Probabilistic inverse model for identification of atmospheric contamination source in an continental-scale.

Accidental and intentional releases of hazardous substances in populated areas are a major concern for those responsible for societal security. Considering the large-scale potential harm from the release of radioactive or toxic materials that are stored, transported, or used in various ways, as well as the significant number of potential casualties, this concern is well justified. Especially in a world marked by evolving social and political conflicts, intentional or inadvertent releases of radiological agents are of critical importance to responsible authorities. The assessment of health and environmental consequences depends heavily on accurate knowledge about the dispersion of released material. A key component of efficient emergency response to accidental releases is reliable prediction of airborne hazardous material dispersion, which is provided by atmospheric dispersion models and a clear understanding of the source characteristics. Apart from forecasting and analyzing the radiological situation, it is sometimes necessary to develop models based on measurements of dangerous substance concentrations. Such measurements, collected by an extensive network of sensors, can help identify the probable source term.

This source term represents the most critical input data because it is almost entirely unknown for any accidental release or similar incident and has a profound impact on predictive modeling. The source term includes the amount of released material, the release rate, temporal variations, and the release pattern (e.g., explosion, spray). In many of the most significant cases, the location of the source is unknown, such as with unnoticed accidental leaks or unfavorable releases detected only through local monitoring stations.

The recent "Ruthenium event" highlighted the importance of the source identification problem for decision-makers. In October 2017, a European network monitoring atmospheric radioactive contamination detected air concentrations of Ruthenium-106. This radionuclide is rarely observed in the atmosphere, but it was detected in nearly all European countries at that time, with measurements reaching up to 140 mBq/m^3. Additionally, another artificial isotope, Ruthenium-103, was detected at independent monitoring stations in Austria, the Czech Republic, Poland, and Sweden. Although these activity levels posed no environmental or health risks, significant measurements from multiple locations suggested that the initial source release rate was quite high. One of the singular challenges of this event was that the location and release rate of the source were unknown when the first detections were recorded. To date, there has been no official confirmation of the event's cause, though preliminary indications point to the Mayak complex in the southern Urals. Since 2017, there have been several other continental-scale releases of radionuclides, such as the release of Selenium-75 in Western Europe in 2019 and the detection of artificially produced radionuclides in Scandinavian countries in June 2020.

The proposed algorithm, named STE-EU-SCALE (Source Term Estimation for European-Scale), aims to identify hazardous release sources based on measurement data from a network of sensors distributed across Europe. The proposed models will integrate advanced continental transport models, novel Bayesian sampling algorithms, data fusion techniques from sensor networks, and distributed computational environments.