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Clean Water, Sanitation and zero emission Industry Pollution Management using nWSN based Green IoT Applications: A Techno-legal impact

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ABSTRACT: We present techno-legal and techno-socio-economical aspects of research to human rights on the clean and safe water, sanitation, pollution free industry infrastructure context in Smart World for 17 sustainable development goals (SDG) item no. 6 & 9 and present views regarding the possible use of the Green Internet of Things (G-IoT) in India and so are intended to be achieved globally by 2030.This research has as main goal to evaluate the feasibility of a Next Generation Nanostructured Wireless Sensor Net-work System (n-WSN) as G-IoT application for fresh air and pollution free industry detection and ecological disaster protection. Although there has been immense dev-elopment of more sensitive and selective nanostruc-tured sensor arrays and Artificial Intelligent (AI) ena-bling advanced data mining technology, there have been very few reports on the applications of electronic nose (e-Nose), electronic tongue (e-Tongue) and elec-tronic vision (e-vision) for the detection of pollution free industry, ecological disaster and forest fire protection and management. The current Techno-legal and Socio-economical and techno-legal research sheds light on the practical applicability of e-Tongue for heavy metal detection from drinking water and waste-water and e-Nose for the pollution free industry and detection of hazards gaseous like as volatile organic compound (VOC) emissions detection, those are ingredient of air pollution, ecological disaster and forest fire.

KEYWORDS: Clean water, Sanitation, GIoT, nWSN, e-Tongue, e-Nose, Zero emission industry.

I. INTRODUCTION

Environmental pollution is a worldwide problem of modern industrial civilization. In Indian constitution human rights to clean dinking water, sanitation, food, fresh air, hygiene and pollution free industry collectively known as HRWASH [1] , are guaranteed under international law as components of the right to an adequate standard of living guaranteed in the International Covenant on Economic, Social and Cultural Rights, as well as in many other human rights treaties. Moreover, clean drinking water, sanitation, agricultural food, hygiene and pollution free industry are inextricably linked to a range of other human rights, including the fundamental rights to life, health, education and housing in our Indian Constitutions. Reporting on progress with the United Nations (UN) Millennium Sustainable Development Goals (SDG) vision 2030, UNICEF states that [2]: (i) More than 760 million people in 2018 lacked access to safe drinking water sources within a convenient distance from their habitation, 389 million of which lived Rajasthan in India and Sub-Saharan Africa. A total of 189 million people were dependent on surface water, of which 152 million lived in Rajasthan in India and Sub-Saharan Africa. (ii) Adequate sanitation facilities, for human excreta disposal in, or close to, peoples' habitation, were not available to 2.9 billion people in 2018, 895 million of which lived in Rajasthan in India and Sub-Saharan Africa. In Rajasthan in India and South Africa, and many other developing countries, a large number of people still do not have an acceptable toilet and cannot easily access safe water to drink or wash their hands. This leaves significant proportions of young children and vulnerable individuals to die of preventable RH-WASH related diseases such as diarrhoea, intestinal nematode infections, lymphatic filariasis, trachoma, schistosomiasis and malaria [3]. This could also contribute to malnutrition and poor school attendance, which could result in cognitive impairment and reduced learning outcomes [4]. It is argued that improvements related to drinking water, food from agriculture, sanitation, hygiene, drinking water and pollution free industry resource management could result in the reduction of almost 15% of the total burden of disease worldwide. Access to adequate HRWASH services is therefore an important mechanism to address risks associated with the burden of disease of any country. The use of green cloud computing and information and communications technologies (ICTs) has been posited as one way to address the burden of disease and improve quality of life for those most at risk. One of the newdevelopments in ICT, the 'Green Internet of Things' (G-IoT), allows for the integration of digital and the sensor-rich data-centric Cyber-Physical Systems (CPS) with an increasing degree of automation, giving rise to Fourth Industrial Revolution, known as Industry 4.0 for Smart Health Care.

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II. BACKGROUND AND CONTEXT

Non-degradable and persistent nature of Cadmium (Cd) poses high toxicity to humans, plants and animals. Several industrial processes generated wastes are the main anthropogenic pathway through which Cd enters into the environment. Although, World Health Organization (WHO) has set the limit of Cd in drinking water as 0.005 mg L^{-1}, the industrial activities release much higher concentrations of metal ions to the water stream than the prescribed limits, which lead to the increasing health hazards and environmental pollution.

Contaminations with heavy metals ions have adversely affected the environment, food safety, and human health. Heavy metals, leaching to water sources from the industrial effluents, can enter into the aquatic and food chains of humans and animals from a variety of anthropogenic sources.

(A) Scope and Approach

Heavy metal detection has been an intensive area of research today. Both laboratory-based analytical instruments and innovative sensor devices like the electronic nose, electronic tongue, and bio/ chemical sensors have increasingly emerged to meet the demand for legislative actions on environmental pollution control and early warning. These evolving technology and developments particularly in the area of nanotechnology and sensors have become key contributing factors in heavy metal detection. The applications categorization is based on gaseous pollutants released from the industries. Calibration and transfer methodologies have been discussed to enhance the applicability of electronic nose (e-Nose) and electronic tongue (e-Tongue) and electronic vision (e-Vision) systems. This new solution for forest fire monitoring and protection could be targeted at both state and private organisations, which are located in regions where fires represent a threat. After a broad socio-economic and technical examination, the research will show tat this type of G-IoT system can offer an efficient approach for reducing economic and biodiversity loss, while helping to prevent human rights and casualties and vision to sustainable development goal (SDG) in a smart world. Olfaction is one of the five major human senses (vision, hearing, olfaction, taste, and touch). The sense of smell is the most mysterious and complex sense; a particular smell can trigger a series of memories in people. In 2004, Axel and Buck won the Nobel Prize in Physiology or Medicine for their research on "odorant receptors and the organization of the olfactory system" [1,5], which shows the interest and value of the research on olfaction. Artificial olfaction also called an electronic nose (e-nose) is a biomimetic olfactory system [1,2] that can replace well-trained experts in dangerous work, or surpass the limits of their abilities. Recently, artificial olfaction has been developed for numerous industry applications [3,6], such as indoor air-quality monitoring, medical care, customs security, food quality control, environmental quality monitoring, military applica-tions, and hazardous gas detection, medical diagnosis [4,5], psychoanalysis, agriculture, pharmaceuticals, to name but a few [5,7]. The biological nose is an obvious choice for such applications, but there are some disadvantages to having human beings perform these tasks due to a variety of reasons such as fatigue, infec-tions, mental state, subjectivity, exposure to hazardous materials, individual variables, etc., and generally it is socio-economically and technically unfeasible to invest a large amount of money in training for tasks that last a relatively short time. The earliest artificial olfaction device can be traced back to 1961, when Moncrieff proposed a mechanical artificial nose. The first elec-tronic nose was developed by Wilkens, Hatman, and Buck in 1964 [6].

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(B) Sources and Value Chain of Water

Industrial effluents, the primary source of groundwater contamination via percolation or runoff through soils and landfills, are a major concern for human health and the environment. Water containing toxic heavy metals is a problem to the world-wide environment in general and aquatic ecosystems in particular. Population growth and economic activity is an exponential increase in waste generation of anthropogenic origin, such as sewage [8,11]. Sewage treatment systems are meant towards minimizing the environmental impacts caused by the release of the toxic substances into the environment, but secondary waste generated through this process must be predisposed of properly [12], as it can be a risk to ecosystem balance through contamina-ting soil and water bodies, and interfere with the food chain [13]. Among various heavy metals, cadmium (Cd) occurs naturally in the environment, therefore it is naturally present everywhere in air, water, soils and foodstuffs. Well known minerals for Cd are greenoc-kite, Cd sulphide (77.6% Cd), otavite, Cd carbonate (61.5% Cd) and pure Cd oxide (87.5% Cd) [4]. Cd, a major by-product from mining and refining, is highly toxic to humans, plants and animals. It is very well recognized for its adverse health effects including renal disturbances, lung insufficiency, bone lesions, cancer and hypertension in humans [10,11]. In general 'formal' water services are a nonstop sequential delivery process from source-to-tap and from tap-to-source. It involves natural water resources, treatment works (processing), distribution infrastructure and effective operation to deliver potable (drinkable) water and safe sanitation. Rainfall runoff flows into rivers and is captured and stored in dams. Water from dams and other sources, such as groundwater, is purified and treated, and piped to reservoirs for distribution to customers (domestic, business and industrial users). Once the water is consumed, grey water (wastewater from washing, laundry etc.) and sewerage are collected and passed through a network of sewers to a treatment works. The wastewater is purified and treated, after which it is released back into rivers or dams, again becoming a water resource [13].

(C) Sources and properties of VOC from industry emission ingredients for air pollution

In nature, methane (CH_4) is produced by the anaerobic bacterial decomposition of vegetable matter under water (where it is sometimes called marsh gas or swamp gas). Methane is colourless, odourless gas that occurs abundantly in nature and as a product of certain human activities. Methane is the simplest member of the paraffin series of hydrocarbons and is among the most potent of the greenhouse gases. Wetlands are the major natural source of methane produced in this way. Other important natural sources of Methane include termites as a result of digestive processes, volcanoes, vents in the ocean floor, and methane hydrate deposits that occur along continental margins and beneath Antarctic ice and Arctic permafrost. Methane also is the chief constituent of natural gas, which contains from 50 to 90 percent methane (depending on the source), and occurs as a component of firedamp or flammable gas along coal seams. Methane in general is very stable, but mixtures of methane and air, with the methane content between 5 and 14 percent by volume, are explosive. Explosions of such mixtures have been frequent in coal mines and collieries and have been the cause of many mine disasters. Methane is lighter than air, having a specific gravity of 0.554. It is only slightly soluble in water. It burns readily in air, forming carbon dioxide and water vapour; the flame is pale, slightly luminous, and very hot.

(D) Environmental Challenges, Constitution and National Policies

India took a bold step to include environmental protection rights and duties in its Constitution. The Constitution of India specifies that the State shall endeavour to protect and improve the environment and to safeguard the natural resources of the country. According to the Constitution, it is the fundamental duty of every citizen of India to protect and improve the natural environment and to have compassion for living creatures. By raising environmental concerns to the constitutional level, India has provided its citizens with a powerful policy tool to protect the environment.

National Policies: In addition to the Constitutional mandate, India has a number of national policies governing environmental management, including the National Policy on Pollution Amendment (NPPA, 1992) and the National Conservation Strategy and Policy Statement on Environment and Development (NCS / PSED, 1992). While these national policies are not judicially enforceable, they serve as guiding principles for the central and state governments to follow.

The NPPA encourages the use of economic instruments to complement traditional command and control approaches to pollution abatement. To integrate environmental considerations into decision making at all levels, the policy adopts the following guiding principles:

- prevention of pollution at source;
- adoption of best available technology;
- the polluter pays principle; and
- public participation in decision making.

The NCS/PSED provides an overarching policy frame-work on environmental management, including conser-vation of natural resources and economic development. Key instruments for promoting environmental change include conducting environmental impact assessments, developing educational campaigns, and ensuring public participation.As the nodal agency, the Ministry of Environment and Forests (MOEF) is responsible for implementing the NPPA and the NCS / PSED.

III. METHODS AND EXPERIMENTAL

(A) Nanostructured Sensor based electronic Nose (e-Nose) and electronic Tongue (e-tongue)

Olfaction is one of the five major human senses (vision, hearing, smell, taste, and touch). The sense of smell is the most mysterious and complex sense; a particular smell can trigger a series of memories in people. A typical and prototype nanostructured electronic nose (e-Nose) is on lines parallel to the human nasal system working in coordination with the brain. Fig. 1(a-b). Shows comparison of the sense of smell and taste with artificial senses. Whenever the ortho-nasal pathway sniffs a compound, it reaches the olfactory epithelium located in the upper nasal cavity. There the interactions of odorants with the appropriate chemosensory receptors take place, and the olfactory neurons of different classes produce electrical stimuli, which are transmitted to the brain [16]. A pattern recognition process assisted by the memory then takes place using all the data to identify, classify, or perform a hedonic analysis. Evidence exists showing that a single olfactory neuron responds to several odorants and that each odorant is sensed by multiple olfactory neurons. On the similar lines of a human nose, electronic nose functions by using an array of sensors. The sensor array after sensing the aroma generates a pattern based on the type of smell. Further, the patterns obtained are trained to interpret and distinguish between various odours and odorants and to recognize new patterns [7]. A design and diagram comparing the fundamental analogies between human nasal sys tem (biological olfaction) and an electronic nose (artificial olfaction) low chart and is shown in Fig. 2 (a-b), Comparing the basic analogies **(a)** between biological olfaction, human nasal system and artificial olfaction; **(b)** block diagram of our prototype n-WSN with G-IoT with electronic nose (e-Nose) as artificial senses.

(B)Nanostructured WSN e-Tongue for heavy metal detection from Water and Waste-Water

Nanostructures sensors enabled G-IoT technologies for Cd removal from waste-water and effluents are ion exchange, reverse osmosis, precipitation, cementation, adsorption, chemical precipitation, and membrane separation Fig. 3 (a-b). However, some techniques are limited to a narrow linear range of concentrations (such as chemical precipitation, ion exchange and membrane separation are effective at 1-100 mg L^{-1}), cost effectiveness; while some technologies generate high volumes of toxic sludge which further require a second treatment process [19]. Apart from the above shortcomings, the conventional Cd removal process has some inherent drawbacks. Recently, to remove heavy metals from waste-water, biological base adsorbents have emerged and extensively used. Removal of heavy metals like Cd using biological means has been identified as a promising alternative to traditional treatment techniques. This overview presents various scientific reports towards low-cost microorganism and agricultural based biosorbents for efficient removal of Cd^{+2} by producing less toxic waste and the future perspective of the process.

(C) Prototype Nanostructure Wireless Sensor Network System (n-WSN) e-Nose and e-Tongue as G-IoT management

This techno-legal and socio-economical research has as main goal to evaluate the feasibility of a Next Generation Nanostructure Wireless Sensor Network System (n-WSN) as G-IoT application for forest fire and industrial emissions monitoring and protection in the smart world. Although there has been immense development of more sensitive and selective nano-structure sensor arrays and Artificial Intelligent (AI) enabling advanced data mining technology, there have been limited reports on the applications of electronic nose (eNose) for the measurement of industrial emissions and forest fire protection. The current techno-legal research sheds light on the practical applicability of e-Nose for the effective industrial order and gaseous emissions measurement.

(D) Environmental monitoring using n-WSN GIoT with e-Nose

Electronic noses and tongues show promise in this regard and find application in monitoring the quality of water and of atmospheric air [17]. The analysis of atmospheric air can be

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performed in several ways. One can, for example, measure the concentration of several pre-defined substances or analyse the air holistically. Both these tasks can be performed using sensor systems. One of the first investigations in this area was performed in the first half of 1990' [18]. In it, a device equipped with CP sensors was used to analyse an aqueous solution of ethanol, diacetyl and dimethyl sulphide. Electronic nose was also used to measure the concentration of nitric oxide, methane and carbon monoxide at 500-2000 ppm concentrations. It is important to note, that when using nWSN e-Noses to determine particular substances there can occur interferences caused by the presence of other chemical compounds. This techno-legal research has shown, that when determining hydrogen sulphide (H_2S), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO) a mixture containing carbon dioxide and water vapour the presence of humidity and CO_2 shown in Table 5 and their Chemical structure and properties of VOCs caused air pollution from Industrial emissions toxic gases in Table 6, had a significant impact on the sensor's response signal, but it was possible to properly identify the components of the gaseous mixture using discriminant factor analysis [17,19]. It is possible to use the electronic nose to determine certain Volatile Organic Compounds (VOCs) at a very low concentration level (ppm level), even below the threshold limit value (TLV). That was the case with benzene, methanol, ethanol, toluene and acetone determined below TLV using a device equipped with nWSN. Sensor drift poses a significant problem, leading to high measurement uncertainties.

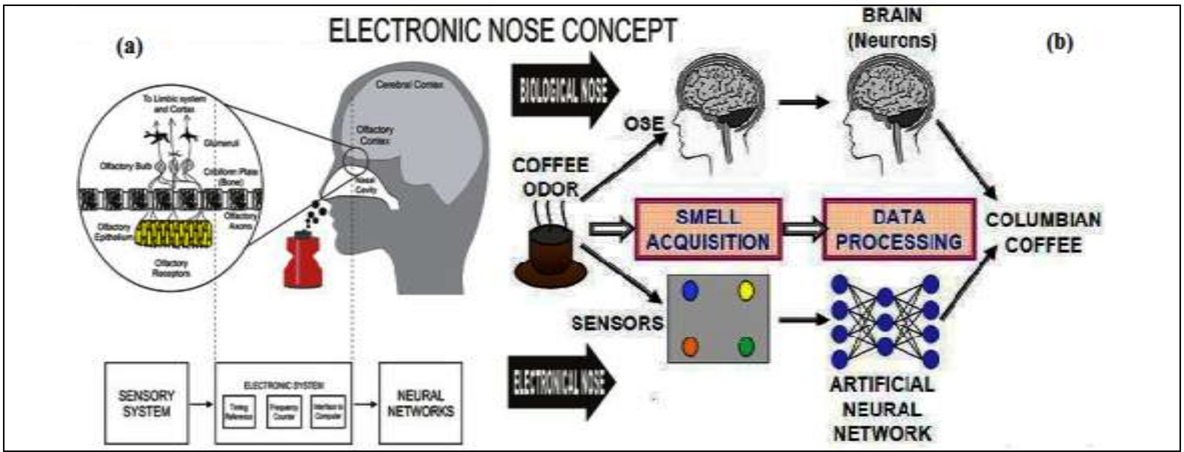

Fig. 1(a-b): Comparing of the sense of smell and taste with artificial senses (a) between biological olfaction, human nasal system and artificial olfaction; (b) block diagram of our prototype n-WSN electronic nose (e-Nose) as artificial senses by artificial neural network (ANN).

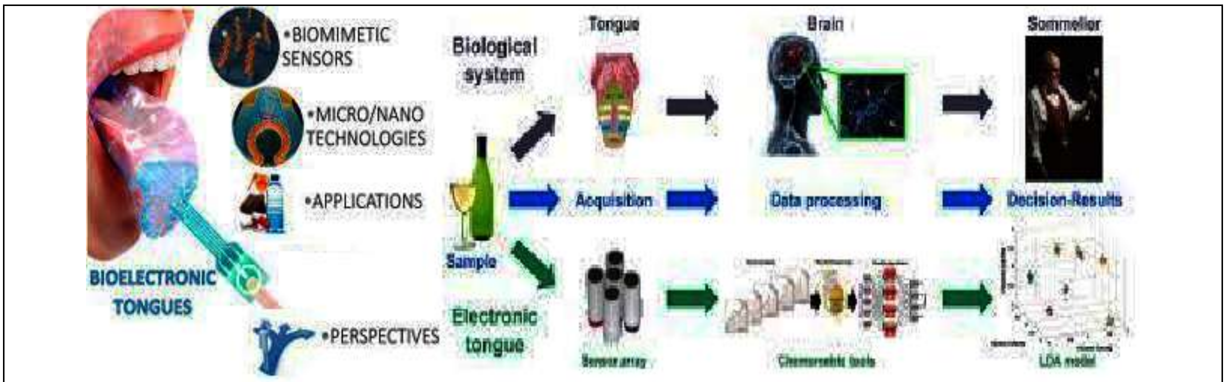

Fig. 2(a-b): Comparing of the sense of smell and taste with artificial senses (a) between biological olfaction, human tongue and artificial olfaction; (b) typical presentation of our prototype n-WSN electronic tongue (e-Tongue) as artificial teste by data analysis and processing (DAP).

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(E) Sanitation and Hygine Value Chain

Once the water is used and consumed, the sanitation process kicks in. The sanitation value chain is fragmented, characterized by a wide range of stakeholders, businesses, from sole traders to multinationals, the majority responding to limited segments of the chain. Only a few companies and organisations have developed a business model that runs almost entirely across the value chain with the majority concentrating their core activities at either end of the value chain. No specified value chain for sanitation for South Africa could be found in literature, but the general value chain for sanitation is also applicable to South Africa. The general sanitation value chain includes six phases [15,18]: capture of sludge, containment of sludge, emptying of sludge, transport of sludge, collection and treatment of sludge, and safe reuse or disposal of treated sanitation waste. This formal water and sanitation sector perspective does, however, not provide the complete picture of the water and sanitation sector of India, South Africa and Africa and others countries. As a start, it excludes the 'non-formal' water sources and sanitation services, as it applies to most of the rural domestic inhabitants. It also excludes the agriculture sector not dependent on the 'formal' water supply. Agriculture is the largest user of water globally. In 2020, agriculture in India used 71 % and South Africa used 65% of the available water in the country [12, 13]. Various heavy metals available in water and associated health risks in Table 1. Summary of conventional techniques for major heavy metal detection from water and waste-water are presented in Table 2. Finally, Table 3: nWSN bio-enzymatic sensors based e-Togue for detection of heavy metals shown in Table3.

Table 1: Various heavy metals available in water and associated health risks[12]

Sl	Heavy Metal	Associated Health Risk
1	**Cadmium (Cd)**	•Nausea, Vomiting, Diarrhea • Liver injury • Convulsions
2	**Arsenic (As)**	• Diarrhea, Heart disease • Numbness, Cancer
3	**Lead (Pb)**	• Intellectual disability • Anemia, Seizures • Coma
4	**Chromium (Cr)**	• Anxiety, Schizophrenia • Kidney and liver diseases
5	**Zinc (Zn)**	•Nausea • Vomiting • Cramps • Diarrhea
6	**Copper (Cu)**	• Vomiting, • Jaundice, Damage to the liver & kidneys.
7	**Iron (Fe)**	• Stomach pain, • vomiting • Metabolic acidosis
8	**Mercury (Hg)**	•Tremors • Insomnia and memory loss • lungs and kidneys, and may be fatal
9	**Nickel (Ni)**	• Chronic bronchitis • Cancer of the lung and nasal sinus • Allergy • Cardiovascular and kidney diseases

Table 2: Summary of conventional techniques for major heavy metal detection from water[12].

Heavy metal	Sample pretreatment	Methods of detection	Detection limit
As^{3+} **Arsenic**	UV digestion and pre-concentration using Aspergillus niger-activated charcoal as biosorbent.	**ETAAS**	**1µg/ L**
	Ref: [13] Shahlaei & Pourhossein (2014)		
Cr^{3+} **Chromium**	pre-concentration using ion exchange media Pyrolysis & atomization using rhodium permanent modifier Solid-phase extraction Separation on a Dionex AS4A anion exchange column	**EDXRFS** **ETAAS** **ICP-MS** **CL**	**0.4mg /L** **0.2µg/L** **4.43ng/L** **0.5µg/L**
	Ref:[14]Menendez-Alonso et al. (1999), [2] de Almeida Pereira et al. (2004)		
Zn^{2+} **Zinc**	Preconcentration on a microcolumn of immobilized Alizarin Red S on alumina Chelating with 5,7-dichlorooxine	**FAAS** **AAS** **AAS**	**0.2µg /L** **0.5µg/L** **0.3µg/L**

	In situ pre-concentration with the dual silica tube atom trap CPE pre-concentration	**FAAS**	**0.095µg/ L**
	Ref:[14]Shabani et al. (2009), [2]Tony et al. (1999)		
Cu^{2+} **Copper**	DLLME pre-concentration CPE pre-concentration	**Spectrophotometric** **FAAS**	**0.5µg/L** **1.5µg/L**
	Ref:[15] Lemos et al. (2007), [2] Wen et al. (2011)		
Fe^{3+} **Iron**	Chelating 1,10-phenanthroline solid-phase extraction selective column extraction	**CL** **FAAS** **CL**	**0.4 nM** **0.2µg/L** **0.05 nM**
	Ref:[16] Rahil-Khazen et al. (2000), [2] Obata et al. (1993)		

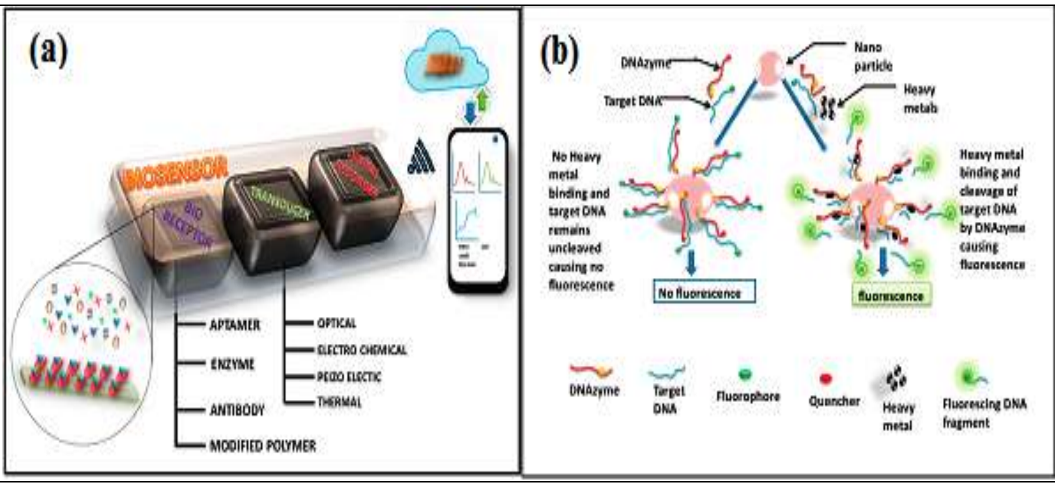

Fig. 3(a-b): Block diagram of (a) nWSN nano-biosensor, (b) Schematic pathway for nWSN DNAzyme based optical e-Tongue detection of heavy metal ions from water and waste-water.

(F) Principles for heavy metal or bio-adsorption detection process

Affinity of the bio-adsorbent towards the sorbate species, the later is attracted and the process persists till equilibrium is reached between the two phases. The degree of affinity for the sorbent towards sorbate regulates the distribution between the solid and liquid phases [19]. Commonly, the Langmuir and Freundlich models have been used for describing bio-adsorption of metals by algae equally well. The Langmuir model has been presented by the following equation (1):

$$\frac{C_e}{q_e} = \frac{1}{K_L} + \left(\frac{a_L}{K_L}\right)C_e \qquad \ldots\ldots\ldots\ldots\ldots.. (1)$$

Where, q_e is the uptake of metal at equilibrium $\left(mgg^{-1}\right)$, C_e is the concentration of metal species in solution at equilibrium $\left(mgL^{-1}\right)$, K_L, a_L are Langmuir constants and $Q_0 = \left(K_L / a_L\right)$ is the maximum metal uptake and the Freundlich adsorption model can be described by the following equation (2):

$$Lnq_e = LnK + {}^{1}\!/_{n} LnC_e \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, K is the measure of the adsorbent capacity and (1/n) gives the intensity of adsorption. The key factors affecting bio-adsorption process are: (i) the solution pH; (ii) the thermodynamic nature of bio-adsorption process; (iii) adsorbent dose; (iv) initial concentration; (v) contact time; (vi) particle size of adsorbents; and (vii) agitation rate.

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Fig. 4 (a-e): Various mechanism and involvement of functional groups towards bio-adsorption of Cd like heavy metal removal from waste-water using nWSN e- Tongue from water and agricultural waste-waste.

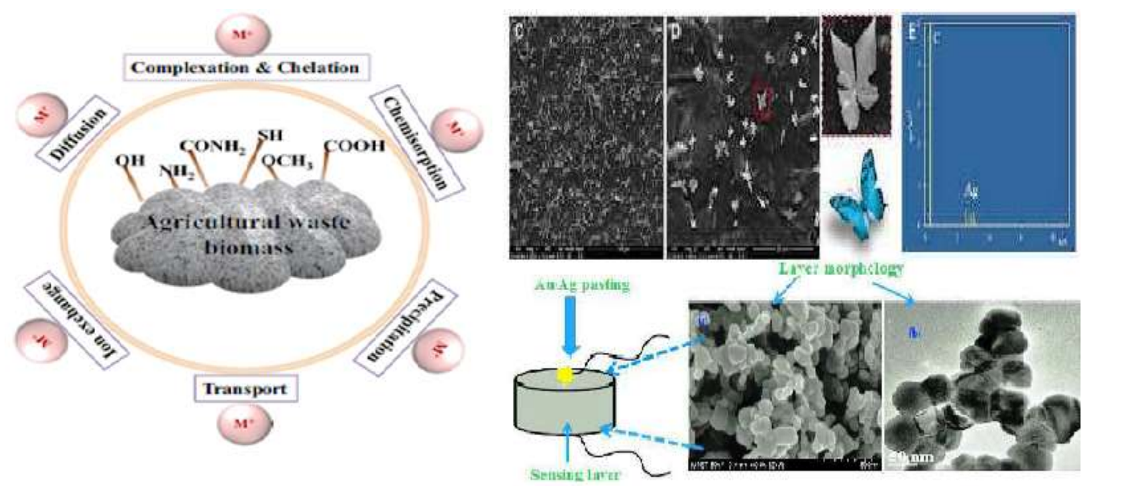

Table 3: nWSN bio-enzymatic sensors based e-Togue for detection of heavy metals.

Detected heavy metals	Sensor configuration	Range of detection
Hg^{2+}, Cd^{2+}, Pb^{2+} and Cr Mercury, Cadmium, Lead and Chromium	GOx entrapped on novel ultra-thin poly (brilliant green) (PBG) films electrodeposited in ethaline DES on multiwalled carbon nanotube (MWCNT) modified glassy carbon electrodes (GCE)	Hg^{2+} (2.5–100 nM), Cd^{2+} (10–100 nM), Pb^{2+} (10–120 nM), Cr (2.5–60 nM)
	Transduction principal	**Amperometric**
	Ref: [13] da Silva, Ghica, and Brett (2020)	
Cu^{2+} Copper	Mg^{2+}-dependent DNAzyme subunits, azide or alkaline modified, immobilized on magnetic beads	10 nM to 10 µM
	Transduction principal	**Fluorimetry**
	Ref: [13] W. Wu, Yu, Chen, and Yang (2019)	
Pb^{2+} Lead	Pb2+-specific DNAzyme immobilized on magnetic beads, coupled to rolling circle amplification (RCA)	**1.0–100 nM**
	Transduction principal	**pH metry**
	Ref:[14] Tang, Xia, Tang, Zhang, and Zhou (2019)	
Cu^{2+}, Pb^{2+}, Cd^{2+}, Copper, Lead, Cadmium	Urease and Glucose Oxidase based biosensor	**10 nM to 1 mM**
	Transduction principal	**Photolu minesce**

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	Ref:[14] Syshchyk, Skryshevsky, Soldatkin, and Soldatkin (2015)	
Cu^{2+}, Hg^{2+}, Cd^{2+}, and Pb^{2+} **Copper, Mercury, Cadmium and Lead**	Ultrathin polypyrrole–glucose oxidase (PPy–GOx) potentiometric biosensor	**0.5 nM/ L**
	Transduction principal	**Pote ntio met ry**
	Ref:[15] Ayenimo and Adeloju (2015), [20] **Das S C et al. (2012)**	

(G) Sanitation and Hygine Value Chain

Once the water is used and consumed, the sanitation process kicks in. The sanitation value chain is fragmented, characterized by a wide range of stakeholders, businesses, from sole traders to multinationals, the majority responding to limited segments of the chain. Only a few companies and organisations have developed a business model that runs almost entirely across the value chain with the majority concentrating their core activities at either end of the value chain. No specified value chain for sanitation for South Africa could be found in literature, but the general value chain for sanitation is also applicable to South Africa. The general sanitation value chain includes six phases [25]: capture of sludge, containment of sludge, emptying of sludge, transport of sludge, collection and treatment of sludge, and safe reuse or disposal of treated sanitation waste. Hygiene value chain guidelines on when to wash hands and how to wash hands. In general hands should, for example, be washed: before, during, and after preparing food, before eating food or feeding children, before and after caring for an infected or 'at risk' person, after using the toilet, after changing diapers or cleaning up a child who has used the toilet, after touching an animal, animal feed, or animal waste, after handling pet food or pet treats, after handling money (or using an ATM), etc. The Centers for Disease Control and Prevention (CDC) [24] recommends a five step process for washing hands when soap and water is available: wet, lather, scrub, rinse and dry. If soap and water are not available, CDC recommends the use of an alcohol based hand sanitiser that contains at least 60% alcohol, although it is said not to be as effective as handwashing when hands are visibly dirty or greasy and cannot eliminate all types of germs and harmful chemicals. If no soap is available or affordable, ash or mud can be used as abrasive, before rinsing. Another alternative in especially South African people is the use of Moringa oleifera powder [26].

HRWASH is the collective term for the associated concepts of clean and safe drinking water (SDG 6.1), safe sanitation and hygiene (SDG 6.2)[20]. According to the WHO/UNICEF Joint Monitoring Programme(JMP) for Water Supply and Sanitation in world wide. JMP is the custodian of global data on RHWASH and has derived a normative interpret-tation for SDG 6.1 and 6.2 is presented in Table 4.

Table 4. JMP service ladder for sanitation in households [12].

	Service Level	Defination
1	**Safely managed**	Use of an improved sanitation facility which is not shared with other households and where excreta are safely disposed in situ or transported and treated off-site.
2	**Basic**	Use of improved facilities which are not shared with other households
3	**Limited**	Use of improved facilities shared between two or more households
4	**Unimproved**	Use of pit latrines without a slab or platform, hanging latrines and bucket latrines
5	**Open defecation or no service**	No toilets or latrines. Disposal of human faeces in fields, forest, bushes, open bodies of water, beaches or other open spaces or with solid waste

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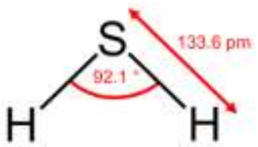
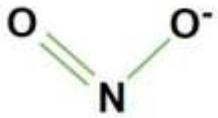
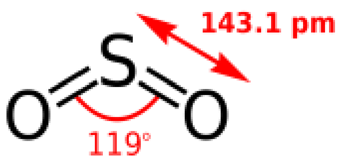
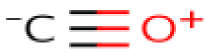
Table 5. Application of Nanostructured e-Noses in data analysis of VOCs caused for Industrial emissions hazards and forest fire gaseous protection [20].		
Place and types of sample	**Analysis process**	**Data analysis method [Ref.]**
Air samples from composting plants, printing houses, sewage treatment plants, recycling plants, settlers	Water vapor, flammable gases, toxic gases, solvents	PCA, LDA
Samples of air from the sewage treatment plant and wetland cattle field and farmhouse	CO, NO_2, CH_4 ,VOC like (benzene, toluene, m-xylene)	PCA, FCM
Indoor air samples from duck and pigs farms	H_2S, NO_2, SO_2, CH_4 , VOC	KNN, SVM
Samples of indoor air from cars and internal air samples	CO, NO_2, ammonia, VOC like benzene, toluene, formaldehyde	PCA, PNN, SVM, KNN

Table 6: **Chemical structure and properties of VOCs caused air pollution from Industrial emissions toxic gases[20].**

 **(a) Hydrogen sulfide**		 **(b) Nitrogen dioxide**	
Properties	**Values**	**Properties**	**Values**
Molecular formula Molar mass Density Boiling point Solubility in water Odour	H_2S 34.08 g mol^{-1} 1.363 g/L −60 °C (−76 °F) 4.0 g/l (at 20 °C) Pungent, like that of rotten eggs	Molecular formula Molar mass Density Boiling point Solubility in water Odour	NO_2 46.006 g mol^{-1} 1.880 g/L 21.15 °C. soluble by hydrolyses Acidic, reddish-brown highly corrosive gas
 **(c) Sulphur dioxide**		 **(d) Carbon monoxide**	
Properties	**Values**	**Properties**	**Values**
Molecular formula Molar mass Density Boiling point Solubility in water Odour	SO_2 64.066 g mol^{-1} 2.6288 g/L −10 °C (14 °F) No, 94 g/L in sulphurous acid Colourless and pungent gas	Molecular formula Molar mass Density Boiling point Solubility in water Odour	CO 28.01g mol^{-1} 1.145 g/L at 25°C -191.5 °C Very less(25 mg in 1L) soluble in benzene Colourless, flammable, highly toxic in nature

IV. EXPERIMENTATION

(A) Sample Preparation

Water samples were collected from tap water in our lab, rainwater, lake water from Denmark and river water from India. These samples were filtered through a 0.45 mm filter. Generally, 200 µl of 1 M acetate buffer pH 4.4 was mixed with 1.8 ml water sample and then analyzed by the optimized DPASV method. The practical application of AgNS/SPCEs was evaluated by spiking the known amount of Cd, Pb, Cu, and Hg into the water samples. Then recoveries were calculated using following equation (3).

$$\mathrm{Re\,covery}\% = \frac{C_{Foundbycalibrationplot}}{C_{Added}} \times 100 \quad \text{.... (3)}$$

(B) Procedures and Measurements

Figure 5 (a-b) shows block diagram of the prototyped nWSN with G-IoT enable e-Tongue system, comprising a sensor array, an interface printed circuit board (PCB), and an microcontroller (µC) board embedded with a pattern recognition algorithm, as well as a verification program. Sensor responses pass through a data acquisition card (DAQ) to a laptop with a self-developed LabVIEW program for the purpose of verifying the function of the portable e-Nose system [24,25] .Figure 5(b) shows data processing and analysis by LabVIEW of the array consists of eight sensors, the Interface PCB includes eight interface processing Circuits (IPC),an eight to one multiplexer (MUX), and an 8-bit analog-to-digital converter (ADC). The eight interface processing circuits are connected to the eight sensors, which actively adapt the circuit to a preset baseline voltage. The multiplexer reduces the need for multiple ADCs by scanning the eight channels and choosing one channel at a time. The ADC converts sensor data into a digital form for data processing.

(C) Data Analysis and Processing Methods

Signals from all sensors (responses) are collected and **fingerprint** of odour made. Name is given for every **odour fingerprint** and odours are associated in classes. E-nose and E-tongue is teach every class of odours and particular measurement can be used as unknown and recognized by special program neuron network, for example sensor signal odour map. Odour mapping with e-Nose and e-Tongue usually is presented in the form of principal components (PC) with 2 and 3 dimensional plot. Measurements of different objects are presented as different groups of points in this plot. If odours are unlike, than point groups are quite distant one from another, but if similar close to each other or overlaps.

Das S.C, Bhattacharyya N, Bandhyopadhyay R, et.al, developed an e-Nose and e-Tongue for quality control, process control, environmental analysis, and medical diagnosis. The instrument is able to identify, classify and also quantify odors and gaseous emissions. There are various applications in which an electronic nose may be used. For example, to monitor the characteristic odour generated by a manufactured product (e.g. drink, food, tobacco, shampoos). Our model is one of first Nanostructured Wireless Sensor Network (nWSN) with Green IoT supported technologies e-Nose and e-Tongue. Those are contains 8 sensors with different gas sensing electrodes (Ni, Co, Fe, Pt, Pd, Cd, etc. doped nanostructured) and working temperatures (20 and 40°C). The odour sampling was made by small membrane pump, which was connected to sensors. This working group having analyzed tobaccos, spirits, wines, textiles, orange juice using first Nanostructured Wireless Sensor Network (nWSN) with Green IoT supported technologies e-Nose and e-Tongue. Fig. 7 (a-b) shows (a) FESEM images of butterfly like droped nanostructured sensor detection at 10000X magnification and (b) Peak currents of Cd, Pb, Cu and Hg using three different (Ni, Co, Pt, doped nanostructured) nWSN e-Tongue for heavy metal detection from drinking water and waste-water. Fig. 8 (a-c): A robust and remote controlled (a) Silver doped Nanostructured Wireless Sensor Network (a) Ag doped nWSN e-Tongue G-IoT based for Concurrent Quantification of (c) FTIR data analysis of Cd, Pb, Cu and Hg heavy metal detection from drinking water and waste-water.

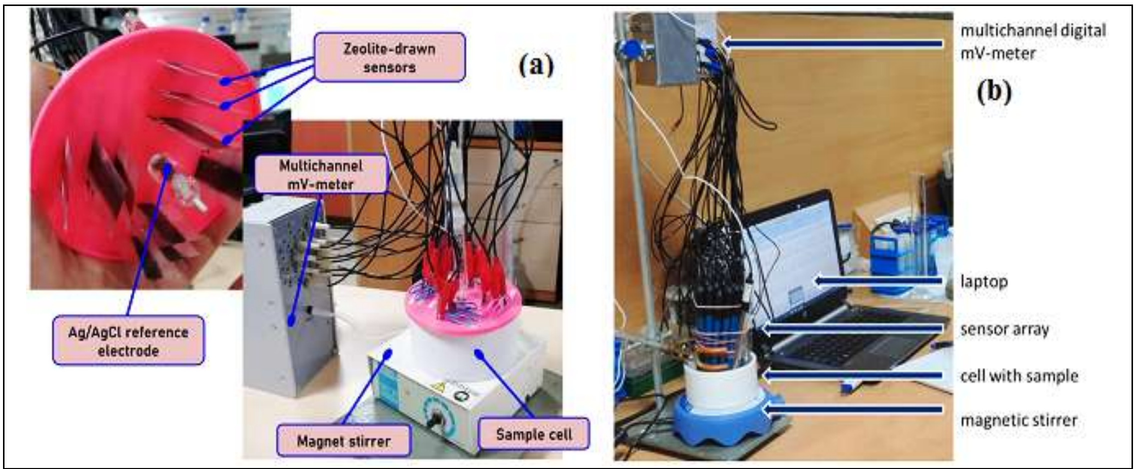


Fig. 5 (a-b): Nanostructured WSN e-Tongue for heavy metal detection from Water and Waste-Water (a) Experimental setup, (b) Data analysis and processing.

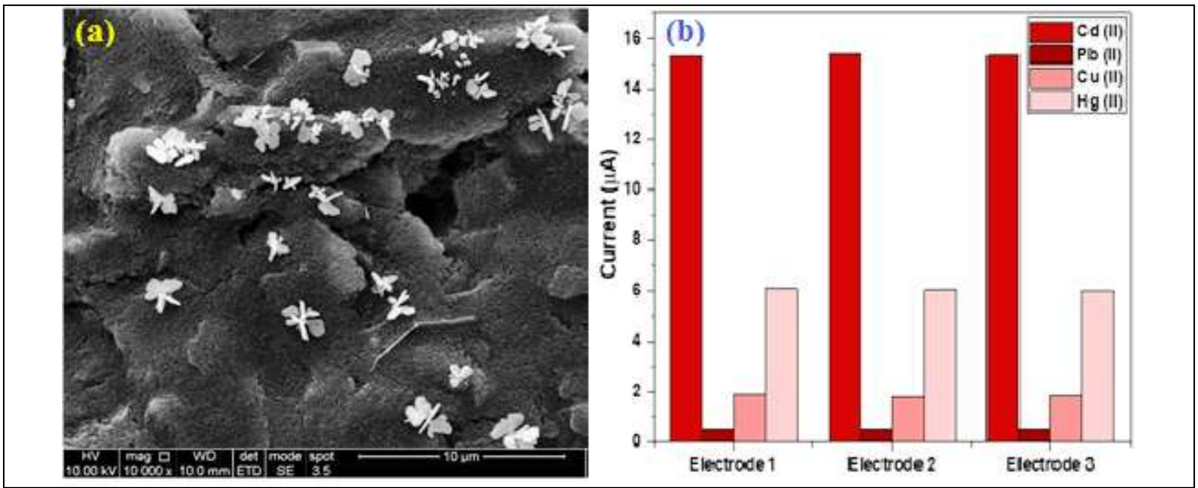


Fig. 7 (a-b): (a) FESEM images of butterfly like droped nanostructured sensor detection at 10000X magnification and (b) Peak currents of Cd, Pb, Cu and Hg using three different (Ni, Co, Pt, doped nanostructured) nWSN e-Tongue for heavy metal detection from drinking water and waste-water.

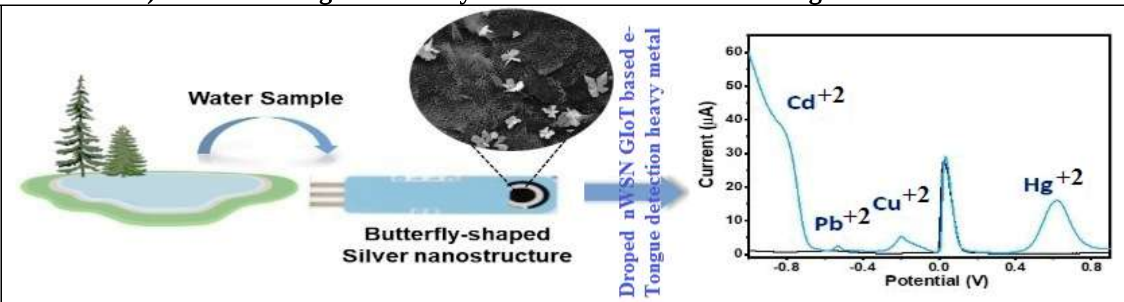


Fig. 8 (a-c): A robust and remote controlled (a) Silver doped Nanostructured Wireless Sensor Network (a) Ag doped nWSN e-Tongue G-IoT based for Concurrent Quantification of (c) FTIR data analysis of Cd, Pb, Cu and Hg heavy metal detection from drinking water and waste-water.

The dataset obtained with the use of our prototype n-WSN electronic nose (e-Nose) as artificial senses contains the response signals of each sensor and usually is very complex. Analysis of this type of data is considerably more difficult, than in the case of a device equipped with only one sensor. For that reason the first step of data processing is usually meant to decrease the dimensionality of the dataset. Table 7 application of nWSN e-Noses in detection analysis and processing data of VOCs caused for Industrial emissions hazards gaseous**.** Doing this whilst retaining as much significant infor-mation as possible is one of key challenges in statistical data processing, as the results of data analysis should lead to reliable and repeatable results. Chemometric methods used for data pro-cessing utilize pattern recognition. Information contained in the sensor's response signal is compared with reference data. The basic steps of data analysis are as follows [20]:

- Pre-processing;
- Selection of variables;
- Classification;
- Decision making.

(D) Sensing Response and Cross Validation

In these mode the circuit is ready for sensing. The multiplexer chooses path "0" in Fig. 9, to form a negative feedback loop, which establishes the sensor resistance of the n-WSN e-Nose. Due to a large time constant R_a and R_g, the sensor resistance of the n-WSN e-Nose can be maintained a long enough time, comparing with the sensor response time. As a result, the IPC responds to the sensor while tuning out background signals; which is similar to the process performed like as biological noses. In this mode, variations in the sensor resistance are translated to a change in output voltage, which is fed into an ADC through an eight to one MUX, whereupon, the ADC output is send to the AI based G-IoT enabled n-WSN e-Noses are electrical resistance modulated sensing devices containing a sensor array capable of producing a digital fingerprint of volatile organic compounds released from any source [26]. The responses of the test hazardous gases have been calculated using the equation (4):

$$Response(R) = \left[\frac{(R_a - R_g)}{R_a}\right] \times 100\% \qquad (4)$$

where, R_a denotes the resistance in air and R_g the resistance in the presence of a test gas. The response of the material is examined with VOC (SO_2, H_2S, NO_2,CO) in the temperature range of 20–40°C, and the sensitivity and response have been observed to be quite appreciable.

The procedure is repeated for each sample. The root mean squared error of the cross-validation (RMSECV) is calculated according the equation (5):

$$RMSECV = \sqrt{\frac{\sum_i (y_i^{pred} - y_i^{real})^2}{m}} \qquad \text{-----------} (5)$$

(E) Algorithms

Users can read and classify odours through the classification interface, which implements six different data analysis methods algorithms, including nearest neighbor (NN), K-nearest neighbor (KNN), support vector machine (SVM), principle component analysis with nearest neighbor (PNN), principle component analysis with K-nearest neighbor (PKNN), and principle component analysis (PCA) with support vector machine (PSVM). Performing six different algorithms simultaneously enables the user to investigate and compare the efficiency and accuracy among each of the algorithms. The classification results, the "smell print", and PCA and LDA plots are also shown in Figure 9(a-d): on the interface. Environmental hazardous gases from industry emission gaseous sensing patterns of (a) sulphur dioxide (SO_2), (b) hydrogen sulphide (H_2S), (c) nitrogen dioxide (NO_2) and (d) carbon monoxide (CO) were used to test in the prototype nWSN based G-IoT enable n-Nose as artificial senses. The data regarding the gaseous odours was collected over a three-day span. On the first day, five different samples of each gaseous were collected. The average response of the four samples was used as the odour signature for that hazardous gaseous. Figure 9(e-h) shows the resulting patterns for testing the odour of the hazardous gaseous samples. The magnitude of each axis indicates the resistance change ratio (ΔR/R) in each sensor when reaching equilibrium.

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V. RESULTS AND DISCUSIONS

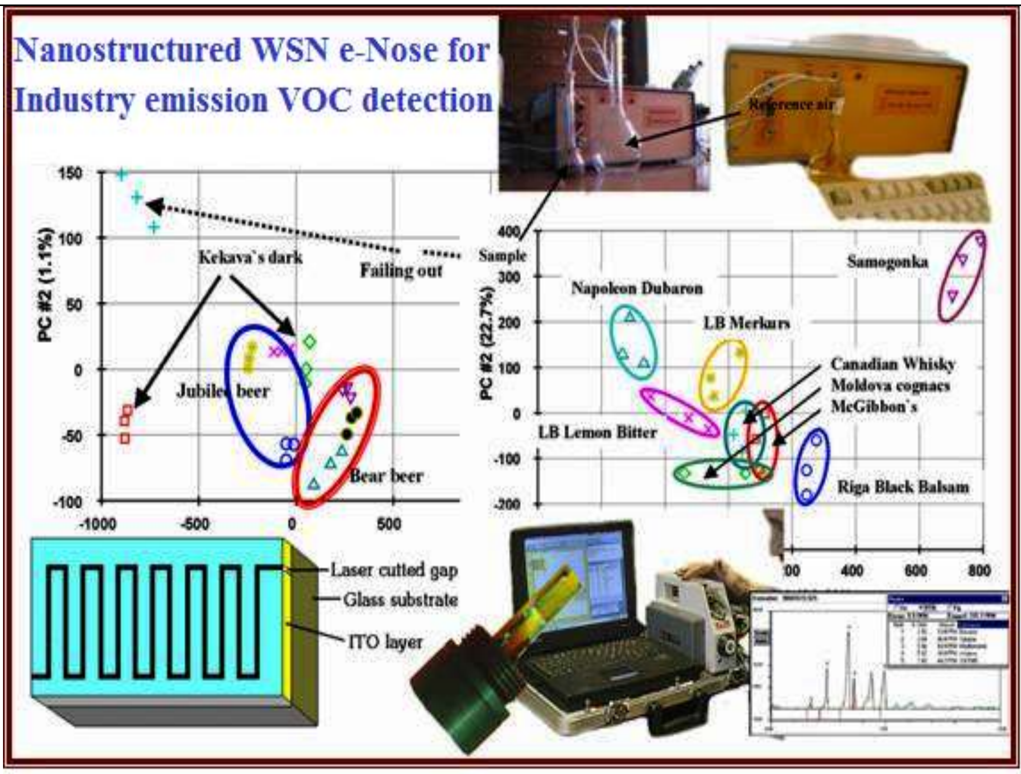

Fig. 9(a-h): Shows the PCA data resulting patterns for testing the odour of the industrial hazardous gaseous samples for (a) Sulphur dioxide (SO_2), (b) Hydrogen Sulphide (H_2S), (c) Nitrogen dioxide (NO_2) and (d) Carbon monoxide (CO). Data analysis of n-WSN base GIoT eNose as a function of time with different concentrations of VOCs caused air pollution from Industrial emissions gaseous

Table 7. Summarized detection of Industrial hazardous gaseous emission sensing pattern of (a) sulphur dioxide (SO_2), (b) hydrogen sulphide (H_2S), (c) nitrogen dioxide (NO_2) and (d) carbon monoxide (CO) odour classification result for the six data analysis and clustering algorithms

VOC Gaseous	PCA	LDA	FCM	PNN	KNN	SVM
SO_2	37/38	37/38	39/40	38/39	35/37	38/38
H_2S	39/39	38/38	38/38	39/40	38/40	39/40
NO_2	36/36	39/40	37/38	35/36	35/36	35/36
CO	20/20	20/22	20/20	20/22	20/21	21/21
TOTAL	131/132	136/138	135/136	136/137	133/134	132/133
ACCURACY (%)	**99.78**	**99.86**	**99.95**	**99.60**	**99.90**	**99.85**
AVG. ACCURACY	**99.75 (%)**					

Between the second day and the third day, two series of experiments were conducted. In the morning noon and evening time, five different places samples of each industry and forest were collected. For the duration of the experiment, the temperature was 20- 40 ºC. Table 7: Summary of sensitivity and average accuracy is more than 99.75 percentage of classification results, its means that of the nearly 100% detection of industry emission hazardous gaseous like as (a) sulphur dioxide (SO_2), (b) hydrogen sulphide (H_2S), (c) nitrogen dioxide (NO_2) and (d) carbon monoxide (CO) for the six data analysis algorithms used in the verification software [27].So, conclude that zero emission of industry hazardous gaseous may spread if industry opted and used our prototyped nWSN based GIoT with e-Nose. Fig.9 (g-h) shows a three-dimensional projection of the PCA results of all data analysis clustering points regarding the odour of industry emission hazardous VOC gaseous.

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VOC Gaseous	PCA	LDA	FCM	PNN	KNN	SVM
SO_2	37/38	37/38	39/40	38/39	35/37	38/38
H_2S	39/39	38/38	38/38	39/40	38/40	39/40
NO_2	36/36	39/40	37/38	35/36	35/36	35/36
CO	20/20	20/22	20/20	20/22	20/21	21/21
TOTAL	131/132	136/138	135/136	136/137	133/134	132/133
ACCURACY (%)	**99.78**	**99.86**	**99.95**	**99.60**	**99.90**	**99.85**
AVG. ACCURACY	**99.75 (%)**					

VI. CONCLUSION AND FUTURE ENDEAVORS

(A) Conclusions

Towards the development of environmentally friendly, low-cost, efficient prototype Nanostruc-tured Wireless Sensor Network System (nWSN) and Green IoT e-Tongue for waste-water treatment, various micro-organism and agricultural based bio-adsorbents have been successfully exploited for bio-adsorption of Cd^{+2}, Pb^{+2}, Hg^{+2} and Cu^{+2} metal ions. These materials possess high affinity for Cd^{+2}, Pb^{+2}, Hg^{+2} and Cu^{+2} removals. Their reusability nature and effective adoptability within very short contact time are applicable in detoxification at trace concentration of Cd^{+2}, Pb^{+2}, Hg^{+2} and Cu^{+2} from water and waste-water. Similarly, developed a prototype of a portable nWSN based GIoT with e-Nose comprising an interface PCB and a digital microprocessor board. We also developed and tested KNN classification algorithms. A parallel verification program was developed to verify the functions and the algorithms of the system. The prototype has been tested with three complex industrial emission gaseous odours, namely, (a) sulphur dioxide (SO_2), (b) hydrogen sulphide (H_2S), (c) nitrogen dioxide (NO_2) and (d) carbon monoxide (CO) also known as natural gas for protection of unwanted forest fire and ecological disaster. The prototype of the proposed portable n-WSN E-Nose system and the verification software achieved a classification accuracy in excess of 99.75%. This E-Nose prototype n-WSN as G-IoT e-Nose applications is highly suitable for implementation as a portable system. G-IoT supported e-Noses are electrical resistance modulated sensing devices containing a sensor array capable of producing a digital fingerprint of volatile organic compounds released from any source. Conductive polymer sensor array take advantage of differential responses of different conducing plastics (within each sensor) to various chemical species in the sample headspace by producing a unique electronic aroma signature pattern (EASP) specific to the anolyte mixture [28]. The response of each sensor is based on the collective effect of the entire mixture of components in the headspace on electrical resistance changes generated by adsorption of analyte to the sensor. New developments include integrated systems the use of molecular beacons and nanobio-sensor production. These should ensure even more rapid and specific detection. The potential development of this technology coupled with remote data acquisition and central processing powered by hybrid artificial intelligence systems could make this appreciate world-wide [29]. So, conclude that zero emission of industry hazardous gaseous may spread if industry opted and used our prototyped nWSN based GIoT with e-Nose.

(B)Advantages from the above results

In human rights 3.0, the “gushers” of data and unprecedented computing power for processing it have made it possible for engineers to create artificial intelligence based on “deep learning” that is, digital neural networks in which computers can learn from data the way that babies learn from the environment around them, starting with little knowledge and then acquiring proficiency and familiarity as they interact with new environments [28, 29]. Deep learning, machine learning, and other disruptive technologies of automated data processing pose different kinds of risks to rights-based societies, often through initiatives intended to make justice more efficient. Software engineers, with their inclinations toward appropriate vulgarity, commonly refer to this problem as “shit in, shit out.” In AI circles and in the literature, it is also referred to as “garbage in, garbage out.”

(C) Early Warning (EW) and Risk Assessment:

United Nations Environment Programme catalogues **wildfires** - and therefore, forest fires - as on-going and rapid/sudden-onset environmental threats (UNEP, 2012). Forest fires create a hazard to lives and properties and are often connected to secondary effects such as landslides, erosion, and changes in water quality [31]; therefore, the UNEP considers that **early warning systems** are of great importance for preventing or limiting environmental and economical damages. **Early Warning (EW)** is defined as "the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response" (UN, 2006), and it implies the combination of four main elements according to the United Nations' International Strategy for Disaster Reduction – (ISDR): (i) **Risk Knowledge and Risk Assessment, (ii) Monitoring and Predicting -** in order to provide appropriate estimates of the potential risk encountered by communities, economies and the environment, (iii) **Disseminating Information** - through electronic communication systems in form of reliable, synthetic and simple warning messages. (iv) **Response** - according to appropriate action plans. Nevertheless, extant research on EW emphasizes, predictions are not useful, however, unless they are translated into a warning and action plan the public can understand and unless the information reaches the public in a timely manner. When monitoring and predicting systems are associated with communication systems and response plans, they are considered early warning systems (Glantz, 2003).

India's Biodiversity Act, 2002 envisages the establishment of a National Biodiversity Authority for discharging the statutory powers provided for under the legislation. The chief concerns of the 1992 Convention on Biological Diversity are conservation of biological diversity, sustainable utilization of its components and equitable sharing of benefits. Thus, the last two and half decades has seen two important international instruments such as the 1992 Convention on Biological Diversity and the 1993 Agreement on Trade Related Intellectual Property Rights (TRIPS Agreement) as a part of World Trade Organization (WTO) and are in force. Most of the TRIPS Agreement members are parties to the 1992 Convention. India is the party to both of these instruments [29]. There are many interrelated provisions and diametrically opposite rights and obligations under these instruments. The two main overlapping areas in these Conventions are protection and access to biological and genetic resources. According to the Article 27(1) provides that patents shall be available for any inventions, whether products or processes, in all fields of technology, provided that they are new, involve an inventive step and are capable of industrial application. However, members may also exclude from patentability of diagnostic, therapeutic and surgical methods for the treatment of humans or animals, plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes. However, members shall provide for the protection of plant varieties either by patents or by an effective sui generis system or by any combination thereof. Thus, the Article 27(2) provides thus: "Members may exclude from patentability inventions, the prevention within their territory of the commercial exploitation of which is necessary to protect ordre public or morality, including to protect human, animal or plant life or health or to avoid serious prejudice to the environment, provided that such exclusion is not made merely because the exploitation is prohibited by their law". In fact [30], Article 8(j) of the 1993 TRIPS Agreement authorizes its members, in formulating or amending their national laws and regulations to "adopt measures necessary to protect public health and nutrition, and to promote the public interest in sectors of vital importance to their socio-economic and technological developments"., provided such measures are consistent with other 1993 TRIPS Agreement provisions [31,32].

(D)Techno-legal aspect of Green-IoT in HRWASH

Vision SDG by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations. The UN also identified a number of cross-cutting criteria for good practices in the WASH sector: non-discrimination, participation, accountability, impact and sustainability.

The true value of GIoT is, however, only manifested when intelligent decisions are being made with the acquired data, resulting in appropriate actions. Furthermore, GIoT is entirely dependent on addressing the 'real' challenge which only becomes possible if the community is part of the GIoT lifecycle. For a broad GIoT deployment, these data observations should ideally be from multiple sensor types (e.g. hand pump utilisation, water quality and flow in the pipe, sanitation pit level, etc.). In such a scaled GIoT deployment, the following general

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benefits can be obtained [31]: Viewing GIoT in relation to the United Nation's crosscutting criteria for HRWASH, several opportunities and benefits can be identified [31,32]:

• **Non-discrimination**: Monitoring use through sensors and mobile-based technologies may assist in detecting/reporting denied or restricted access to sanitation facilities and/or water resources [32].
• **Participation**: Using mobile-based technologies linked to sensors, communities can contribute to improving their own HRWASH context [32,33].
• **Accountability:** Armed with the data from the community based IoT solutions, entities responsible for maintenance and planning can make evidence-based decisions.
• **Impact:** Valid and justifiable choices have a higher probability for impact.
• **Sustainability:** With the inclusion of communities and the ability to solve that community's specific challenge, the probability of a sustainable intervention is higher [33].

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