Genotoxic potential of particulate emissions from residential solid fuel boilers: the effect of technology, fuel, and operation output

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Aim of the study

- ➢To compare genotoxic potential and oxidative DNA damage by organic compounds bound to particulate emissions from various boilers.
- ➢To asses the effect of boiler`s technology, fuel and operation output.

Background

- • Combustion of various solid fuels in different types of small boilers is a widely used form of heating of family houses.
- • However, these types of combustion processes emit large quantities of harmful gaseous and PM emissions.
- • Epidemiological studies show that PM created in small heating appliances contains carcinogens and mutagens and thus may have undesirable and harmful impacts on human health.
- • The quality of combustion is affected by the combustion technology, user operation, and fuel used, all of which affect the formation of emissions.

Conclusions

- **Mass of particulate emissions from boilers highly correlates with PM2.5, the correlation with benzo(a)pyrene level is lower suggesting the contribution of other PM components to the total genotoxicity.**
- **For all fuels, the highest genotoxicity was observed for over-fire and down-draft boilers compared to gasification and automatic boilers.**
- **Reduced output exhibited more emissions and higher toxicity than nominal output.**
- **In over-fire boiler are emissions from coal substantially higher and more genotoxic than from biomass.**
- **Modern boilers (gasification and automatic) produced much lower emissions and exhibited much lower genotoxicity and DNA oxidative damage than old technology boilers per GJ of power.**

Results

Genotoxic potential – DNA adducts

- • Highest levels of DNA adducts were induced by emissions by organic compounds emitted by over-fire boiler while automatic boiler exhibited ~100-fold lower genotoxic potential (**Figure 1**).
- • The differences between +S9 and -S9 samples suggest substantial contribution of genotoxic PAHs to the total adduct levels.
- • Reduced output is connected with higher genotoxicity.

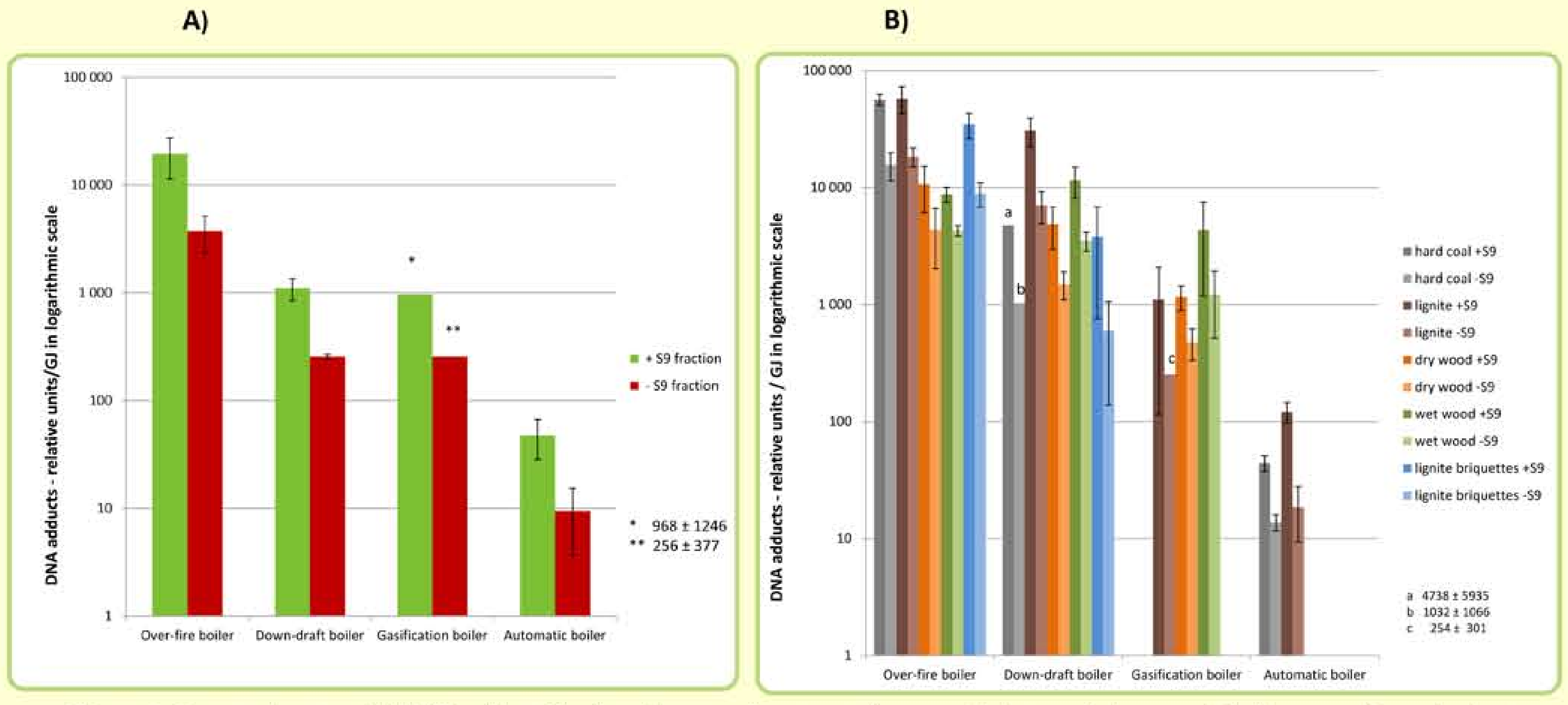

Figure 1: Genotoxic potential (DNA adducts) induced by organic extracts from particulate emissions per GJ of power: A) nominal output (hard coal only); B) reduced output (various fuels).

Genotoxic potential – oxidative DNA damage

- • Highest levels of 8-oxo-dG were induced by emissions by organic compounds emitted by over-fire boiler while automatic boiler exhibited ~5-fold lower toxicity (**Figure 2**).
- • The differences between +S9 and -S9 samples suggest substantial contribution of genotoxic PAHs to the total adduct levels.
- • Reduced output is connected with higher oxidative DNA damage.

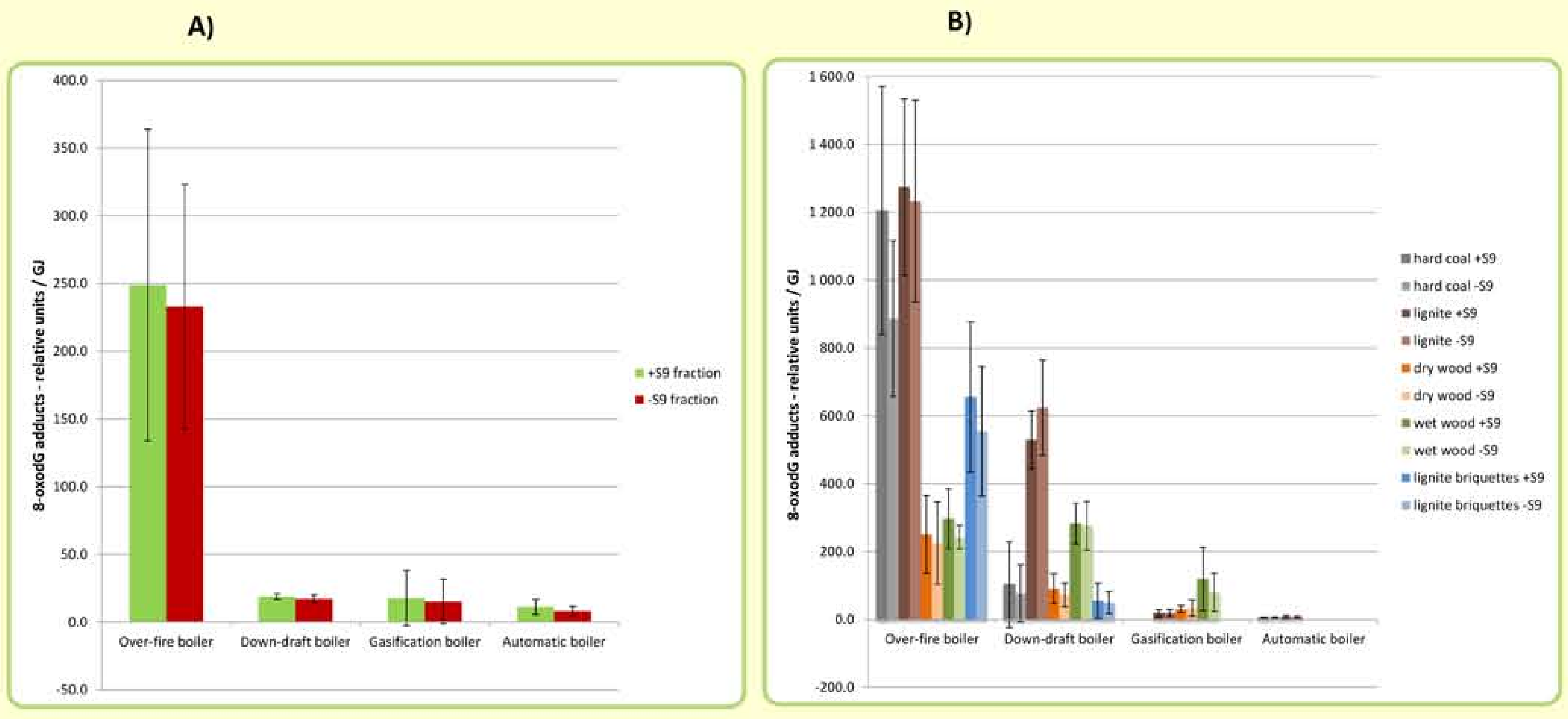

Figure 2: Genotoxic potential (oxidative DNA damage) induced by organic extracts from particulate emissions per GJ of power: A) nominal output (hard coal only); B) reduced output (various fuels).

PM size distribution and chemical analysis

- • The size distribution of PM emissions strongly suggests that most of PM is sized between 0.1–1 μm for all types of boilers (**Figure 3**).
- • PM mass is much higher for old technologies of boilers than for new technologies. The same apply for PAH content normalized per GJ of power (**Figure 3**).

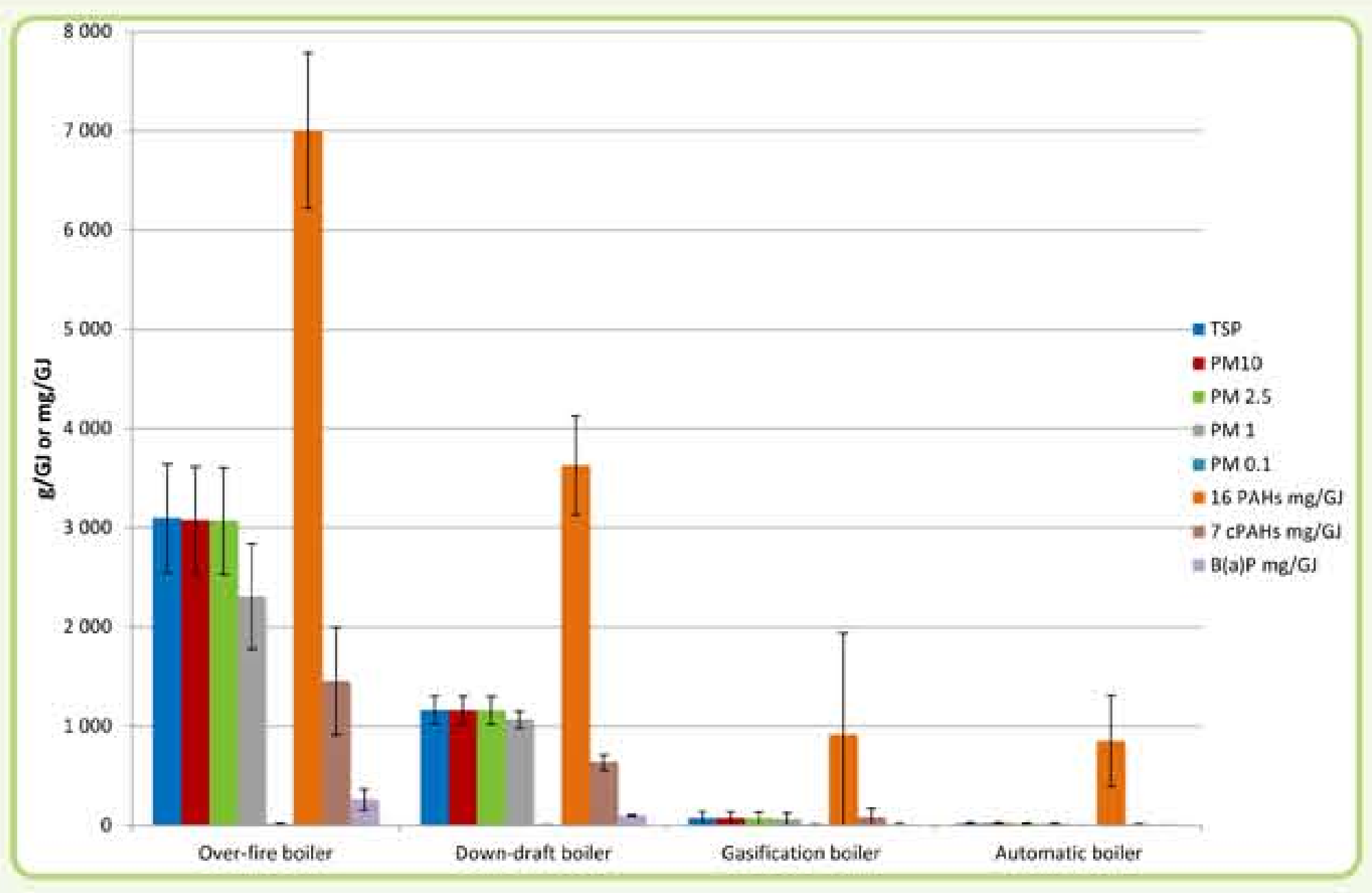

Figure 3: Basic characteristics of particulate exhaust and chemical analysis of organic extract normalized per GJ of output (example lignite and reduced output).

Correlation of genotoxicity with PM and BaP

- • Genotoxic potential as detected by DNA adduct formation correlates with PM mass (**Figure 4A**).
- • The correlation with BaP level is lower suggesting the significant contribution of other PM components to the total genotoxicity (**Figure 4B**).

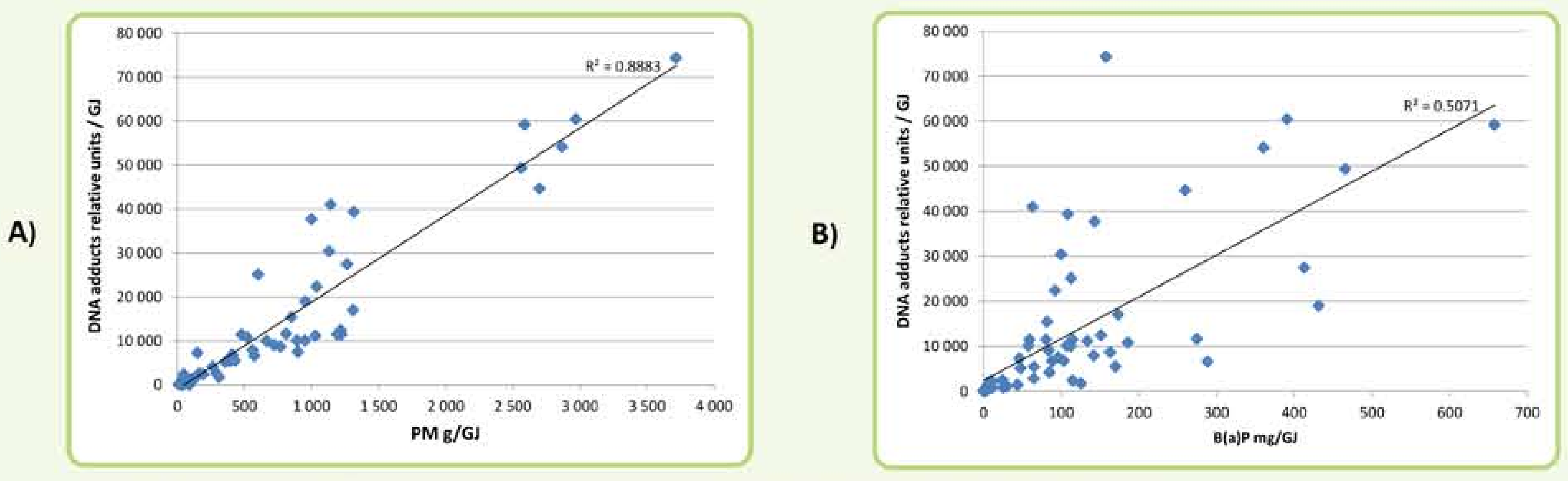

Figure 4: Correlation of genotoxic potential (DNA adduct levels) with: PM mass (A); BaP (B).

Methodology

- • Four types of small domestic boilers representing both old structural design (over-fire and down-draft boilers) and also up-to-date combustion devices (gasification and automatic boilers) shown in **Figure 5** were compared in specialized testing laboratory (**Figure 6**).

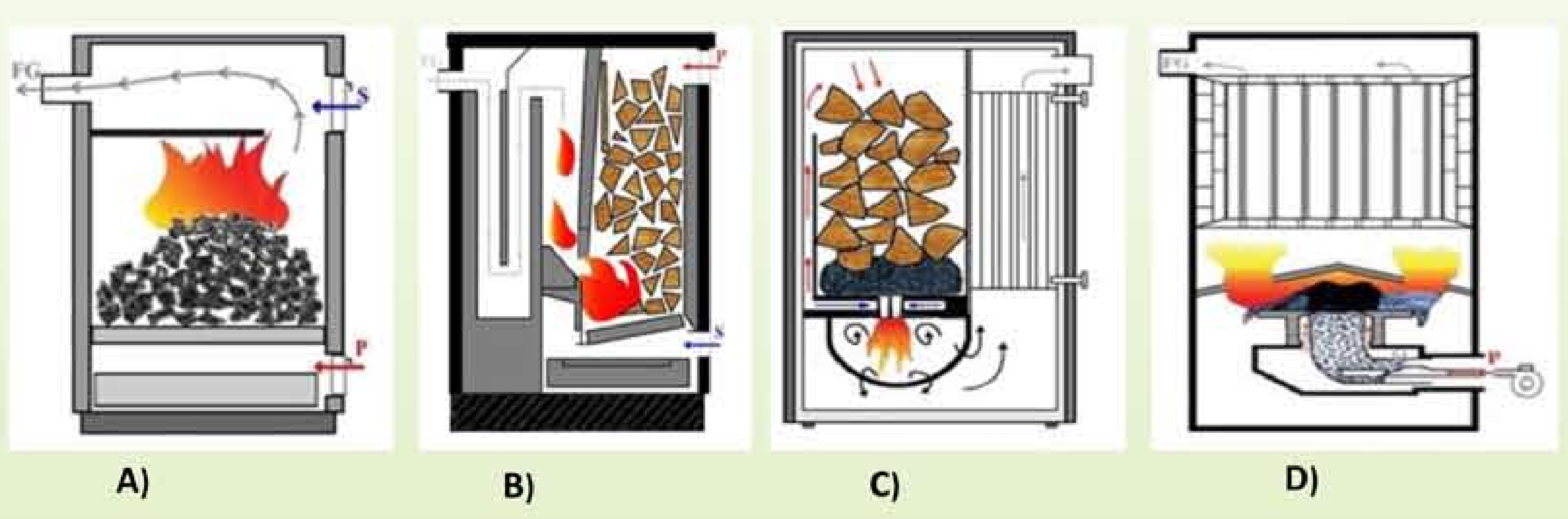

Figure 5: Types of boilers in the study: A) Over-fire boiler; B) Down-draft boiler; C) Gasification boiler; D) Automatic boiler.

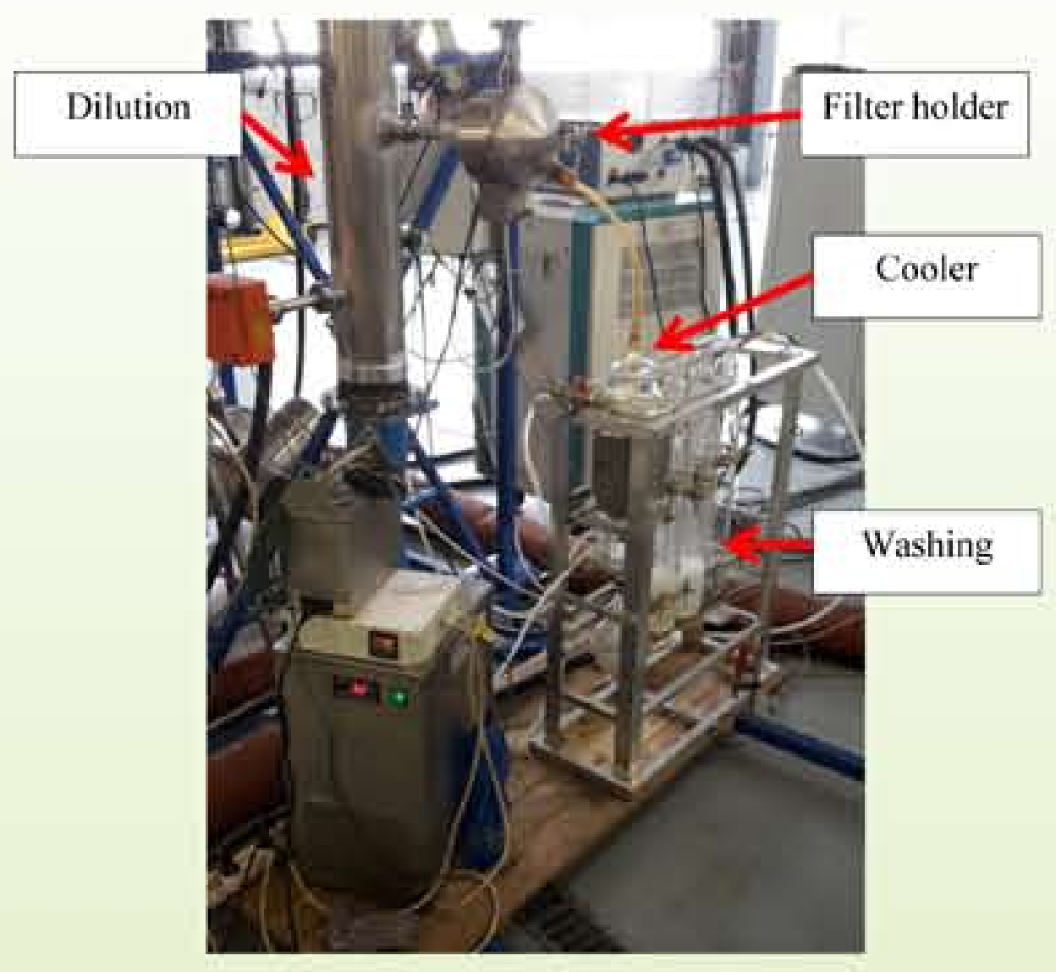

Figure 6: Sampling laboratory for emissions from boilers .

- • Various solid fuels (hard coal, lignite, dry wood, wet wood, lignite briquettes, wood pellets) were burnt.
- • Two different performance outputs (i.e., nominal and reduced) of boilers were tested to compare the concentration of organic PM components and their genotoxic potentiality.
- • The organic components of collected total particulate matter (formed by 93-100% by PM2.5) were extracted, 16 priority PAHs were quantified in extracts by GC-MS.
- • The analysis of the genotoxic potential of extracts using acellular assay of DNA adducts by ^{32}P-postlabelling and the analysis of 8-oxo-deoxyguanosine (8-oxo-dG) in calf thymus DNA was employed.
- • 50 μg of extract/ml, 24 hours incubation with/without metabolic activation of PAHs by microsomal S9 fraction (+/- S9).

Acknowledgements

This project was supported by Czech Science Foundation (grant No. P-503-12-G147) and by the Ministry of Education, Youth and Sports of the Czech Republic (Research Infrastructure NanoEnviCz - Project No. LM2015073). This work was prepared within the project „Innovation for Efficiency and Environment – Growth“, identification code LO1403 with the financial support from the Ministry of Education, Youth and Sports in the framework of the National Sustainability Programme I.