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AIR POLLUTION MONITORING SYSTEM USING NEAR ROOM TEMPERATURE AIR RESISTIVE GAS SENSOR

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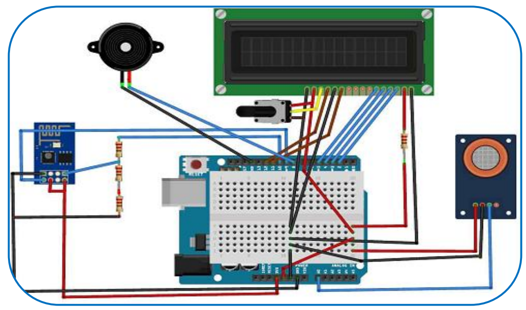
ABSTRACT :

The boom of industries and other human activities have led to ever increasing digit of pollutant in both indoor and outdoor spaces. These pollutants have dangerous effect on humans and winder ecology. Hence, Air quality monitoring system is needed and involves the robust monitoring and another toxic gases and volatile organic components in case, the concentration of any pollutant cross the safe limit in a given location. The paper shows the different sources of indoor and outdoor pollutants, feedback the current status of gas sensor, and explanation the role of new two dimensional materials in detection the hazardous gases as less power, i.e., close to the ambient temperature. Here, we survey different synthesis techniques of 2-D materials and discuss the sensing performances of pristine and functionalized nanomaterial's for some of the important pollutants such as NOx, NH_3, SOx, CO, formaldehyde, toluene, and so on. The survey concludes with some proposed system to help in reducing air pollution today.



KEYWORDS : *2-D nanomaterials, air quality monitoring (AQM), near room temperature sensing, resistive gas sensors.*

INTRODUCTION

There has been an increasing interest to design the new low-cost and low-power gas sensors for various application-specific locations. This includes air pollution monitoring of both indoor and outdoor spaces, finding of toxic gases in and near industrial premises and also sensors for biomedical applications. In past years, there has been a growing rise in levels of toxic gases and volatile organic compounds (VOCs) in air, particularly in urban spaces. This is mostly true for many areas in under-developed or developing countries. For example, a recent scenario from the World Health Organization (WHO) in 2018 shows that 15 Indian cities and 21 Chinese cities are amongst the 50 most polluted cities in the world. In 2019, air pollution is considered as the greatest environmental risk to health. The major sources of polluted air are fuel wood and biomass burning, burning of large-scale crop residue, fuel adulteration, uncontrolled emission from vehicles and factories, traffic congestion, and rapid construction These sources defect smog and, hence, increase the airborne particulate matter (e.g., PM10, PM2.5), NOx , NH_3 , SOx , CO, and other VOCs in the air. All these pollutants are well in excess of the human permissible limit in capital cities like Delhi (sixth in WHO list), Kampala (16th in WHO list), Doha (21st in WHO list), Kabul (28th in WHO list), and so on.

The quality of indoor air is of equal importance as that of outdoor air because we spend most of our time indoor and indoor pollution can be many times the level of outdoor pollution! Smart buildings (e.g., houses, hospitals, schools at smart cities in developed countries) are such places where different hazardous gases and VOCs such as CO_2, CO, formaldehyde, benzene, toluene, ethyl benzene, and xylene (popularly known as BTEX) along with humidity are monitored and restricted to permissible limit through proper detection and ventilation. However, there is a lack of awareness and a detailed understanding of the long-term acute effect of these air pollutants among populations. Excessive exposure of air pollutants leads to increase in respiratory and cardiovascular diseases, such as acute lower respiratory infections (ALRIs), chronic obstructive pulmonary disease (COPD), lung cancer, ischemic heart disease (IHD), pneumonia, and strokes. Thus, air pollution is the reason behind many diseases that are proven to be fatal. Globally, almost 7 million deaths were caused by household and outdoor pollution in 2013, the fourth-highest cause of deaths worldwide. This makes air quality monitoring (AQM) an urgent and essential assessment. Many review papers have been published on metal oxide based resistive sensors for detecting toxic gases over the years [8]–[10]. There are many reports published on air pollution. Recently, several review papers highlighted 2-D layered material based resistive sensors [12]–[15]. However, the authors believe that it is necessary and of utmost important to review the sources of air pollution, status of resistive sensors available in the market for detecting toxic gases, highlighting the necessity to develop near-room temperature resistive sensors (which will reduce the power consumption drastically and fetch the way for *things* in the Internet), different ways of synthesizing/functionalizing 2-D nanomaterials, their performances to detect different pollutants, and possible approaches to tackle with the air pollution.

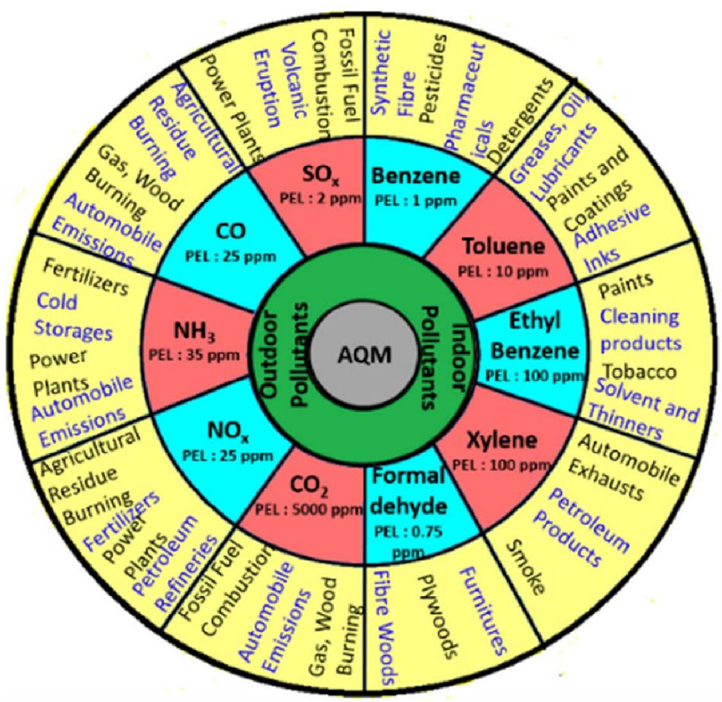


Fig1: Different indoor and outdoor pollutants with their safe-limits and sources.

SOURCES OF AIR POLLUTANTS:

In recent years, the growing industrialization across various parts of Asia (especially in India and China) has been a boon to the economy. Unfortunately, the rise in industrialization and the standard of living are coming with poor implementation of governmental rules and regulations, which result in increased concentration of air pollutants. Fig. 1 shows the different indoor and outdoor pollutants that are generally present in the air because of different user/person activities. The pollutants shown in Fig. 1 are harmful to living beings and the environment if exposed beyond permissible exposure limits (PELs) as published by the occupational safety and health administration (OSHA), U.S. In order to devise a mechanism to monitor and check air pollution, it is necessary to design gas sensors that can detect these gases/VOCs. Current trends in gas sensors are presented in the next section.

WHERE DOES AIR POLLUTION COME FROM?:

Most air pollution, harmful gases and particles in the air, affecting national parks is developed outside park boundaries.

TYPES OF SOURCES:

There are four main types of air pollution sources:

- mobile sources – such as cars, buses, planes, train, and trucks
- stationary sources – such as power plants, oil refineries, factories and industrial facilities
- area sources – such as agricultural areas, cities, and wood burning fireplaces
- natural sources – such as wind-blown dust, wildfires, and volcanoes

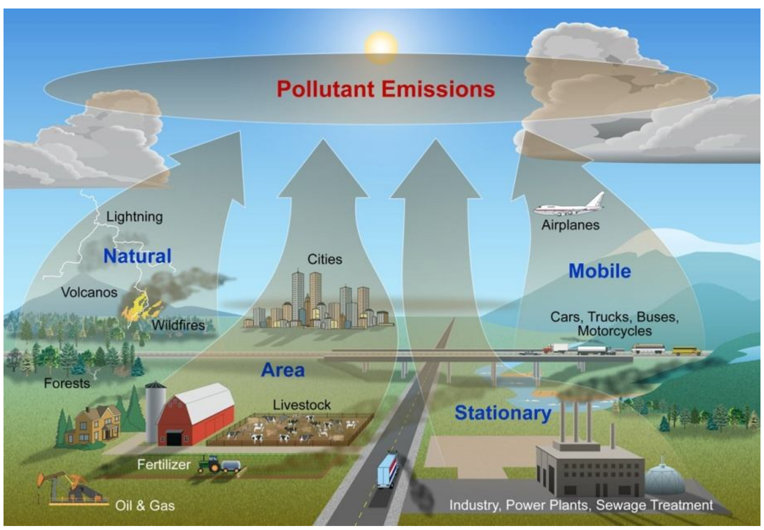


Fig2: Mobile, stationary, area, and natural sources all emit pollution into the air.

Mobile sources account for more than half of all the air pollution in the United States and the primary mobile source of air pollution is the automobile, according to the Environmental Protection Agency. Stationary sources, like power plants, emit large amounts of pollution from a single location, these are also known as point sources of pollution. Area sources are made up of lots of smaller pollution sources that aren't a big deal by themselves but when considered as a group can be. Natural sources can sometimes be significant but do not usually create ongoing air pollution problems like the other source types can.

POLLUTION ON THE MOVE:

Pollution from human-generated and natural sources is often created in one place and transfer through the air. Many times chemical reactions in the atmosphere change pollutants before they are deposited. Pollutants in the air can down haze, making it harder to see, and pollutant deposition can have biological effects. NPS areas experience these effects just like other places. Location and even the time of year can determine which pollution sources are most important to each park.

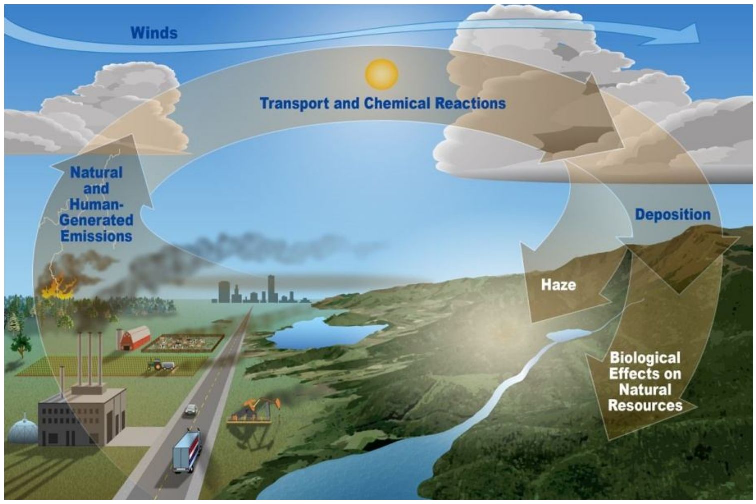


Fig3: Wind can move air pollutants short or very long distances before they cause harmful impacts.

Parks downwind of power plants that lack modern pollution controls can have increased smog. Tailpipe emissions from cars and trucks, as well as industrial processes such as oil and gas development, give rise to elevated ozone concentrations. Summertime wildfires can also reduce visibility in NPS areas. There are even examples of pollutants that originated from other countries and were transported thousands of miles arriving at parks. The effects of this pollution can be seen as haze and through negative biological effects. Learn more about effects of air pollution on nature and visibility, and human health.

SYNTHESIS TECHNIQUES OF PRISTINE 2-D LAYERED NANOMATERIALS

The synthesis framework of a nanomaterial can be broadly differentiate into two categories: top–down approach and bottom–up approach. Different methods in each category have been described over the years to customize the synthesis of 2-D layered materials for different sources. This review focuses on described some of the widely explored system which are frequently employed for the synthesis of these nanomaterials.

A. Mechanical Exfoliation:

This is the simplest and most economical system for the synthesis of nanomaterials. It is a top–down framework which is employed to reduce mechanically one or more dimensions of bulk materials to the nanoscale. Geim and Novoselov produced highly pure graphene flakes by isolating monolayer carbon sheets of highly oriented pyrolytic graphite (HOPG) using this method ("Scotch-tape method").

B. Chemical Vapor Deposition

This bottom–up system of nanomaterials synthesis is based on the chemical reactions that occur between the precursors and substrate, thereby, producing high-quality 2-D material thin films of a large area. The molecules of the gas precursors are put into a reactor and passed through a hot zone (700 ◦C–1200

◦C) where the reactants dissociate and deposit onto the substrate, which is placed at a relatively lower temperature in the reactor.

C. Epitaxial Growth

This is another sophisticated system of synthesis of nanomaterials. For epitaxial growth of any nanomaterial, it is necessary to have a substrate with a specific crystallographic orientation so that the atoms of the substrate can coalesce into a uniform, single-crystal layer of that particular nanomaterial with a minimum number of grain boundaries

D. Liquid Exfoliation

This is a low-cost method for nanomaterial synthesis in which the bulk precursor is exfoliated using suitable chemical reagents. The system of isolating different nanosheets using liquid exfoliation is schematically.

ACTIONS YOU CAN TAKE TO REDUCE AIR POLLUTION

Follow these Tips Every Day to Reduce Pollution:

- Conserve energy - at home, at work, everywhere.
- Look for the ENERGY STAR label when buying home or office substances.
- Carpool, use public transportation, bike, or walk whenever you possible.
- Follow gasoline refueling instructions for efficient vapor recovery, being careful not to spill fuel and always tightening your gas cap safely.
- Consider purchasing portable gasoline containers labeled “spill-proof,” where possible.
- Keep car, boat, and other engines extremely tuned.
- Be sure your tires are properly inflated.
- Use environmentally safe paints and cleaning products whenever possible.
- Mulch or compost leaves and yard waste.
- Consider using gas logs instead of wood.

On Days when High Ozone Levels are Expected, Take these Extra Steps to Reduce Pollution:

- Choose a cleaner commute - share a ride to work or use public transportation.
- Combine errands and reduce trips. Walk to errands when possible.
- Avoid excessive idling of your automobile.
- Refuel your car in the evening when it’s cooler.
- Conserve electricity and set air conditioners no lower than 78 degrees.
- Defer lawn and gardening chores that use gasoline-powered equipment, or wait until evening.

On Days when High Particle Levels are Expected, Take these Extra Steps to Reduce Pollution:

- Reduce the number of trips you take in your car.
- Reduce or eliminate fireplace and wood stove use.
- Avoid burning leaves, trash, and other materials.
- Avoid using gas-powered lawn and garden equipment.

GAS SENSING BY PRISTINE 2-D LAYERED NANOMATERIALS

A. Graphene-Based Gas Sensors

Graphene has outstanding electrical (conductivity and carrier mobilities) and mechanical framework which are desired for gas sensing. The first topic on graphene-based gas detectors was reported by Schedin in which they demonstrated that mechanically exfoliated graphene sheets have the potential to detect single molecules of gases. River reported NH_3, NO_2, and ethanol sensing by graphene synthesized with the help of CVD.

B. Intrinsic GO/RGO Based Gas Sensors

Soon after the discovery of graphene, GO/RGO based gas sensor study was also going on. Robinson demonstrated molecular gas sensors fabricated with the help of RGO. They first synthesized GO and then reduced it chemically using hydrazine to get RGO which was used for sensing acetone and dinitrotoluene (DNT).

C. TMDs Based Gas Sensors

2-D, layered, and semiconducting TMDs are also offering promise as the potential alternatives to near-room temperature gas sensing materials. Of different TMDs like WS_2, MoS_2, SnS_2, TaS_2, and TiS_2, MoS_2 based gas sensors have been explored the most so far. All the other TMDs are still in the embryonic stage but they are expected to demonstrate excellent sensing results in the near future because of their benefit properties. Ou reported excellent NO_2 sensing by SnS_2 flakes.

APPROACH TO REDUCE AIR POLLUTION

To finding air pollution efficiently, it is utmost important to create low-power and low-cost sensors (as described above) that can be deployed in numerous sensor nodes. However, we suppose that the following points are also need to be strictly adopted to give a chance for our future generation and perhaps a right to breath.

- As explain above, burning fuelwood for cooking combine significantly to air pollution. So, evolving with clean household fuel and making it accessible to normal people would help to improve the condition.
- Pollutants from automobiles can be controlled by enforcing tighter law and also by monitoring road infrastructure to decrees traffic congestion.
- Exploring renewable sources of energy and explaining the technologies to deploy the same efficiency would bring down the power plant emissions especially.
- Precision agriculture which includes early detection of disease infestation and then precise and limited spraying of pesticides would help in decreases the pollution caused by agro-chemicals.
- Campaigns similar to Breathe Life (led by WHO, UN Environmental and the Climate and Clean Air Coalition) can be initiated by governments to deployed social awareness about the effect on health due to the air pollution and the climate change.
- Concepts like smart cities and smart buildings with efficient monitoring framework and waste management should be created and executed. Special care should be taken to preserve natural assets like forests, rivers, etc. while designing the areas.
- There should be several sensor nodes in smart cities (instead of only a few fixed monitoring stations), internet of sensors, whose data will be accessible to normal people (maybe through a mobile app) so that the individual can make their travel plan to reduces pollution.

CONCLUSION:

Our survey describes the different sources of indoor and outdoor pollutants and the methods in which these pollutants can be detected presently. This study reviewed different synthesis system of new 2-D layered materials for gas sensor applications, the study that has been carried out so far on gas sensors based on intrinsic 2-D materials and described the limitations of such 2-D gas sensors. The advantages of functionalization of carbon nanomaterials and TMDs are also shown. Another ways of functionalizing these sensing layers are explained and the performances of different composite sensors reported so far are presented. The final section of this review discussed some of the possible ways to minimize air pollution. It is shown that more focused study in developing gas sensors based on these new 2-D materials could lead to the development of much more efficient AQM systems, which can reduce the 7 million deaths annually associated with polluted air as well as improve well-being for less polluted spaces.

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