THE ENVIRONMENTAL IMPLICATIONS OF EMISSIONS FROM CHARCOAL PRODUCTION

BioRegional Development Group

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An overview of the effects of the emissions from charcoal production.

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With the recent revival of interest in British charcoal production there are good signs that this formerly neglected industry will increase in both size and production.

As a consequence the implications of any possible risk of pollution or threat to health and safety of this process are increasingly relevant.

AIM

The aim of this report is to examine the implications of emissions from charcoal production upon the environment, their health and safety implications and the legal status of the process.

METHOD

In order to obtain information for this study, information was obtained from both literature and telephone interviews.

The literature available on charcoal burning tends to concentrate more on its production than chemistry. Perhaps the most useful information as regards the latter was found in old chemical textbooks which predate the dominance of the petro-chemical industry and where the destructive distillation of wood was a valuable source of chemicals.

Also of interest were general textbooks on wastes and waste disposal.

Further information was obtained by telephone interview with staff at HMIP and local government environmental health officers as well as with charcoal production increase.

LEGAL STATUS

At present charcoal burning is not a prescribed process. Statutory Instrument 472, which describes processes prescribed for regulation by her Majesty's Inspectorate of pollution (HMIP), in section 1.2, Part A (a) states:

"The pyrolysis, carbonization, distillation, liquefaction, partial oxidization or other heat treatment of coal, lignite, oil or other carbonaceous material (as defined in section 1.1) or mixtures thereof otherwise than with a view to gasification or making of charcoal".

Neither is charcoal burning subject to local authority control as a prescribed process.

Whilst there is, a "catch all" regulation which applies to the processing of any animal or vegetable matter (section 6.9) which is provided to cover miscellaneous processes, this is unlikely to apply to charcoal burning. In fact the Local Authority Unit of HMIP advise local government against using this section to prescribe charcoal burning. The reason being that in a court of law if a process is specifically excluded from the section of regulation most appropriate to its activity, it will be unlikely to be prosecuted under another more ambiguous section.

For the future the European Draft Directive on Integrated Pollution Control may possibly affect charcoal burning as HMIP believe it is not excluded. However, this is only draft legislation which has not been finalized.

Charcoal burning is consequently only subject to the nuisance regulations given in the 1990 Environmental Protection Act in whatever environment, whether urban and rural, in which it takes place.

The recent proposals for local councils to control carbon monoxide emissions could also effect charcoal production.

Legislation that is also relevant to the production of charcoal is the Health and Safety at Work Act 1974 and the Control of Substances Hazardous to Health Act (COSHH) 1991. The former regulates the maximum amount of dust that an employee may be exposed to and the latter covers the duties of protection imposed on employers to protect employees and other persons who may be effected by the work.

THE EMISSIONS

Although charcoal burning is not a prescribed process the Local Government Unit at HMIP felt that this was the result of charcoal burning being a comparatively rare process, not because the emissions were definitely harmless. Consequently there is a need, with the increasing interest in charcoal production, for greater awareness of the environmental, health and safety implications of this process. This is borne out in a statement from the British Charcoal Group's information pack: "For ring kilns emissions can constitute a public nuisance and a personal hazard to health."

Charcoal is formed in either retorts or kilns by pyrolysis, a process by which the chemical structure of the wood breaks down under high temperature and absence of oxygen leaving a relatively pure carbon.

During the pyrolysis process, the cellulose, hemicellulose and lignin in the wood breakdown into a complex series of chemicals referred to as the pyrolysis products. Some of these products are driven off in the form of gas, the remainder forming liquid matter. Broadly speaking the following are produced as wood converts to charcoal:

-Charcoal
-Water (both as steam and in the aqueous phase)
-Wood tars and oils
-Gases
-Wood vinegar (pyroligneous acid)

These byproducts have in the past been as or even more important than the charcoal itself, for example the Romans used the tar products as caulk for their ships. As coke superseded charcoal in steel production, the byproducts were an essential part of the European Chemical Industry until largely replaced by oil based products.

However, "one of the difficulties in prolysis on both a lab or pilot scale is the variation of effluent products " (Baum and Parker 1974). Consequently, whilst all the substances listed above will be produced in the charcoal making process, the amount produced and the type of emission will vary depending on several factors.

VARIABILITY

The byproducts from the charcoal making process will vary as a result of a number of factors of which the most pertinent are:

- -Method of charcoal production e.g. kiln or retort
- -Pyrolysis temperature
- -Moisture content of wood
- -Type of wood

Methods of production

Simplistically there are two main methods of charcoal production: the kiln process and the retort process. The former involves burning some of the charge of wood that is being made into charcoal in order to provide the heat for the process. The latter process converts the wood to charcoal inside a closed vessel with the heat being provided externally.

The portable ring kiln, which is the common practice in the UK, has the disadvantage of releasing considerable amounts of tars and volatiles into the atmosphere.
The Gaylard Retort on the other hand has the advantage of using the volatile gases it produces, after the steam has been driven off, as a means of combustion. This obviously reduces emissions to atmosphere.

Gases are also combusted in a new British design the Hutchinson Viper. This is effected by the controlled introduction of air into the chamber. This method is perhaps the most efficient as regards emissions as it avoids the emissions during the early part of combustion which characterize the Gaylard Retort.

The method of charcoal production is therefore crucial to the amount of emissions produced. Whilst the ring kiln method is both cheap and very portable, it may as a result of its emissions cause problems if the charcoal industry is to expand.

Pyrolysis temperature

The higher the temperature of pyrolysis the less charcoal is produced, however although less is produced its carbon content (i.e. quality) is higher, this is as a result of more volatiles being driven off.

A higher pyrolysis temperature also means a lower liquid yield as well as an increase in hydrogen emissions but a decrease in carbon dioxide (see table 1).

As may be seen from tables 1 & 2 the temperature of pyrolysis is important as regards the amount of emissions. Obviously a balance has to be struck between the quality of the charcoal and the amount of emissions. Obviously in a retort this is less of a problem as higher temperatures mean a greater supply of volatiles released for combustion and less liquid waste.

Wood type

The type of wood used may also vary the type and amount of emissions (see Anderson and Tillman's comparison between hardwoods and softwoods under destructive distillation). Simplistically softwoods release turpines hardwoods do not.

Wood moisture content

Initial moisture content of the wood increases the time of pyrolysis, which may in itself prolong any nuisance, and increase the amount of steam.

It is also worth noting that to the above points can be added numerous other factors such as the gas flow and rate of temperature ruse in the retort or kiln.

Whilst the above factors will cause variability in the byproducts from charcoal production other factors will also determine as to whether emissions will cause problems namely:

-Atmospheric conditions such as wind speed and direction or other effects, which may cause gaseous emissions to be a problem.

-Location, in this case not only where the actual site is but also whether production is moved regularly.

-The amount of kilns in operation.

GASEOUS EMISSIONS

It is believed that the smoke given off from ring kilns contains up to 200 different compounds (British Charcoal Group information pack 1994). Indeed pyrolysis is as yet little understood, not only because it is a complex process, but as a result of reactions inside a kiln being difficult to test.

As has been noted there can be some variability as to the quantity and type of gaseous emission.
The two following studies give some idea of the gaseous content of the emissions.

The main gases given off are, as may be seen from the results of test for retort production by Surrey University (table 1) are:

Gas composition (Volume %)	Temperature (Degrees C)		
	500	600	800
Carbon Dioxide	44.8	31.8	20.6
Carbon Monoxide	33.5	30.5	34.1
Methane	12.4	15.9	13.7
Hydrogen	5.56	16.6	28.6
Ethane	3.03	3.06	0.77
Ethylene	0.45	2.18	2.24

A smoke test by Cardiff University for kiln production (table 2) identifies:

Time/hours	30 min	1 hour	2 hours
Flue temp. Deg. C	200	85.9	86.1
% Oxygen	2	3.7	7.2
% Carbon dioxide	18.6	17	13.5
% Carbon Monoxide	3.7	3.6	3.6
ppm Nitrogen dioxide	400	200	140
ppm Nitrogen oxide	1	0	0
ppm Sulphur dioxide	215	68	29

As may be seen these tests do not compare well which may go to illustrate the differences between retort and kiln production.

It is also worth noting in the case of the Surrey University study that gas composition is not the gas emitted, in fact a large part of the gases will be burnt as part of the pyrolysis process.

Liquid products

The liquid products that result from pyrolysis other than steam generally comprise of waste at the bottom of a retort. In the case of kilns, which are open to the earth underneath, this waste drains into the soil. This generally consists of two layers, a phenolic tar and pyroligneous acid, the latter being an aqueous phase consisting of acetic acid, methanol and acetone.

Dust

Dust is produced largely from the charcoal chips and ash and may prove a problem on emptying kilns or retorts and also when bagging charcoal.

EFFECTS OF THE EMISSIONS

Air emissions and their effects

The most significant noxious emission to atmosphere from charcoal burning is **carbon monoxide.** In a retort if managed correctly the amount produced is negligible only care must be exercised in opening the retort after a burn. Even for a single ring kiln the amount produced is again negligible when compared say to heavy road traffic and occurring as it usually does in a remote rural location can again be discounted.

The amount of **carbon dioxide** produced by charcoal burning is again hard to consider as a hazard to the atmosphere especially as improved woodland management that results from coppicing to supply the process may increase the uptake of this gas.

Small amounts of **nitrogen dioxides** will be emitted by charcoal production as they are from internal combustion engines. This gas can effect breathing but again as long as due care is exercised, i.e. avoiding direct inhalation of emissions from the kin, the low levels emitted will not be harmful.

Methane emissions are again too low to cause any significant problems.

Acetic acids releases in the vapour and smoke may make the eyes water and also may cause some leaves on trees nearby to shrivel. However, the trees will not die and the smarting of the eyes will occur in the same way and have the same effect as bonfire smoke.

Perhaps the most problematic emission is **sulphur dioxide, which** can in the amounts shown in the Cardiff study cause respiratory problems and damage to vegetation. Nadel (1971) notes that sulphur dioxide content as low as 2-5 ppm can restrict the lower airways. Studies from Britain, largely associated with the smog problem, note an increased mortality and an aggravation of the symptoms of chronic bronchitis associated with increased amounts of smoke particles and sulphur dioxide. Other studies show that concentrations of sulphur dioxide of 10-20 ppm can cause damage to vegetation. Whilst these points may engender some concern it is worth noting that the problems with sulphur dioxide were largely created by the widespread burning of coal for both industrial and domestic purposes. Charcoal is unlikely to be produced, except at a very local level, with the intensity, which will cause its sulphur dioxide emissions to be a problem.

Other substances emitted are in such small quantities that their effect on the environment, health and safety is minimal.

It is also worth noting that much of the gas produced such as carbon monoxide and methane is actually flared off. Furthermore the majority of the vapour produced from a kiln is steam.

Liquid wastes

The liquid waste that is left at the bottom of a retort or kiln must be dispersed or disposed of carefully as if it were discarded in the environment over a period of time it could cause damage. Generalized observations as to acute and chronic toxicity's of these residues are difficult given the variable nature of the chemical species present.

However, during high temperature thermal processes such as the pyrolysis of timber or coal, polynuclear aromatic hydrocarbons (PAHs) are produced. Under certain circumstances PAH especially in high concentrations are carcinogenic. The PAH content of wood is much lower than in fossil fuels and the significance of low exposure as is more likely in the case of the present scale of charcoal burning is not as yet fully understood (DOE 1977). In fact it is possible that man has always been exposed to PAH via natural sources, for bacteria present in wheat, lentils and rye synthesize these compounds. Further investigation is needed in this area especially where kilns have used the same sites over a long period. As a precaution against the build up of PAHs it is recommended that the burn site be moved regularly (even by a few metres). The ashy topsoil can be dispersed to dilute any PAHs, and because of the fertilizing properties of ash even mixed with compost for horticultural use.

The alcohols present in liquid byproducts such as methanol are as a rule relatively non-toxic and their biodegradation is rapid under suitable conditions.

Phenolic compounds are more toxic but again can biodegrade readily.

It is reiterating that in the past there have been a plethora of uses for charcoal byproducts, which may be worth investigating as regards their revival. For example the aqueous phase, pyroligneous acid, in the past known as essence of smoke, can be used as an item in food flavouring.

Dust

The dust that can be produced from charcoal chips and ash after a burn has been assessed as a substance with a low hazard to health (RBG Kew 1993). As such when the kiln is emptied and the charcoal bagged contact with eyes should be avoided and the dust should not be breathed in. Kew also recommends the use of disposable masks and keeping the skin covered.

CONCLUSIONS AND RECOMMENDATIONS

Whilst because of their variability, it is impossible to give absolute definitions concerning the emissions from charcoal production they are neither mainly harmless as has been popularly supposed, or terribly dangerous. Looked at simply there is unlikely to be a huge difference between the emissions from a garden bonfire or a ring kiln, and whereas both can be nuisances they are hardly life threatening.

The key point is the intensity and location of production which as yet in Britain cannot be said to engender any great risk to humans or their environment so long as due caution is exercised.

Perhaps the only caveat concerns the liquid byproducts, which can soak in to the soil from ring kilns, however, if pit steads are moved regularly potential problems may be reduced.

It is also worth noting that in the UK the prevalent means of production, the ring kiln, is although the cheapest the least satisfactory as regards emissions.

However, inspite of the ring kilns draw backs the emissions from them are not generally either harmful or even a nuisance. Where emissions may become a problem is if there are numerous kilns (particularly ring kilns) on a fixed site operating constantly. Even in this case as with BPL's site at Battle, which had, up to twelve kilns, the local environment health department received a low level of complaint over some thirty years of operation. When BPL's kiln operation ceased recently there was local regret at the passing of what was regarded as an appropriate rural industry. Even the environmental health officer spoken to mentioned how she liked the smell.

Large-scale charcoal production is in any case not the norm and traditionally charcoal burning operates on a small-scale seasonal basis, typically one kiln, which is moved from site to site.

Further nuisance may also be avoided by tailoring burning times to suitable times of the day and taking into account wind conditions. Coupled to this controlling the burn to an optimum temperature may also reduce harmful emissions especially in the retort method.

Whilst it is more expensive newer technology such as the Hutchinson Viper, or the retort method may well be the answer to the problems associated with increased charcoal production for here both the gases and liquid emissions are more readily controlled and reused.

Bibliography

Baum and Parker 1974, Solid Waste Disposal Vol.2, Reuse, Recycle and Pyrolysis, Anne Arbour Science, Michigan

British Charcoal Group 1994, Information Pack.

Bloxham C L 1884, Chemistry Organic and Inorganic, Churchill.

Cardiff University 1994, Unpublished smoke tests on ring kiln.

Desai P and Evans M 1994, Charcoal and Coppice: A background to the industry and its potential in the Weald, Bioregional Development Group.

DOE 1977, Tarry and Distillation Wastes and Other Chemical Residues, HMSO, London.

Nadel J 1971, Effects of Air Pollution on Health, in Combustion Generated Air Pollution, Ed Starkman S, Plenum, New York.

Royal Botanical Gardens (RBG) Kew 1993, COSHH Assessment Sheet 56706, Charcoal Chips.

University of Surrey 1993, Charcoal Production by the Carbonization of Wood in a Gaylard Retort, Final Year Research Project.