Reconstructing urban CO$_2$ emissions utilising the radiocarbon composition of tree rings from the Wellington Region, New Zealand

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This study demonstrates the utility of tree ring radiocarbon analysis to quantify a temporal record of recently-added fossil fuel-derived CO$_2$ (CO$_2$ff) in the urban atmosphere, to retrospectively measure emissions and potentially validate local emissions inventories.

Measurements of the $^{14}$C content of cellulose from the annual tree rings of a Kauri tree (Agathis australis), located in the downtown area of the Wellington suburb of Lower Hutt, have been used to reconstruct a retrospective record of CO$_2$ff. We compare this record with tree rings from two Kauri located at a nearby coastal site and the long-term clear air $^{14}$CO$_2$ record from Baring Head, 11km from the test site.

**METHODS**

1. Dendrochronology
   Counting of annual growth rings to establish chronology

2. Sample Preparation
   Wood samples prepared using a scalpel to cut into slivers

3. Chemical pre-treatment
   Rafter organic solvent washes followed by the ANSTO cellulose extraction technique

4. Sample measurement
   EA combustion, graphitisation and AMS analysis

5. Data analysis
   Fossil fuel calculations with biosphere correction

**RESULTS + DISCUSSION**

Pre-1960, a natural level of $^{14}$C existed - with cosmogenic production balancing radioactive decay. The "bomb spike", occurs at 1965 due to Southern Hemispheric site location. Post-bomb era sees uptake of bomb $^{14}$C by oceans and terrestrial biosphere. Additions of $^{14}$C-depleted fossil fuel CO$_2$ becomes dominant in the KNG52 record from the 1980’s.

**Figure 1:**
A$^{13}$CO$_2$ of urban tree rings (KNG52; red) compared with the Baring Head clean air record (BHD; black) and tree ring measurements representative of background atmosphere (NIK; green). The KNG52 record exhibits a decrease in A$^{13}$CO$_2$ corresponding to an increase in $^{14}$C-depleted fossil fuel emissions.

**Figure 2:**
The CO$_2$ff record was calculated using this equation:

$$\text{CO}_{2\text{ff}} = \frac{\text{CO}_{2\text{bg}}\Delta_{\text{obs}} - \Delta_{\text{bg}} - \Delta_{\text{ff}} - \Delta_{\text{bg}} - \beta}{\Delta_{\text{ff}} - \Delta_{\text{bg}}}$$

$\beta$ is the biospheric effect (green line), which became less prominent from the 1980s when CO$_2$ff dominates.

**Figure 3:**
The averaged KNG52 CO$_2$ff record was compared with New Zealand CO$_2$ data collated by CDIAC. Both sets of data appear to approximately double over time.

**CONCLUSIONS**

- NIK provides an accurate record of background $^{14}$CO$_2$
- Calculations of CO$_2$ff (derived from the KNG52 $^{14}$CO$_2$ record) doubles in concentration over a 40-year period.

**ACKNOWLEDGEMENTS**

Many thanks to Dr Gretel Boswijk (UoA), Andrea Davies (VUW) and the NIC staff for their assistance in dendrochronology, sample preparation and data analysis.