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# Harvesting of Hartbeespoort Dam micro-algal biomass through sand filtration and solar drying

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## HIGHLIGHTS

- Microalgae were harvested through sand filtration and solar drying.
- Volumetric harvesting yield of 4.6 kg $L^{-1}$ $a^{-1}$ was achieved.
- Aerial harvesting yield of 47.3 kg $m^{-2}$ $a^{-1}$ was achieved.

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## ABSTRACT

Renewable energy sources such as biomass are becoming more and more important as alternative to fossil fuels. One of the most exciting new sources of biomass is microalgae. One of the major obstacles in the commercial production of microalgae as feedstock for biomass-to-liquid fuels, is the development of energy efficient and cost effective harvesting methods for the separation of micro-algal biomass from its growth medium. In this study, a promising method of harvesting micro-algal biomass from the Hartbeespoort Dam through a combination of sand filtration and solar drying was investigated, which could be used to increase the energy efficiency and cost effectiveness of an integrated biomass-to-liquids process. Micro-algal biomass was collected from the Hartbeespoort Dam and the wet biomass was allowed to separate from the aqueous phase for 24 h through its natural buoyancy. The bottom aqueous layer was drained and the top green layer of wet biomass was poured onto metal palettes containing buildings sand and left in the sun to dry for 24 h. An average dry weight of 7.6 g of dried micro-algal biomass from the Hartbeespoort Dam was harvested after one day of sun-drying on a patch of 0.0484 $m^2$ or 497.7 g of building sand. An average, annualized, volumetric harvesting yield of 4.6 kg $L^{-1}$ $a^{-1}$ of dry weight micro-algal biomass was achieved per liter of Hartbeespoort Dam pulp and an average, annualized, aerial harvesting yield of 47.3 kg $m^{-2}$ $a^{-1}$ of dry weight micro-algal biomass was achieved per square meter of drying area. Micro-algal biomass from the Hartbeespoort Dam was successfully harvested by sun-drying on building sand. The building sand substrate improves the separation of water from the wet micro-algal biomass. As water is absorbed into the sand, it increases the drying area and thus increases the drying rate of the micro-algal biomass. Solar radiation provides the energy to evaporate the moisture. Thermo-chemical liquefaction is one of the preferred methods to extract bio-oils from microalgae, but is very energy-intensive. After extraction of bio-oils, micro-algal biomass rests could be sand-filtered, sun-dried and combusted to provide heating for the liquefaction section. Sand filtration and solar drying has the potential to produce 9938 GJ $ha^{-1}$ $a^{-1}$ of renewable energy which could be used to offset the energy requirements of an integrated biomass-to-liquids process. Harvesting costs could also be reduced from 20% to 30% of the total cost of biomass-to-liquids production to 18–19% by utilizing sand filtration and solar drying.


## 1. Introduction

According to the Energy Information Administration [1], global energy demand is projected to increase by 49% in the next 25 years. Global oil consumption is expected to grow from 86 million barrels per day in 2007 to 104 million barrels per day in 2030. The world's total proven oil reserves are estimated at 1.293 trillion barrels according to the Oil & Gas Journal [2]. Under these growth assumptions, less than half of the world's total proven oil reserves would be exhausted by 2030. As these oil reserves shrink, alternative liquid fuels, like biodiesel and bio-ethanol, are becoming more and

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**Nomenclature**

| | |
|---|---|
| $A$ | drying area ($m^2$) |
| $CV$ | calorific value (MJ/kg) |
| $t$ | ideal drying time (days) |
| $V$ | volume of liquid (L) |
| $W_d$ | dry weight of micro-algal biomass (kg) |
| $W_w$ | wet weight of micro-algal biomass (kg) |
| $y_A$ | annualized aerial harvesting yield per drying area (kg $m^{-2}$ $a^{-1}$) |
| $y_D$ | harvesting yield of dry weight micro-algal biomass per wet weight fraction of biomass (wt.%) |
| $y_E$ | annualized energy harvesting yield per drying area (GJ $ha^{-1}$ $a^{-1}$) |
| $y_V$ | annualized volumetric harvesting yield per volume of dam water (kg $L^{-1}$ $a^{-1}$) |
| $\eta$ | effective drying time per year (d/a) |

more important as alternative energy sources to oil. The world produced over 33 billion liters of these bio-fuels in 2004. Biodiesel production is the fastest growing alternative liquid fuel, growing at a rate of more than 30% per annum, and production is projected to reach the 12 billion liter mark at the end of 2010 [3]. Among the many oil sources for biodiesel production, such as rapeseed oil, soybean oil and sunflower oil, microalgae promises the highest yield per kilogram of biomass. Microalgae have much faster growth-rates than terrestrial crops and their oil yield per unit area are estimated at approximately 9.84 L $m^{-2}$ per year; this is 16 times greater than the next best crop, oil palm [4]. One of the largest reservoirs of micro-algal biomass in South Africa is the Hartbeespoort Dam, located 37 km west of Pretoria, and covering a surface area of approximately 20 $km^2$. The Hartbeespoort Dam has great potential for micro-algal biomass production and beneficiation due to its size and close proximity to major urban and industrial centers. The harvesting of micro-algal biomass is one of the most inefficient and costly steps in the whole biomass-to-liquids (BTL) value chain. Cultivation costs may contribute between 20% and 40% of the total cost of BTL biodiesel production [5], while harvesting costs may add 20–30% to the total cost of oil production through algal biomass [6]. One of the major obstacles in the commercial production of microalgae as feedstock for biomass-to-liquid fuels, is the development of energy efficient and cost effective harvesting methods for the separation of micro-algal biomass from its growth medium. In this study, a promising method of harvesting micro-algal biomass from the Hartbeespoort Dam through a combination of sand filtration and solar drying was investigated, which could be used to increase the energy efficiency and cost effectiveness of an integrated biomass-to-liquids process.

## 2. Theory

### 2.1. Cyanobacteria and microcystis aeruginosa

Dense populations of the cyanobacterium *Microcystis aeruginosa* dominate the Hartbeespoort Dam throughout the year, comprising over 90% of the total algal biomass. These algal blooms are stimulated by the influx of large quantities of nitrates and phosphates from the run-off of fertilized agricultural land and effluent from sewage plants [7]. Buoyancy in cyanobacteria, like *M. aeruginosa*, are regulated by a number of mechanisms, such as turgor pressure regulation, the form of stored carbohydrates, and the regulation of gas vacuole synthesis [8].

### 2.2. Harvesting yield equations

The annualized volumetric harvesting yield of harvesting micro-algal biomass from the Hartbeespoort Dam through sand filtration and solar drying can be calculated according to the following equation:

$$y_V = \frac{W_d \eta}{V \cdot t} \quad (1)$$

where $y_V$ is the annualized volumetric harvesting yield in (kg $L^{-1}$ - $a^{-1}$); $W_d$ is the dry weight of micro-algal biomass in (kg); $V$ is the volume of liquid from the Hartbeespoort Dam in (L); and $t$ is the ideal drying time in days; and $\eta$ is the effective drying time per year (d/a). The annualized aerial yield of harvesting micro-algal biomass from the Hartbeespoort Dam through sand filtration and solar drying can also be expressed as the dry weight of micro-algal biomass harvested per square unit of drying area per unit of time, and can be calculated according to the following equation:

$$y_A = \frac{W_d \eta}{A \cdot t} \quad (2)$$

where $y_A$ is the annualized harvesting yield in (kg $m^{-2}$ $a^{-1}$); $W_d$ is the dry weight of micro-algal biomass in (kg); $A$ is the surface area available for sand and solar drying in ($m^2$); $t$ is the ideal drying time in days; and $\eta$ is the effective drying time per year (d/a). The yield of harvesting micro-algal biomass from the Hartbeespoort Dam can also be expressed as the dry weight of micro-algal biomass harvested per wet weight micro-algal biomass fraction in the Hartbeespoort Dam pulp, and can be calculated according to the following equation:

$$y_D = \frac{W_d}{W_w} \times 100\% \quad (3)$$

where $y_D$ is the harvesting yield in weight percentage; $W_d$ is the dry weight of micro-algal biomass in (kg) and $W_w$ is the wet weight fraction of micro-algal biomass in Hartbeespoort Dam pulp obtained through natural buoyancy separation in (kg).

### 2.3. Energy yield equation

The annualized energy yield of harvesting micro-algal biomass from the Hartbeespoort Dam through sand filtration and solar drying and then combusting it can be calculated according to the following equation:

$$y_E = y_A \times CV \times 10 \quad (4)$$

where $y_E$ is the annualized energy yield in (GJ $ha^{-1}$ $a^{-1}$); $y_A$ is the annualized harvesting yield in (kg $m^{-2}$ $a^{-1}$); $CV$ is the calorific value of the dried micro-algal biomass in (MJ/kg).

## 3. Experimental

### 3.1. Source of harvesting

Samples of micro-algal biomass were collected from the Hartbeespoort Dam (Fig. 1).