Review of Moxham Report operations at Biochar industries

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Background

This report summarises the findings of an on-site assessment of the Moxham retort operations at Biochar Industries, Kunghur, New South Wales, Australia. The assessment was conducted over the period 19 to 21 July 2012, by Dr. James Joyce and Mr. Christian Gruhler, of Black is Green Pty Ltd., with a follow up visit on 28 July by Dr. Joyce and Mr. Trevor Barrows and 12-13 January by Dr. Joyce.

Objective of assessment

Black is Green Pty Ltd. (BiG) is a both a producer and buyer of carbonised biomass. These materials are most often sourced by BIG for end use as biochar based products. BiG's company values dictate that biochar must be:

- Sourced as locally to the end use as possible; for example BIG will not import product sourced from outside Australia for the Australian market.
- Produced from ethically sourced and traceable biomass feedstocks of consistent quality.
- Be produced in a manner consistent with the principals espoused in the British Biochar Foundation Biochar Quality Mandate. This includes considerations such as:
    - Control of emissions to appropriate modern standards
    - Operation to modern standards for protection of health, safety and the environment
    - Life cycle emissions of the production process

Included in this assessment report are recommendations to improve the emissions controls, yield and productivity of the Biochar Industries Moxham kiln system and the product finishing activities (grinding and screening).

Operations

During the first assessment visit a large (1800 mm diameter) Moxham kiln was operated over a 12 hour cycle and assessed. The operation of a smaller Moxham was visually evaluated during the second site visit.

The light up procedure utilises a small amount of fossil fuel, however from a life cycle analysis perspective this was minor compared to the overall time of operation and quantity of char produced.

Feedstock characteristics

The primary feedstock used by Biochar Industries is self-harvested timber from a previously neglected forestry operation, collected as part of a land maintenance activities conducted by Biochar Industries. The timber available includes several Eucalyptus species. Most of the timber used at this stage is previously fallen timber. The plan with respect to felled timber is to season this in a stacked form for a period of more than 12 months prior to use.

On occasions other feedstocks, such as pallet waste and demolition waste is used. This material was seen to introduce nails into the product and has some, albeit small, potential to introduce treated wood or contaminated wood into the production process.

Moisture

Moisture is a primary consideration in the production of biochar via almost any technology. During the assessment visit rainfall affected the prepared feedstock to the extent that yield from the kiln was noticeably impacted (possibly by as much as 50%).

The Biochar Industries Kunghur site is in a high rainfall area, hence uncovered storage and handling of prepared feedstock is not feasible for much of the year. Dry storage and, ideally, active drying capacity is recommend.

> Recommendation: Biochar industries install a 20 or 40 foot shipping container to allow storage and drying of prepared (ie. split) timber. Drying options in include passive solar, activate ventilation and hot air circulation from a heat source such as a Moxham kiln, a batch biochar retort, rocket stove or small wood combustor.

Operating principal

The Moxham concept is simple and robust in operation. It may be described as a top lit updraft (TLUD) gasifier with a variation from the standard TLUD approach that feedstock (ie. lumber and split timber) is progressively introduced onto the top of the char bed. The concept is not dissimilar to the fire pit methods practiced in the past by Josiah Hunt of Hawaii Biochar and others. The key difference from fire pit methods is that all of the flame from freshly pyrolysing feedstock is contained within the main chamber on the Moxham Klin, where it is more effectively oxidised (combusted) than under conditions where heat is rapidly lost on exposure to ambient air.

The kiln emits significant heat from the steel side wall. This heat can be used to pre-dry feedstock that is placed in close proximity to the side of the kiln. Doing so provides the benefit of shielding other equipment and personnel from inadvertent direct contact with the heat from the kiln sides. The existing baskets (IBC frames) can be used for this purpose, provided adequate access to the kiln is maintained.

Each burn currently uses approximately 7 baskets of timber, to yield approximately 1 cubic meter of char. This is a volumetric yield of 14% and an estimated mass yield of 9%. This is a low yield by modern standards for carbonisation technology which seek to achieve yields above 20% by weight. Dry fuel and semi-continuous operation should be capable of increasing the mass yield to better than 15%.

Recommendations

The following recommendations are made to improve the productivity and performance:

a) Feedstock drying and dry storage

Dry feedstock will reduce light up time and emissions. This was evident in across the different burns conducted at each site visit.

b) Regular day time operation is easier to manage and safer to conduct than a 14-18 hour burn.

Biochar Industries have already implemented changes that facilitate burn times of less than 10 hours.

c) Modify site layout to reduce the number of materials handling operations and the labour intensity.

The site is naturally sloped and has been terraced. This can be used to advantage by ensuring that the process flow of materials is from the top to the bottom of the site. This means cutting and splitting timber at the top terrace (ie. where the Moxham is located now), operating the retort at the next level down (ie. between the current Moxham location and the char grinding shed), then grinding, screening and bagging below that (ie. in the existing open shed)

d) Set up for semi batch operation, i.e. char removal on the run.

This will increase yield and hence productivity and total emissions. One means of achieving this is illustrated later in the report.

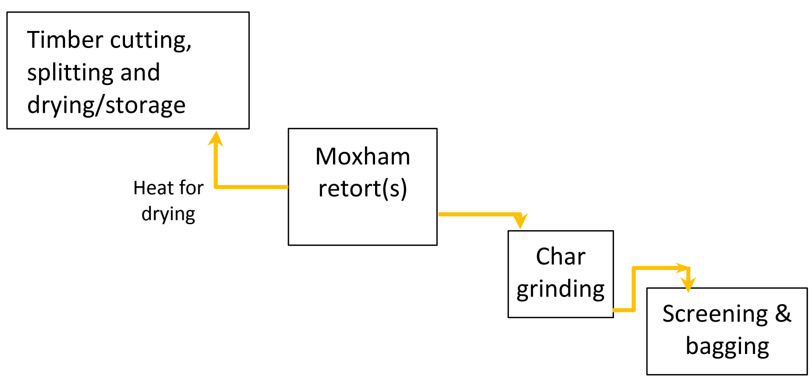


Figure 1 Recommended Process flow

Emissions performance

Qualitative assessment

Figure 2 shows the emissions during early light up and later in the light-up phase. Visible smoke emissions were moderate during light-up and minimal during operation. The generation of visible emissions (in particular the white coloured indicator of ash release) is used as a means to determine when timber should be added. Particulate emissions were not measured during the assessment, however visual assessment was made. The visible emissions, even during the 30-40 minutes of early light-up were vastly less than a traditional charcoal operation (pit or retort style).

Figure 2 Klin during early light up and late in the light up phase

The key to effective control of emissions from biomass pyrolysis or gasification is **T**ime **T**emperature and **T**urbulence. For this reason it is recommended that the Moxham not be filled or operated in a manner where flames rise above the sides of the vessel. In simple terms flames exposed to open air lose heat too rapidly to achieve efficient destruction of pollutants. In fact open flames provide the correct conditions for the formation of dioxins, one of the most carcinogenic and environmentally persistent group of compounds known.

Quantitative assessment

Exhaust gas quality was assessed visually and using a Testo 340 gas analyser with integral sample pump, temperature probe, and chemical cells for ppm by volume readings of carbon monoxide (CO) and oxygen (O_2) Carbon dioxide is calculated by the Testo on the assumption of a preselected carbon to hydrogen ratio in the off-gas, based on a preset “fuel” selection. For the tests the “Light Oil” preset “fuel” was selected to represent the carbon to hydrogen ratio of the offgases. This utilises a CO_{2max} value of 15.4 vol% and reference oxygen of 3vol% O_2 (as opposed to 20.3 vol% and reference oxygen of 13 vol% for full wood combustion).

Emissions readings were taken throughout the 12 hour burn on 20/21 July 2013. CO readings varied from 1500 to 5000 ppmv.

The figure below compares the emissions performance of the large Moxham retort against other technologies.

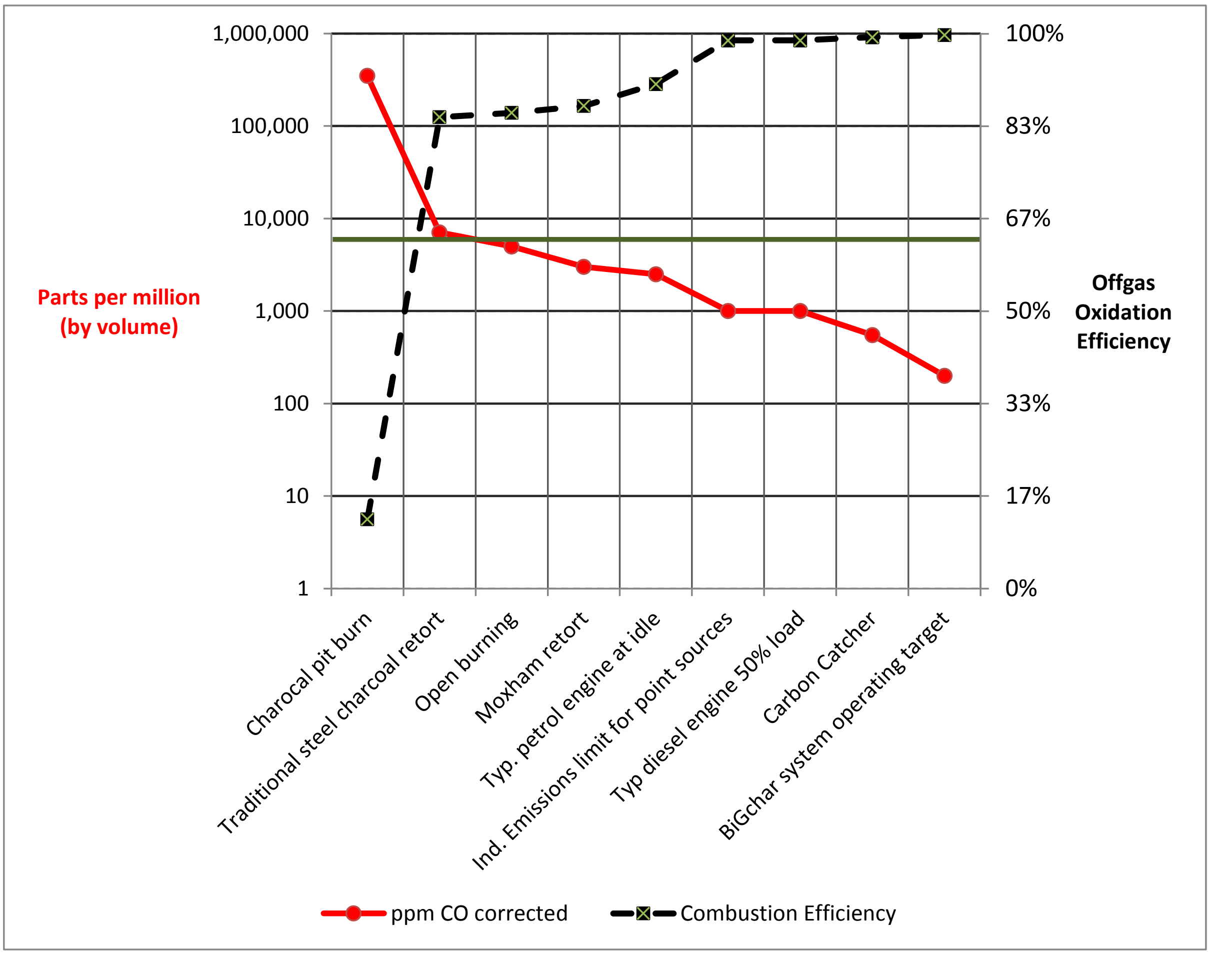


Figure 3 Emissions performance compared against typical thermal processes and industrial limits

Conclusions

The large Moxham, as tested had a better emissions performance than conventional open burn or traditional pyrolysis techniques (such as pit or retorts with little or no off-gas treatment). While not specifically measured the mini-Moxham will not have the same level of performance because the flames typically extend beyond the up edge of the side-wall.

The off gas oxidation performance of the large Moxham was acceptable for an invensitive non-urban location however it was poorer than that typically required of industrial point sources (83% vs 99%, or 3000 ppmv CO vs 1000 ppmv). BiG considers that further optimisation of the oxidation process would enable this outcome to be achieved. Recommendations along these lines are outlined on the next page.

The mini-Moxham functions in the same fashion as the large Moxham, however the height of the vessel is short relative to flame dimensions and the low to the ground. Both characteristics have a negative influence on emissions performance.

Recommendations

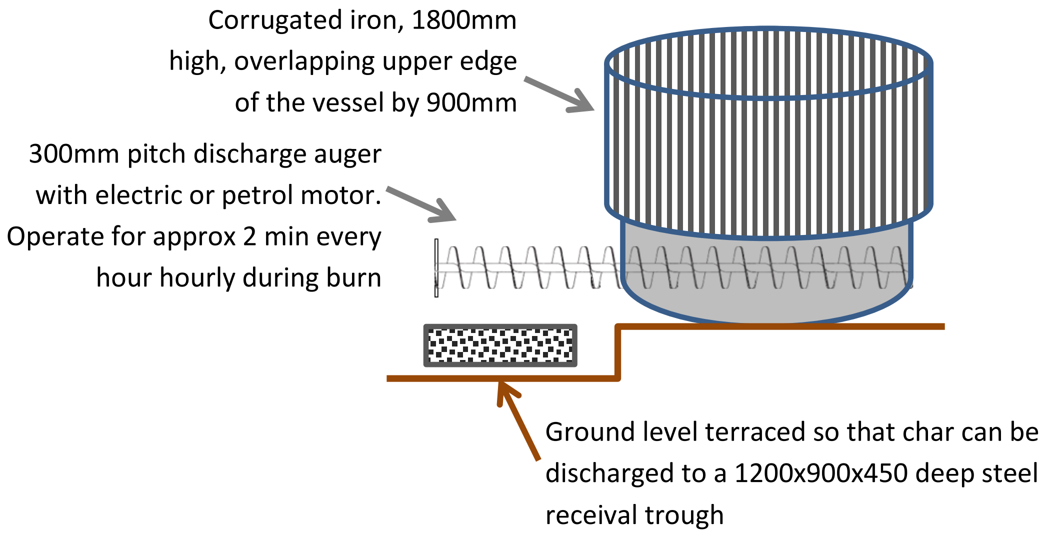
The large Moxham, as tested had far better emissions performance than conventional pyrolysis techniques (such as pit or retorts with little or no off-gas treatment). Perhaps the greatest deficiency is in terms of productivity per unit of labour and per hour. Relatively minor physical modifications and procedural modifications may improve the performance. These are:

a) Explore options to operate the Moxham in a semi-continuous fashion, by implementing a means to withdraw char from the base of the Moxham during operation. Installation of a 300mm discharge auger in the centreline of the vessel at base may suffice, if the means to push in from the side is considered.

b) Provide a means to extend the height of the side walls while not impeding the airflow necessary to achieve burn-off of the emissions. BiG has found previously that cladding a cylindrical flue with corrugated iron provides a good compromise, because it provides protection from radiant heat while allowing air to preheat and rise up through the corrugations to mix with flue gases. Corrugated iron also has innocuous thermal expansion behaviours (ie. it is already rolled/buckled so it tends expand with those buckles rather than buckle in an unpredictable manner).

c) Install temperature measurement in the top region of the Moxham (at two locations separated by 90 degrees, high in the side wall but well below the top of the extension piece. To enable the operating conditions to be monitored and maintained by the operator.

The figure below indicates a suggested configuration:



Safety

The following recommendations are based on observations made during the assessment period. A detailed safety audit was not conducted, so this list is not intended to be exhaustive.

Of particular concern is site housekeeping, because this potentially impacts on safety, operating efficiency and environmental performance. On the last point in particular, with the current arrangements on site there is a risk of hydrocarbon (oil and fuel) contamination of the land and nearby dam, due to a lack of spill containment.

The Moxham kiln concept is fundamentally simple and hence is not prone to complex sequences of events that may lead to injury. The principal risk, in order of risk score (likelihood x severity) are:

a) Crush injuries resulting from mobile plant, handling of heavy equipment or during wood splitting operations.

b) Entanglement in moving machinery components, particularly unguarded rotating parts.

c) Slips/trips/falls. This is currently a significant risk. The site is sloped and uneven; housekeeping requires attention.

d) Inexperience with the site and operations, leading to accidental injury.

e) Burns. The vessel is uninsulated so contact burns are possible. The char discharge and quenching process represent additional risks. Experienced operators, using appropriate personnel protective equipment (PPE), such as heat resistant gloves, closed shoes and long sleeved cotton shirts will be at a low risk.

f) Entanglement with moving machinery, eg. rotating drive shafts

g) Ignition of flammable materials near the operating unit.

h) Exposure to carbon monoxide

Recommendations

a) One of the most common cause of on-farm or industrial site fatalities is as a result of crush or roll over events when operating on or near mobile plant. Australian standards outline the requirements for roll over protection, lighting and audible warnings on mobile plant (eg. bobcats, loaders). Compliance with these requirements is a requirement under state and federal workplace legislation. Most sites also implement a policy of high visibility workwear in areas shared by mobile plant and personnel.

b) Australian standards outline the requirements for guarding of moving machinery to avoid entanglement. Such events are the most common cause of non-fatal injuries for personnel working around machinery. Compliance with these requirements is a requirement under state and federal workplace legislation. Removal of trip hazards. Installation of steps up the embankment nearest to the work area.

c) Site housekeeping improvements are implemented, where possible incorporating consideration of workflow to reduce the creation of slip/trip fall hazards during operation and maintenance of the plant, site and equipment.

d) A safety induction process should be developed for existing and new personnel, to ensure all personnel are familiar with the specific risks and control measures on site. Personnel training should include requirements to control flammable materials in a safe manner.

e) Where feasible heat shields or access barriers should be installed to reduce the chance of contact with hot surfaces.

f) Personnel need to be made aware of the signs of carbon monoxide poisoning and how to avoid and treat exposure.

g) A reticulated water supply be installed the work area, to facilitate fire control, burns first aid and to reduce the trip hazard presented by long hose runs.

h) All fuel and oil storage and handling areas be upgraded to include spill capture and containment provisions.

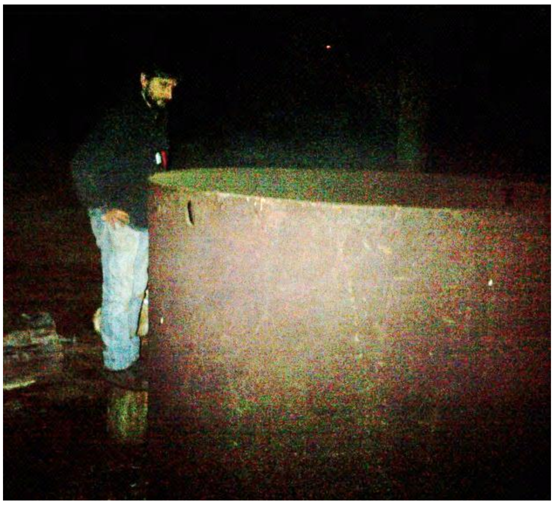
Selected site visit images with notes


Harvested timber ready for cutting into stumps suitable for splitting

Timber splitting. This is a very labour intensive operation and is a productivity bottleneck


Split timber loaded in baskets ready for use. Each burn currently uses approximately 7 baskets, to yield approximately 1 cubic meter of char.





Images taken during operation.

Site viewed from upper laneway. Large Moxham in mid-shot near partly completed shed, char grinding shed in the background.

Closer view of large Moxham next to shed that is recommended for timber splitting storage and drying.


Char during discharge onto steel sheet to reduce risk of ground contamination

Product discharged onto metal sheets to reduce soil contamination risk.

Char product. Heavily contaminated and clean

Grinder – Requires guard over belt drive and pulleys