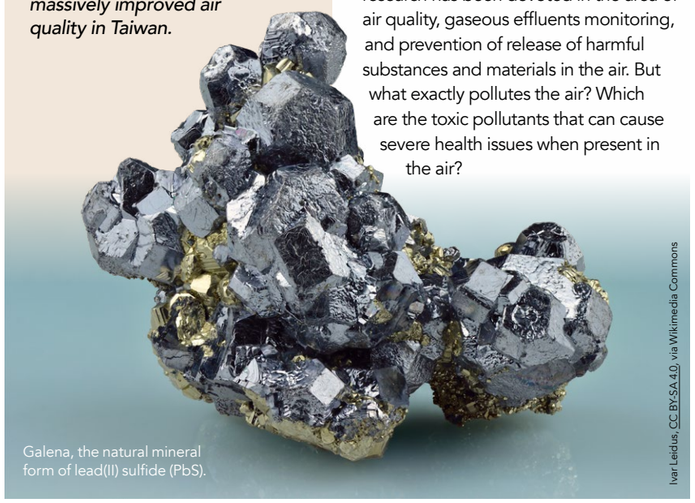
Monitoring toxic pollutants for better air quality

Air quality is imperative for our and the environment's health. Research around air quality has been focusing on the monitoring, testing, and investigation of toxic pollutants, such as heavy metals, polychlorinated and polycyclic aromatic compounds, or particulate matter ($PM_{2.5}$). Professor Guo-Ping Chang-Chien, director of the Super Micro Mass Research and Technology Center at Cheng Shiu University of Science and Technology in Taiwan, and his team have focused their research efforts around the aforementioned areas over the past 20 years. Their work has massively improved air quality in Taiwan.

According to the well-known quote 'we are what we eat', one could also claim that 'we are what we breathe'. Unfortunately, the air we breathe is not always clean as it may contain viral loads and toxic pollutants, depending on where we are, who is around us, and what is happening around us. Especially in some sectors where various combustion processes are taking place, workers and people in nearby areas might face problems due to the air quality. This effect can become even worse in industrial areas, or densely populated urban areas with increased non-sustainable fuel burning vehicle traffic.

Presence of toxic pollutants in the air is not a brand new phenomenon. Much research has been devoted in the area of air quality, gaseous effluents monitoring, and prevention of release of harmful substances and materials in the air. But what exactly pollutes the air? Which are the toxic pollutants that can cause severe health issues when present in the air?



Galena, the natural mineral form of lead(II) sulfide (PbS).

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THE LEXICON OF TOXIC POLLUTANTS

Before diving into what pollutes the air, let's start with how the air gets polluted. Combustion, scientifically known as the rapid combination of substance with oxygen that results in production of heat, light, and gaseous products, is basically the process of burning something. Combustion usually refers to burning of fossil fuels like coal or petrol, or biomass like wood or dry woody plant parts. One way or another, we have all been exposed to an open fire outdoors or car fumes, and we probably tried to avoid the smoke associated with the process.

Toxic pollutants present in smoke are derived from various combustion processes. These pollutants are not always the same; their composition, concentration, and combination highly depend on the substance that is being burnt and the conditions of combustion. Toxic pollutants present in gas streams associated with combustion can, among others, include heavy metals, polycyclic aromatic compounds, polychlorinated or polybrominated compounds, and particulate matter. Heavy metals are usually associated with industrial combustion, for example within the steel industry, and can comprise of lead (Pb), mercury (Hg), chromium (Cr), cadmium (Cd), and arsenic (As). Polychlorinated compounds can include polychlorinated biphenyls (PCBs), polychlorinated-p-dibenzo dioxin (PCDDs), polychlorinated diphenyl ethers (PCDEs), and polychlorinated dibenzofurans (PCDFs),

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Industrial combustion releases flue gas into the air – this can contain a mixture of toxic gases along with other substances that cannot be burned.

and these are often associated with combustion. Similarly, for polybrominated compounds, the most important category is polybrominated diphenyl ethers (PBDEs). Last but definitely not least, another toxic pollutant often found in combustion gases is particulate matter.

Restriction of vehicle idling reduced emissions of $PM_{2.5}$, $PM_{0.1}$, PAHs and black carbon levels.

Particulate matter are tiny solid or liquid solid particles with a diameter measured in microns (one millionth of a meter). An often used standard size for particulate matter is a diameter of 2.5 microns ($PM_{2.5}$). At that size or lower, particles can penetrate deep into lungs and cause severe health issues.

TOXIC POLLUTANTS IN FLUE GAS

Flue gas is the technical term used for the exhaust products during industrial combustion. It can contain a mixture of all toxic pollutants mentioned earlier, along with residual fuel and residual substances that could not be burned.

Flue gas has been a major issue for chemical plants as it is the equivalent of exhaust fumes for cars, but in a much larger and continuous format. Controlling the quality of flue gas and, specifically, monitoring the concentration of toxic pollutants that are released in the environment is of imperative importance, especially in the last few years that environmental and health protection have received much attention.

Professor Guo-Ping Chang-Chien, director of the Super Micro Mass Research and Technology Center at Cheng Shiu University, Taiwan, and his research team have been focusing their efforts in the area of monitoring and controlling toxic pollutants in flue gas and other combustion gases. For the past 20 years, the researchers have focused on toxic pollutants in flue gas emissions including dioxins, PCBs, polycyclic aromatic compounds, heavy metals, and $PM_{2.5}$. Because of the testing and investigation services offered and the collaboration of local industries with the Super Micro Mass Research and Technology Center, Taiwan has attained a 90% overall reduction of dioxin concentration in the past 20 years.

A recent publication by researchers associated with the Super Micro Mass Research and Technology Center on the assessment of potentially toxic elements produced from coal burning boilers and sintering furnaces in a steel production plant highlighted the reduction in toxic pollutants present in effluents. Pollutants' reduction was attributed to the implementation of available air pollution control devices (APCD) as a step before the release of flue gas into the atmosphere. This research focused on the examination of emission factors (EFs) of toxic pollutants, as they were calculated via field investigations and laboratory experiments, rather than following the available EF guideline from the Taiwan Environmental Protection Agency (EPA), as the standard values could be inadequate to represent the true picture. Emission factors, a

The Center's mobile air quality monitoring station truck.


Alex_Ishchenko/depositphotos.com

The research team showed that restriction of vehicle idling reduced emissions of $PM_{2.5}$, $PM_{0.1}$, PAHs, and black carbon levels.

common index for emission estimation, correspond to the weight of pollutant per unit of product, or per duration of the activity that emits the pollutant, and they are used to measure potentially toxic emissions.

RESEARCHING EMISSION FACTORS FOR TOXIC POLLUTANTS

Focusing on a steel production plant, the researchers set up a sampling system for the collection of effluent samples from coal-fired boilers and sintering furnaces, with the collection point being after the APCD, and analysed those samples for heavy metal concentrations. It was shown that obtained results from field investigations were considerably lower than emission factors set by EPA, a fact that could indicate overcharging of plants for this particular issue, even if plants are equipped with state-of-the-art APCD.

In a different research project, Professor Chang-Chien investigated the emission factors of polychlorinated and polybrominated compounds during rice straw biomass burning in fields. Air samples were collected from three different points during burning periods and non-burning periods and analysed for concentration of PCDDs and PBDEs. Results showed that during burning periods, the concentration of these toxic pollutants was much larger than during non-burning periods, especially when samples were collected very close to the burning site. It was shown that the emission factor for PBDEs was almost 19 times higher than that for PCDDs. Interestingly, looking at the composition of rice straw, PBDEs were not originally present, which leads to the fact that they were synthesised during combustion. The production of PBDEs during rice straw burning in open fields and the high emission factor of this toxic pollutant indicated that this phenomenon should not be neglected.

Touching on the emission factors of PM, $PM_{2.5}$ specifically, researchers from the Super Micro Mass Research and Technology Center also explored the difference idle vehicles (vehicles with running engine but not in motion) could make in air quality around a school site. They monitored the concentrations of toxic pollutants such as $PM_{2.5}$, Polycyclic Aromatic Hydrocarbons (PAHs), and black carbon at normal conditions and when idling vehicles were restricted in the surrounding area. The sampling methodology included stationary and mobile sampling for spatial analysis of emission factors, and analysis of results included chemical mass balance modelling, in order to calculate the contribution of various emission sources towards the $PM_{2.5}$ emission factor. Results showed that restriction of vehicle idling reduced emissions of $PM_{2.5}$, $PM_{0.1}$, PAHs, and black carbon levels, with PAHs showing the highest reduction, by almost 50%.

The highlighted research examples showcase that collaboration between industry and research institutions can lead to spectacular breakthrough.

MONITORING THE AIR QUALITY

The highlighted research examples from Professor Chang-Chien and the Super Micro Mass Research and Technology Center showcase that collaboration between industry and research institutions can lead to spectacular breakthrough, in this case around air quality. Monitoring air quality is imperative, as what we breathe affects our health and can contribute to environmental concerns. Through testing and investigation, as well as adoption of APCD and implementation of emission control regulations, the concentration of toxic pollutants can be monitored and reduced, leading to overall improved air quality.

Behind the Research

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Research Objectives

Professor Chang-Chien and his team study different emission reduction approaches relating to ambient air toxic pollutants: specifically, dioxins, polychlorinated biphenyls (PCBs), polycyclic aromatic compounds, heavy metals, and $PM_{2.5}$.

Detail

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Bio

For the past 20 years, researchers at the Super Micro Mass Research and Technology Center have focused on toxic pollutants in flue gas emissions including dioxins, polychlorinated biphenyls (PCBs), polycyclic aromatic compounds, heavy metals, and $PM_{2.5}$. Taiwan has attained a 90% overall reduction of dioxin concentration in the past 20 years, and under the guidance of the director, Professor Guo-Ping Chang-Chien, the Center offered very instrumental services of testing and investigations.

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Personal Response

Can findings from this research form the basis of new policy implementation, e.g., controlled burning of biomass, prohibition of idling vehicles around schools, etc.?

" Yes, the findings from this research can be applied as a basis for new policy implementation. For instance, industrial plants equipped with APCDs could be encouraged to pay air pollution fees for the emission of potentially toxic elements based on specific EFs for their devices rather than the Default EFs from respective environmental protection agencies. This will help industrial companies to save money and, ultimately, encourages them to install and maintain APCDs. Idling of vehicles, especially those with diesel engines, could be limited to a certain number of minutes in crowded places in order to lower the concentrations of ambient air $PM_{2.5}$. "