64 |
| Cassava peelings | 0.65 | 0.092 | 1.93 |
| Yam peelings | 0.2 | 0.298 | 0.544 |
| Sugarcane trash | 0.08 | 0.138 | 0.48 |
| Oil cakes: | | | |
| Neem cake | 5.2 to 5.3 | 1.0 to 1.1 | 1.4 to 1.5 |
| Groundnut cake | 7.0 to 7.3 | 1.5 to 1.6 | 1.3 to 1.4 |
| Cottonseed cake | 6.4 | 2.9 | 2.2 |
| Castor cake | 4.3 | 1.8 | 1.3 |
| Palm kernel cake | 2.8 | 0.34 | 0.698 |
| Sheanut cake | 2.3 | 0.37 | 3.1 |
| Coconut cake | 3.0 to 3.2 | 1.9 to 2.0 | 1.7 to 1.8 |
| Saw dust | 0.2 | 0.18 | 0.458 |

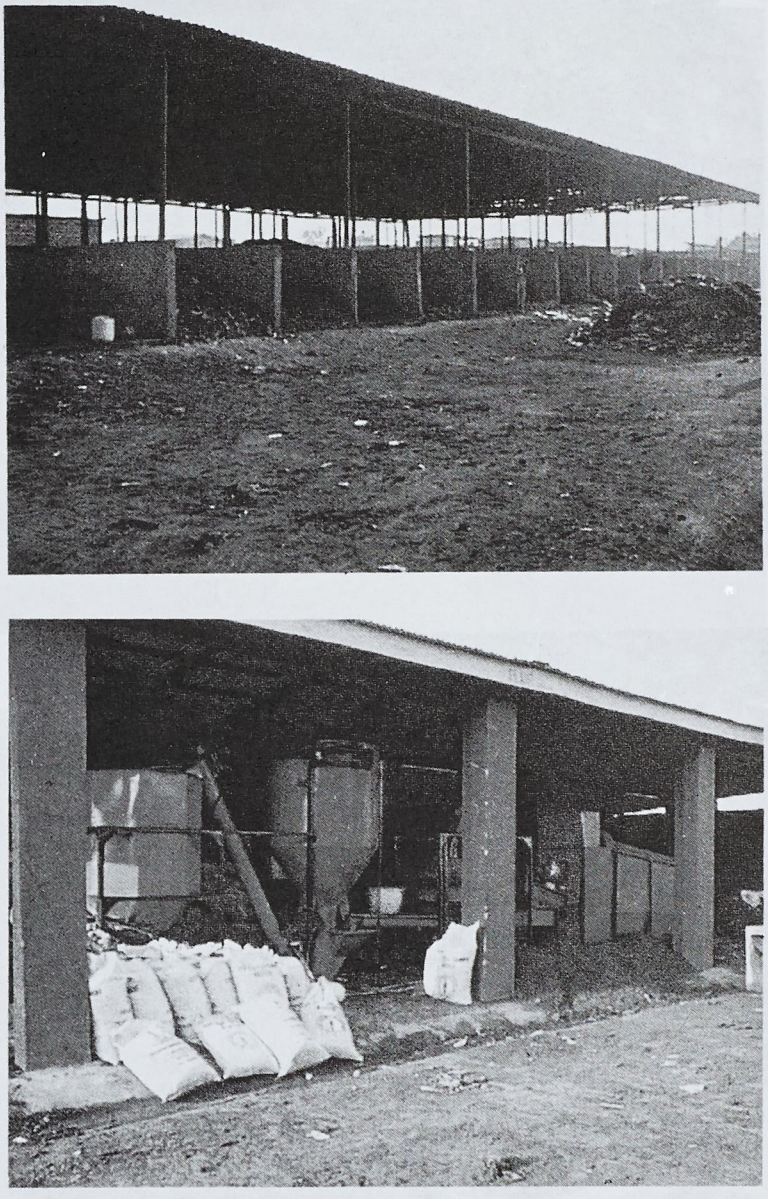

Fig. 2. Pace Setter Organo-mineral Fertilizer Plant at Bodija Market, Ibadan

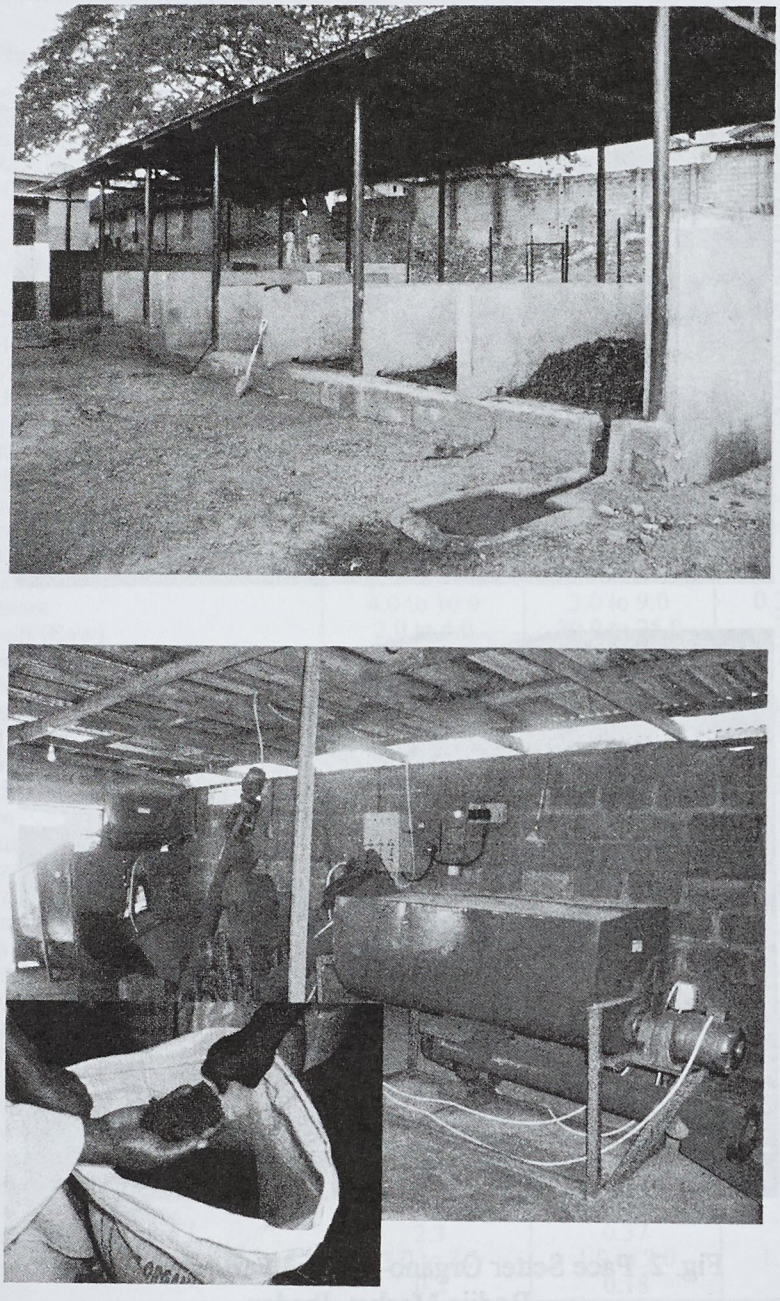

Fig. 3. A Community Based Waste Sorting Centre at Ayeye Community, Ibadan

Fig. 4 Composting Plant at Forcados to Treat Food Wastes

**Table 5. Composition of Pace Setter Organo-mineral Fertilizer as compared to Others Used in the State**

| Composition (dry weight basis) | Pace Setter, Grade A, (Amended) n=10 | Pace Setter, Grade B, (Natural) n=12 | Market source Oyo A n=4 | Market source Oyo B n=4 |
|---|---|---|---|---|
| Nitrogen, N % | 3.25 | 1.244 | 1.16 | 0.94 |
| Phosphorus, P % | 1.795 | 0.799 | 1.48 | 0.28 |
| Potassium, K % | 1.652 | 1.094 | 1.82 | 1.15 |
| Calcium, mg/Kg | 3.61 | 2.042 | 3.62 | 1.19 |
| Magnesium, mg/Kg | 0.84 | 1.38 | 0.18 | 0.11 |
| Iron, ppm | - | - | 0.27 | 0.25 |
| Zinc, ppm | - | - | 276 | 290 |
| Copper, ppm | - | - | 25 | 22 |
| Manganese, ppm | - | - | 32 | 19 |
| Chromium, ppm | - | - | ND | ND |
| Lead, ppm | - | - | ND | ND |

Samples were analysed during the years 1998 and 1999; results were provided by Mr. T. T. Tairu, Project Manager, Pace Setter Fertilizer Plant; International standards: N=not less than 1.0%, P=not less than 0.5%; K=not less than 0.5%

Table 6. Maize yield under various treatments

| Fertilizer treatment | Plant height, cm | Grain yield, Tons/Ha | Number of seeds per cob |
|---|---|---|---|
| Control soil, (n=12) | 177.97 | 2.02 | 197 |
| NPK fertilizer (15:15:15) (n=10.2) | 237.67 | 5.40 | 463 |
| Organo-mineral fertilizer, 1.5 Tons/Ha (n=14) | 212.5 | 6.06 | 435 |
| Organo-mineral fertilizer, 3 Tons/Ha (n=12) | 238.93 | 6.52 | 546 |

Maize variety: SUWAN-1 DMR-SRW; Soil has N=0.15%, P=13.29mg/Kg; K=0.05 cmol/Kg

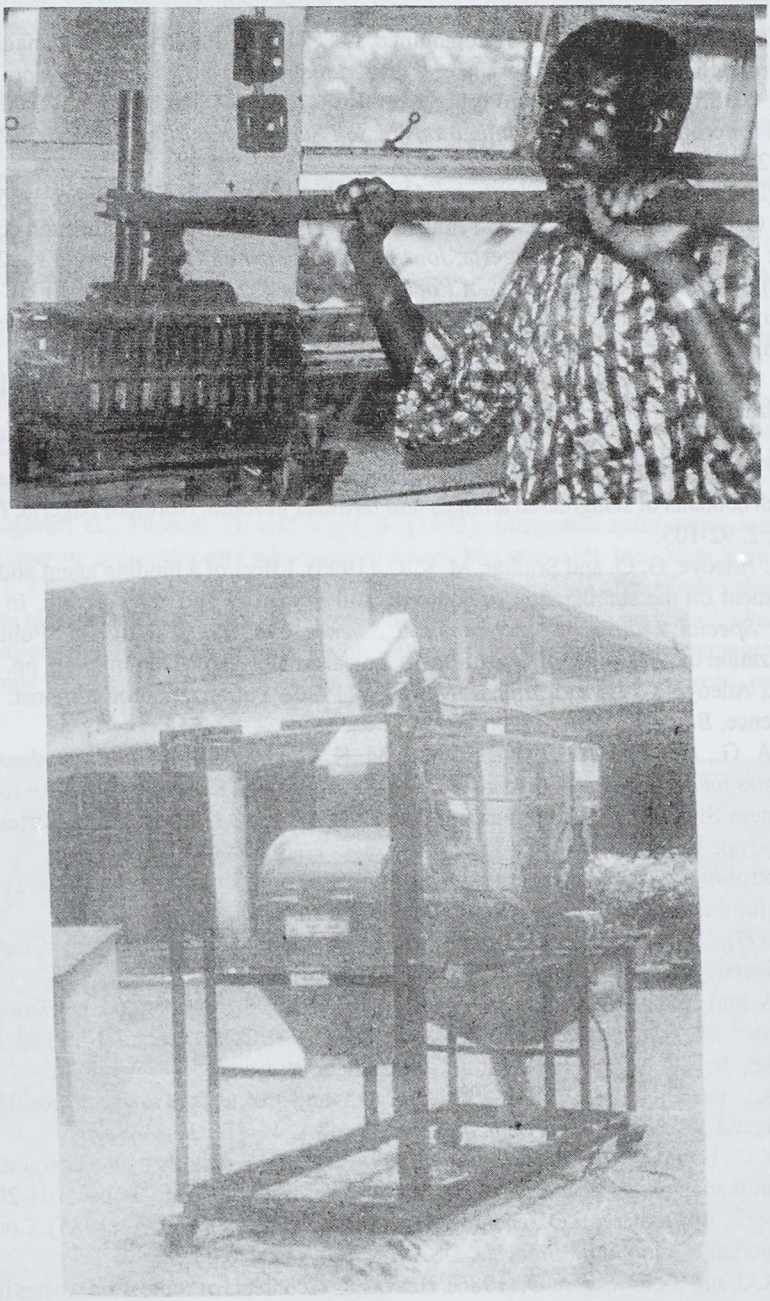

**Fig. 5. The First (Top) and the Improved Pelletizer, Ibadan**

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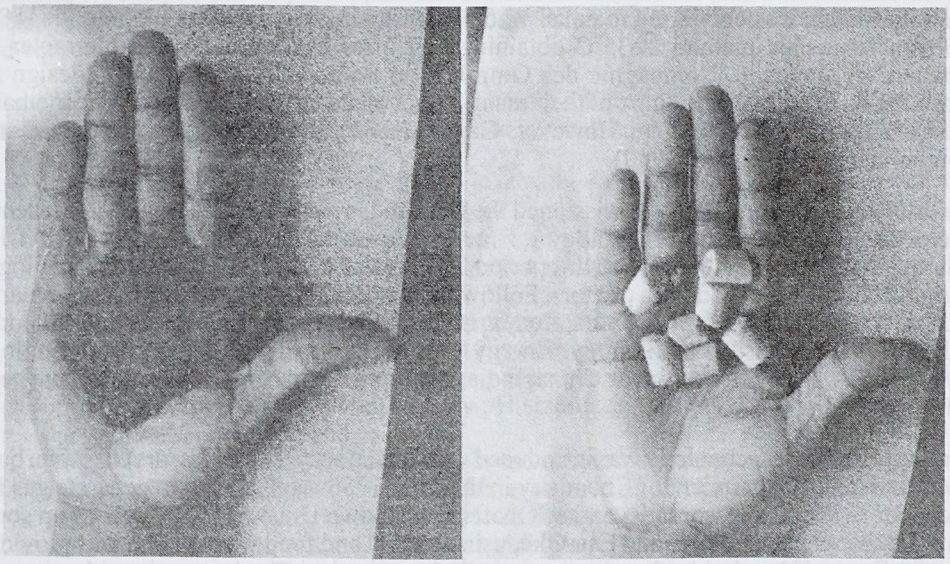

Fig. 6. Organo-mineral Fertilizer: Powder and the Pellet Forms