

UNILORIN SCIENCE AND ENGINEERING PERIODICALS  
(USEP)

1 - 104

ISSN 0189 - 8787



*Journal of*  
**Research Information in Civil Engineering**  
**(RICE)**

Published  
by

Department of Civil Engineering  
University of Ilorin  
Ilorin, Nigeria

**Vol. 5, No. 1, 2008**

**USEP: Journal of Research Information in Civil Engineering**  
Published by  
Department of Civil Engineering, University of Ilorin, Ilorin,  
Nigeria

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## **WATER HYACINTH BASED WASTEWATER TREATMENT SYSTEM AND ITS DERIVABLE BYE- PRODUCTS**

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### **Abstract:**

The public health consequences of poor management of wastewater treatment systems are becoming enormous while on the other hand the need to minimize wastages and to make the most valuable use of nutrients in wastewater is receiving global interest. This paper analyzes the bye products from a water hyacinth (*Eichhornia crassipes*) based wastewater treatment system. A combination of empirical and analytical methods was adopted. The empirical method involved the pilot plant study on water hyacinth grown on domestic wastewater while the analytical method is the laboratory analysis of the bye products. The results indicated that the harvested water hyacinth biomass has appreciable moisture content of 93% and the dry matter was 7%. On dry matter basis, the inorganic components in parts per million (ppm) are 24 of copper, 20 of iron, 20 of zinc, and 18 of Manganese. Crude ash represents 19.25% of dry matter while fibre and protein represent 18.08% and 10.13% of dry matter respectively. The chemical composition in g/kg of sludge ash are 10.00 of Calcium, 1.25 of Sulphur, 0.83 of Magnesium, 0.77 of Aluminum, 0.70 of Sodium, 0.58 of Silicon, 0.55 of Potassium, 0.41 of Copper, 0.38 of Iron, 0.37 of Zinc, 0.36 of Manganese, 0.29 of Nickel and 0.1 of lead. The average pH value of the sludge ash was 7.32 and the average bulk density was 275 kg/m<sup>3</sup>. Based on the nutrient resources contained in the biomass, it could be converted into products such as animal feed, fertilizer, compost, mulch, paper, fibre and biogas.

### **Keywords:**

Wastewater, water hyacinth, biomass, sludge ash, nutrient, bye-products.

### **1. Introduction.**

Over the years, the use of aquaculture concepts for treatment of wastewater is to optimize recovery of nutrients or pollutants from wastewater. When wastewater

is free of toxic compounds, the nutrients are recovered and transformed into valuable biomass, which is easy to harvest. Different methods exist for the treatment of wastewater. All wastewater treatment technologies are required to reduce the level of suspended solids and organic matter in wastewater.

Conventional wastewater treatment processes consists of a combination of physical, chemical and biological processes and operations to remove solids, organic matter and, sometimes nutrient from wastewater (Wisaam et al., 2007). The use of aquatic plants for recovery of nutrients and recalcitrant compounds from wastewater represents an alternative technology with high potential for application in small and medium sized cities. Biologically, the aquatic plant systems are far more diverse than present day mechanical treatment systems.

Several aquatic plants have been used in wastewater purification. Among the most widely used are water hyacinth (*Eichhornia crassipes*), duckweed (*Lemna* spp, *Spirodela* Spp and *Wolffia* spp), totora and cattails. Most aquatic treatment systems consist of one or more treatment chambers (ponds). Typically; each chamber is dominated by one species of plant, but in some cases a variety of plants will be combined for a particular treatment objective (Chongrak, 1989). *Eichhornia crassipes* can be distinguished from most other floating and mat-forming aquatic plants by its highly glossy leaves, the almost one-sided swelling of its petioles and its showy lilac flowers (Holm, et al., 1991). It can tolerate extremes of water level fluctuation and seasonal variations in flow velocity, and extremes of nutrient availability, pH, temperature and toxic substances (Gopal, 1987). It is believed to have invaded Nigerian waters in Lagos in 1985. Water hyacinth is a large tropical aquatic plant with attractive lavender flowers and shiny, bright green leaves on long petioles. The central structure of the plant from which the stem, roots and stolons arise, is a stoloniferous rhizome, 6cm in diameter and up to 30cm in length with several short internodes. Each node bears a leaf and roots (Gopal, 1987).

Untreated wastewater has a BOD<sub>5</sub> ranging from 100mg/l to 300mg/l. Pathogens or disease causing organisms are present in wastewater. Wastewater also contains nutrients (such as ammonia and phosphorus), minerals, and metals. Ammonia can range from 12 to 50 mg/l and phosphorus can range from 6 to 20mg/l in untreated wastewater (Karen, 1996; Metcalf and Eddy, 2003; Wisaam et al., 2007).

There are many potential benefits offered by the use of treated wastewater, including safe and low-cost treatment and disposal of wastewater; the conservation of water and replenishment of groundwater reserves; and productive use of nutrients in wastewater.

In recent years all wastewater treatment systems have come under more critical examination and more stringent discharge requirements. Consequently, a large percentage of communities, especially those with wastewater treatment lagoons, have been required to upgrade their existing facilities. One new method that has been the focus of several, recent research projects involves the use of vascular aquatic plants as the principal, biological filtration agent. Water hyacinth (*Eichhornia crassipes*), in particular, has received much attention because of its hardiness and high productivity, especially when grown in domestic sewage lagoons (Rebecca et al., 1980).

The results from several studies have shown that water hyacinth will use appreciable amounts of the inorganic forms of Nitrogen and phosphorous found in wastewater. Over the years, different wastewater treatment systems have been developed while some are presently on experimental scale. The absence of opportunities for resource recovery to defray the high operation and maintenance costs of conventional treatment systems attracts other methods with naturally based technologies. As viable alternatives, these newly found approaches contribute to a reduction in the pathogenic contamination of surface and ground water.

Scarbrook and Davis (1971) showed how water hyacinth removed 6.9g of Nitrogen, 2.9g of phosphorous and 8.7g of potassium from sewage pools. In studies where the ability of water hyacinth to remove lead, cadmium and mercury was tested, the plant removed approximately 65% of mercury from polluted water with 10ppm (parts per million) of lead and 1ppm (part per million) of cadmium and mercury (Wolverton and McDonald, 1978). Wolverton and McKown (1976) observed that one hectare of water hyacinth plant is potentially capable of removing 160kg of phenol per 12 hectare from water polluted with phenol. A similar experiment by Wolverton and McDonald (1975) indicated water hyacinth's ability to remove about 0.44mg of silver, 0.57mg of cobalt and 0.54mg of strontium per gram of plant dry matter in 24 hours. The plants can potentially extract 263g of silver, 341g of cobalt and 326g of strontium per hectare per day provided that the metal-saturated plants are harvested at regular intervals. Organic loading rates and detention times used for water hyacinth systems are similar to those used for conventional stabilization ponds that treat raw wastewater. However, effluents from water hyacinth systems can be much better in quality than from a conventional stabilization pond, particularly with respect to suspended solids (algae), metals, trace organics and nutrients.

The main objective of wastewater treatment is to get a clear effluent but associated with this effluent is sludge. Sludge is produced in large volumes and

it is composed of substances responsible for the offensive character of untreated wastewater. In recent years, aquatic weeds such as water hyacinth (*Eichhornia crassipes*) have received great attention, not only in the management of water resources but also their use as the principal biological agent in low cost aquaculture technique for treating wastewaters. During wastewater treatment, water hyacinth in conjunction with micro-organisms living on and around the plant's root recovers nutrients and pollutants from wastewater. On many occasions, water hyacinth has demonstrated that it is an excellent depollutant for wastewaters (Ojoawo, 2002).

The plant is extremely tolerant towards, and has high absorbing capacity for heavy metals, such as Cd, Cr, Co, Ni, Pb and Hg etc, which could be utilized for the biocleaning of industrial wastewater (Upadhyay and Tripathi, 2007; Abou-Shanah 2007; Maine, 2006; Skinner, 2007). Not only the heavy metals, *Eichhornia crassipes* can also remove toxins, such as cyanide, a process which is environmentally beneficial in areas that have endured gold mining operations (Ebel, 2007).

Fig.1 shows a schematic diagram of a waste water cycle utilizing water hyacinth for treatment. From the diagram, the end product is the treated effluent. Accumulated sludge and the harvested water hyacinth biomass are bye products. The average moisture content of the examined water hyacinth was 93% while the dry matter was 7%. The objectives of this study are targeted at identifying the bye-products during wastewater treatment in a system utilizing water hyacinth for treatment, determination of the physical and chemical properties of the bye-products and finding out how the bye-products and end products could be harnessed for useful purposes.

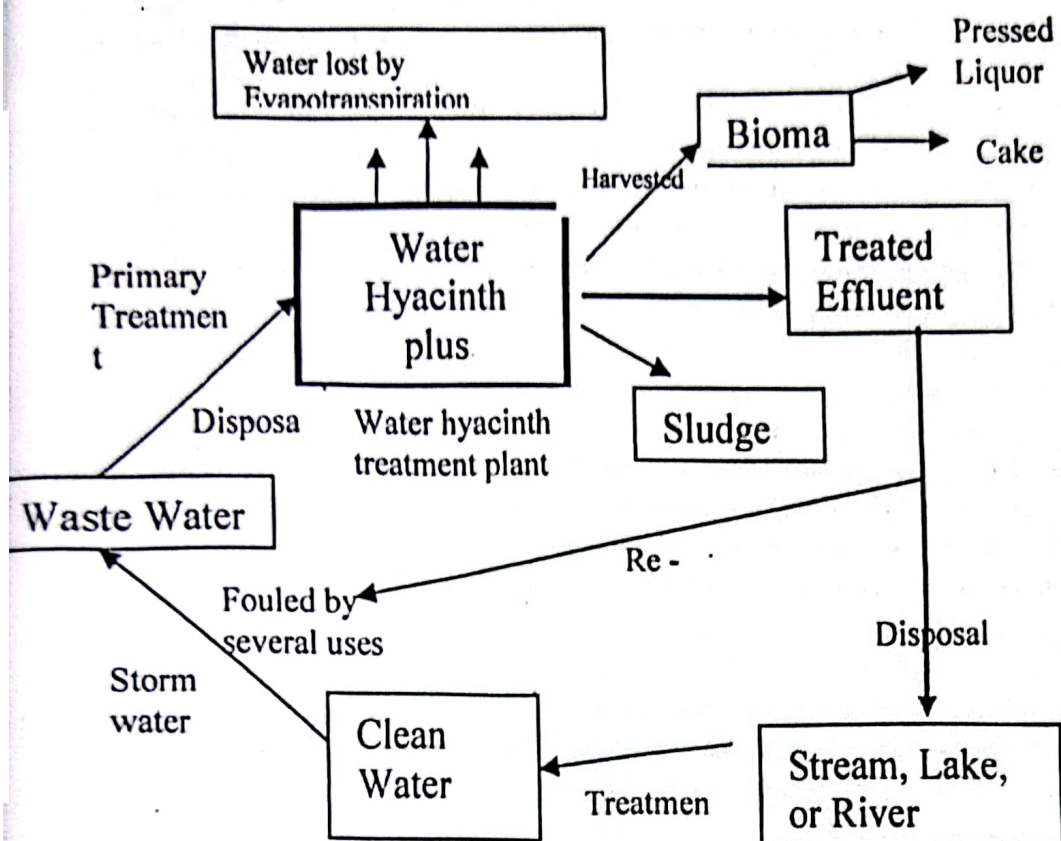


Fig. 5. Summary of a water hyacinth based wastewater treatment process

## 2. Research Methodology

### 2.1 Materials and Methods

The method adopted to achieve the objectives of the study is a combination of empirical and analytical methods. The empirical method involves pilot plant studies on water hyacinth grown on domestic wastewater. The analytical method is a laboratory analysis of the by products. Complimentary collections of information from various sources and the results from the laboratory tests were then compared with the components of existing products to determine their viability for usage either as equal substitutes or as better alternatives. Water hyacinth seedlings were collected from a water hyacinth stand at the University of Ibadan. The wastewater for this study was obtained from a septic tank serving a residential building. It is a water carrying wastes containing human excreta (domestic wastewater). About 50 liters of wastewater was carefully placed in 45cm diameter plastic container. The duo makes up a plastic pool.

Two plastic pools were stocked with water hyacinth seedlings to make a pilot plant of a water hyacinth based treatment facility.

The hyacinths were kept in active growing phase by clipping dead plant tissues weekly. One-quarter of the surface area was cleared once in two weeks by harvesting. The domestic wastewater in the plastic containers were renewed weekly so as to replenish the nutrients up taken by the plants during wastewater treatment and to replace water lost by evapo-transpiration. After ten weeks, all the hyacinths were harvested and the water column between the plastic surface and the accumulated sediments were removed. The organic particles and the accumulated plant materials that settled at the bottom of the plastic pools (sludge) was partially de-watered by squeezing out the water in a perforated container and sun-dried for two weeks for complete removal of moisture while the hyacinths were taken to the laboratory for analyses immediately after harvesting. The dewatered sludge was fired at 700°C to remove organic matter in a furnace at the food technology laboratory, University of Ibadan. The sludge ash collected after the burning process was taken to the soil microbiology laboratory of Institute of Agricultural Research and Training, Moor Plantation, Ibadan, for analysis. The samples were analyzed chemically according to prescribed official methods for analysis described by the Association of official Analytical Chemist (A.O.A.C, 1984).

The analysis was replicated twice for each sample. The bulk density of the sludge ash samples was determined as described by Anderson and Ingram (1993) while a glass-electrode pH meter was used to measure sludge pH. The nitrogen content of the hyacinths was determined by the routine semi-micro Kjeldahl procedure. The crude protein content of the dried sample was estimated as kjeldahl Nitrogen x 6.25. Dry matter content was obtained by oven drying at 100°C to a constant weight. It is based on the loss of water and other volatile matter at 100°C.

When the organic component of the water hyacinth sample was burnt off at 550°C, the residue is ash, which consists of inorganic components in the form of their oxides. Crude fibre was determined by filtration of the sample through glass fibre papers and drying at 105°C to a constant weight. This is to drive off moisture. It was later ashed at 550°C. The difference in the weights gives the weight of fibre.

The amount of copper, zinc, magnesium, manganese and iron present in the samples were found using Atomic Absorption Spectrophotometer (AAS). They were calculated in parts per million (ppm). The levels of calcium, sodium and potassium were read in a Jenway Digital flame photometer after being

standardized with respective minerals. Phosphorus was determined by the vanado-Molybdate colorimetric method. Turbid metric method was used to determine the amount of sulphur in the sample digest. The percent light transmittance was read on the Bausch and Lomb Spectronic -70- Electro-Photocolorimeter. The chemical compositions of the sludge ash were analyzed in the laboratory using atomic absorption spectrophotometer. The bulk density of the sludge ash sample was determined as described by Anderson and Ingram (1993) while a glass electrode pH meter was used to measure sludge pH.

### 3. Results and Discussion.

#### 3.1 Results

The chemical composition of water hyacinth expressed on dry matter basis is presented in Figures 2. The raw sample analyses show that the samples have an average moisture content of 93 percent and 7 percent dry matter. The chemical properties of the sludge ash collected after the burning process are presented in Table 1 and Figures 3 to 5. The physical characteristics of raw sludge based on pilot plant studies show that it is essentially composed of organic particles and detritus plant materials. It is brownish in colour and has inoffensive odor. The average pH value of the sludge ash samples is 7.32 and the average bulk density is  $275\text{kg/m}^3$ . It shows that hyacinths have appreciable high moisture content. On dry matter basis, the inorganic components consists mainly of 1.58% of Nitrogen, 0.80% of Sulphur, 0.16% of Calcium, 0.16% of magnesium 0.12% of Phosphorus, 0.04% of potassium, 0.03% of sodium, 24 ppm (parts per million) of copper, 20 ppm of iron, 20 ppm of zinc, and 18 ppm of Manganese. Crude ash represents 19.25% of dry matter while crude fibre and protein represent 18.08% and 10.13% of dry matter respectively. The chemical composition in g/kg of sludge ash are 10.00 of Calcium, 1.25 of Sulphur, 0.83 of Magnesium, 0.77 of Aluminum, 0.70 of Sodium, 0.58 of Silicon, 0.55 of Potassium, 0.41 of Copper, 0.38 of Iron, 0.37 of Zinc, 0.36 of Manganese, 0.29 of Nickel and 0.1 of lead. The average pH value of the sludge ash was 7.32 and the average bulk density was  $275\text{ kg/m}^3$ . Crude protein represents 10.13% of the dry matter while crude fibre and ash represents 18.08% and 19.25% of dry matter respectively.

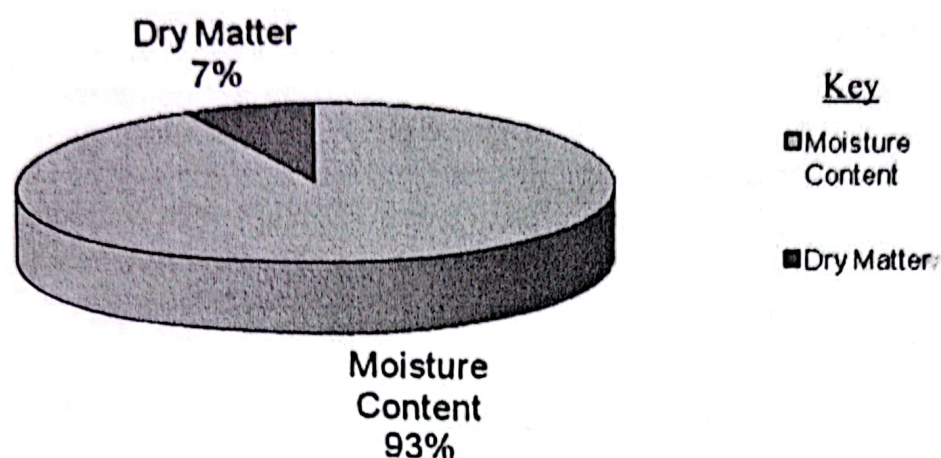


Fig.2. Dry Matter and Moisture Content of Water Hyacinth Samples

Table 1. Chemical Properties of Sludge Ash

| Mineral   | Composition in g/kg |
|-----------|---------------------|
| Lead      | 0.1                 |
| Nickel    | 0.29                |
| Manganese | 0.36                |
| Zinc      | 0.37                |
| Iron      | 0.38                |
| Copper    | 0.41                |
| Potassium | 0.55                |
| Silicon   | 0.58                |
| Sodium    | 0.70                |
| Aluminium | 0.77                |
| Magnesium | 0.83                |
| Sulphur   | 1.25                |
| Calcium   | 10.00               |

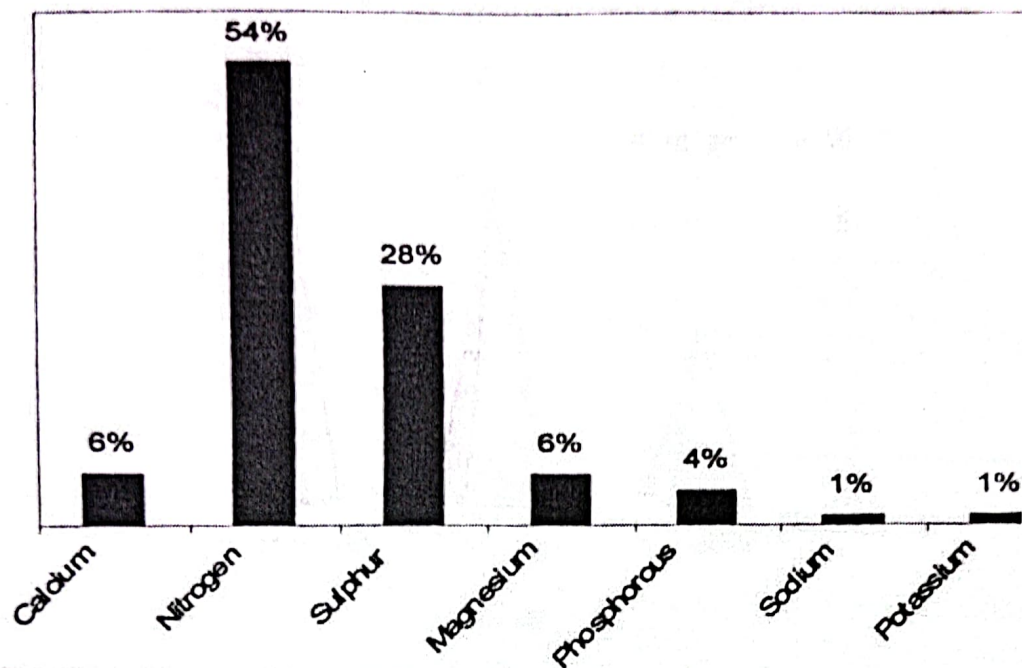
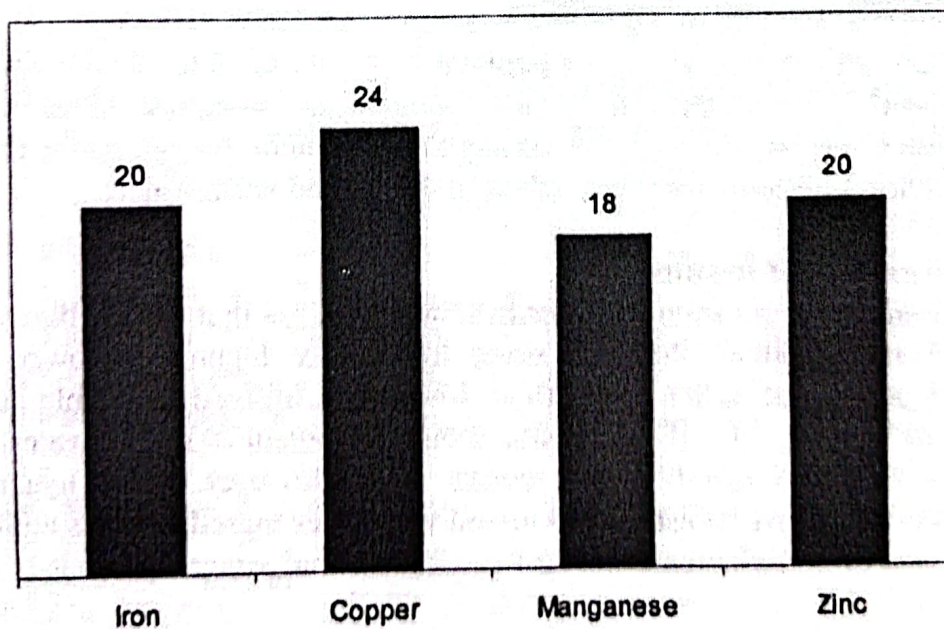


Fig. 3. Percentages of Macronutrient Content of Water Hyacinth Sample (Matter Basis)



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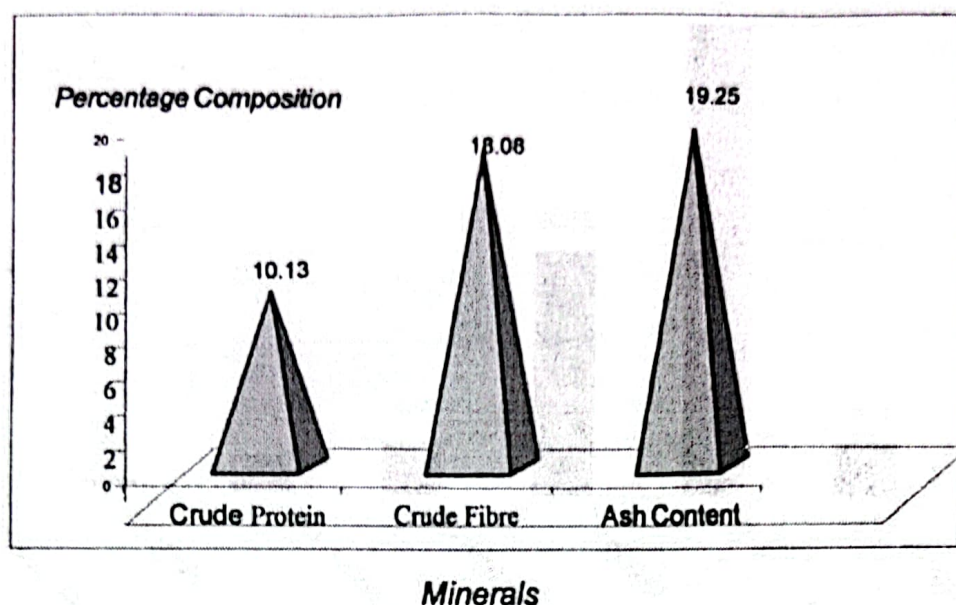


Fig. 5. Percentage of Minerals in Sludge Ash (Dry Matter Basis)

Based on green house studies on a water hyacinth culture (Ojoawo, 2002), laboratory analyses indicated water hyacinth's ability to reduce the faecal coliform count of raw wastewater sample by 20%, Biochemical Oxygen Demand (BOD) by 51.1%, the Chemical Oxygen Demand (COD) dropped by 53.8% while pH slightly reduced. The pungent and irritating odour of the raw wastewater sample disappeared during the treatment period while the colour (deep yellow) turned almost colourless in the treated wastewater.

### 3.2 Discussion of Results

The chemical composition of water hyacinth vis a vis that of Alfalfa (*Medicago sativa* L.); an edible foliage of some forage tree legumes, showed that the mineral content of water hyacinth is low when utilized as edible foliage as shown in Table 2. Also the excessive moisture content (93%) in water hyacinth samples limits its suitability as animal feed. However, when hyacinths are processed to remove moisture and mixed with other ingredients, its edibility and nutritional value is increased. The table shows that water hyacinth is lower in protein content, richer in copper, magnesium and zinc content and has almost the fibre content as Alfalfa. This shows that the harvested water hyacinth can be used as hay and silage for animal once protein supplement is added. The high Ash content may make it unpalatable and can react on the general animal metabolism. Addition of appropriate wheat bran, groundnut cake and fish waste will provide the needed protein supplement and increase its palatability. The mixed product could be boiled to aid the mixing processing and increase the

digestibility of the fibre content. Also the high nutrient content make is a good mulching or compost material. When used as mulch, it will suppress weeds and conserve moisture and decayed residues will serve as a source of organic matter and nutrients to the soil. Because of high ash content, burnt water hyacinth residue will be valuable as a base for commercial fertilizer.

Table 2. Chemical Composition of Water Hyacinth and Alfalfa

| Item        | Water Hyacinth (%)<br>**(A) | Alfalfa*(%) |
|-------------|-----------------------------|-------------|
| Protein     | 13.03                       | 24.22       |
| Crude Fibre | 20.16                       | 19.91       |
| Calcium     | 3.09                        | 0.56        |
| Phosphorus  | 0.45                        | 0.30        |
| Potassium   | 4.04                        | 2.70        |
| Sodium      | 0.05                        | 0.12        |
| Magnesium   | 0.42                        | 0.37 (ppm)  |
| Copper      | 3.23                        | 11.95       |
| Manganese   | 554.66                      | 39.83       |
| Zinc        | 21.00                       | 21.53       |
| Ash Content | 19.25                       | 9.4         |

\*NRC (1971). \*\*Aremu (2002). PPM = Parts Per Million

## 4.0 Conclusion

The analytical results from the chemical composition of water hyacinth and sludge ash show that as bye-products of waste water treatment they would find applications in agriculture, as raw materials, replacement for construction materials and as energy sources. However, fluctuations in the chemical composition of hyacinth and sludge under different conditions make it difficult to predict a general usefulness as animal feed, compost or bio-fertilizer. Water hyacinth mineral content is a function of its stage of growth and the quality of the waste water in which it is grown. Growth rates of the plant seem to have optimum levels and the plants are periodically harvested to prevent overcrowding. Biogas production from anaerobically digested waste water sludge can fluctuate depending on volatile solids content of the sludge feed. Since the plant has abundant nitrogen content, it can be used a substrate for biogas production and the sludge obtained from the biogas process can then be used as compost or fertilizer. It can also feed live stocks, such as cattle, sheep or chicken (Gunnarsson and Peterson, 2007). However, due to easy accumulation of toxins, the plant is prone to get contaminated when used as feed.

The possibility of using harvested hyacinths as a source of pulp, paper, egg trays and craft items is limited to purposes for which high mechanical strength would not be required. To eliminate the risks of mineral imbalance and contamination (due to contact with human or animal waste and other contaminants), it is suggested that hyacinths should be used for non-edible purposes, or chopped, ashed and ensiled before use. Optimum utilization of sludge can best be achieved after incineration at high temperature.

Used up water from residences, institutions, establishments or industries may contain hazardous compounds, large amounts of impurities and pathogenic micro-organisms, hence from thence; it must be collected and given suitable treatment before it is released to the environment.

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