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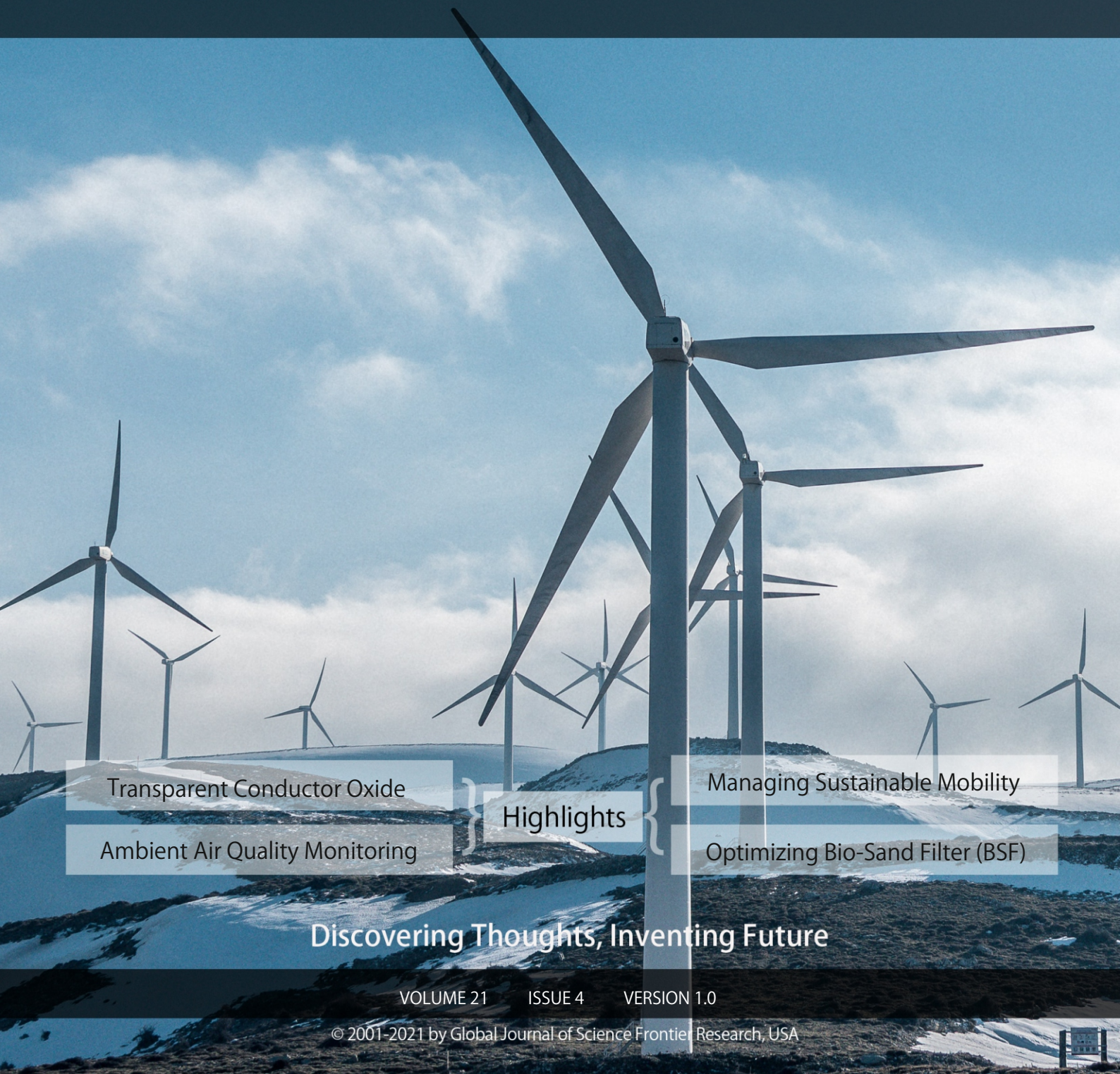

Transparent Conductor Oxide

Ambient Air Quality Monitoring

Highlights

Managing Sustainable Mobility

Optimizing Bio-Sand Filter (BSF)

Discovering Thoughts, Inventing Future

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Copper Decorated on Fluorine Doped Tin Oxide as a Transparent Conductor Oxide for Photovoltaic Energy by DSSCs

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Abstract- In this work, films of fluorine doped tin oxide (FTO) with and without copper have been successfully synthesized by spray pyrolysis on conductive transparent substrates without acid addition. Sprayed film samples were used in the determination of photovoltaic parameters in the dye-sensitized solar cells (DSSCs), including open-circuit voltage (Voc), short circuit current density (Jsc), fill factor (FF), efficiency (η), shunt (Rshunt) and serial (Rserial) resistances. Characterization techniques determined the sheet electrical resistance, optical transmittance, thickness, band gap, topographical and structural characterizations, and flat-band potential of the sprayed films. The X-rays diffraction showed peak distribution of the sprayed products similar to the tin dioxide phase. There was morphological change, with smaller and more compact grains by adding copper. Also, conduction band edge, sheet resistance, optical transmittance and optical band gap change as function of the amount of copper.

Keywords: spray pyrolysis, characterization, photovoltaic, environmental.

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Abstract- In this work, films of fluorine doped tin oxide (FTO) with and without copper have been successfully synthesized by spray pyrolysis on conductive transparent substrates without acid addition. Sprayed film samples were used in the determination of photovoltaic parameters in the dye-sensitized solar cells (DSSCs), including open-circuit voltage (Voc), short circuit current density (Jsc), fill factor (FF), efficiency (η), shunt (Rshunt) and serial (Rserial) resistances. Characterization techniques determined the sheet electrical resistance, optical transmittance, thickness, band gap, topographical and structural characterizations, and flat-band potential of the sprayed films. The X-rays diffraction showed peak distribution of the sprayed products similar to the tin dioxide phase. There was morphological change, with smaller and more compact grains by adding copper. Also, conduction band edge, sheet resistance, optical transmittance and optical band gap change as function of the amount of copper. After the characterization, fluorine doped tin oxide films with and without copper, on transparent substrate, were used in the dye-sensitized solar cells assembly. The results showed this methodology as an environmentally friendly way for preparation, characterization and application of copper decorated FTO films in photovoltaic devices. The aim of this work is to divulge the results on the copper decorated SnOx: F sprayed films obtained from the techniques cited applied in DSSCs.

Keywords: spray pyrolysis, characterization, photovoltaic, environmental.

I. Introduction

Transparent electrical conductor materials (TECMs) can be of various structures, such as oxides. Fluorine doped tin oxide (FTO) semiconductors as well as oxides mixtures, non-oxides and organic materials using acidic solutions can be cited as examples [1, 2]. TECMs are unique, exhibiting both transparency and electrical conductivity.[1] The interest on TECMs for application in the interfacial charge transfer process, in particular the photovoltaic area, has been growing in the last years due to their unique characteristics.

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The material properties are affected by doping. The choice of dopants must be done to minimize the net distortion and preserve the phase [1]. Therefore, the structural, electrical and optical properties of tin dioxide (SnO_2) semiconductor have been tailored by dopants such as fluorine (F) [3-9], antimony (Sb) [8], molybdenum (Mo) [10], manganese (Mn) [11], copper (Cu) [12] and chromium (Cr) [13].

The fluorine doped tin oxide semiconductor film is one TECM typically used in the dye-sensitized solar cells (DSSCs) assembly [14-31]. Fluorine doped tin oxide (SnO_x:F) films have been made from inexpensive raw materials, using simple spray pyrolysis technique [3,8]. The "x" superscript in the chemical formula indicates the absence of oxygen atoms, i.e, stoichiometric deviation. The oxygen holes combined with the fluorine (F) doping are the key to the electrical conductivity and transparency in SnO_x: F films [1, 32].

The two points method associated with the Equation 1 has been used in the electrical characterization of films by sheet electrical resistance (R_s) measurements [3, 5, 33]. In SnO_x: F films deposited by spray pyrolysis technique, equation (1) is used for measurement of the R_s, from electrical resistance (R) value measured by digital multimeter [5]. Besides the R_s measurements, the films have been characterized by superficial morphology [14, 15, 20] and thickness [5, 17, 22] by scan electron microscopy (SEM).

$$R_s = \frac{\rho}{t} = R\left(\frac{W}{L}\right) \quad (1)$$

where ρ is the electrical resistivity, t is the film thickness, W is the width, L is the length and the ρ/t ratio is called sheet resistance (R_s).

The UV-vis spectroscopy has been usually employed as a tool for the optical characterization of materials through transmittance [9-12, 35]. The determination of the band gap (E_g) value by the Tauc method (Equation 2,3) using optical transmittance data has been reported [4,6,9,10,13,36]. Also, the thickness determination (t) from optical transmittance was reported [7, 35]. Additionally, Equations (4, 5 and 6)

were used as tool to determine t, using optical transmittance data [7].

$$\alpha hv = t\left(hv - E_g\right)^{i} \quad (2)$$

$$\alpha = -\frac{1}{t}\ln(T) \quad (3)$$

where h: Planck constant, v: light frequency, which is the ratio between the light speed constant and the wavelength (λ), i = 1/2 (direct transition semiconductor) and i = 2 (indirect transition semiconductor), α: absorption coefficient, T: transmittance data and t: film thickness.

$$C(\lambda) = \frac{T^{+}(\lambda) - T^{-}(\lambda)}{2T^{+}(\lambda)T^{-}(\lambda)} \quad (4)$$

$$n_{film}(\lambda) = \frac{\left[8n_{sub}C(\lambda) + (n_{sub}+1)^2\right]^{1/2} + \left[8n_{sub}C(\lambda) + (n_{sub}-1)^2\right]^{1/2}}{2} \quad (5)$$

$$t = \left(2\left[\frac{n_{film}(\lambda_1)}{\lambda_1} - \frac{n_{film}(\lambda_2)}{\lambda_2}\right]\right) \quad (6)$$

where, n_{film}: film refractive index, n_{sub}: substrate refractive index, $T^{+}(\lambda)$ and $T^{-}(\lambda)$ are transmittance values in the peak top and bottom at each wavelength (λ), respectively.

By X-ray diffraction (XRD) characterization, the SnO_x:F films manufactured by the spray pyrolysis technique, which commonly has addition of acid, have been characterized as a pure stoichiometric tin oxide (SnO_2) phase [4-8]. The absence of the SnO_x: F phase has been attributed to the dopant nature of the fluorine (F) and the oxygen vacancies, where their concentration in sprayed films are below the detection limit of the XRD equipment. Thus, SEM, UV-vis spectroscopy and other techniques have been combined with XRD to help characterize sprayed films as SnO_x:F.

Additionally, the electrochemical characterization studies the interfacial charge transfer process from between two or more materials junctions. The electrochemical methods have been used as tools to derive properties of semiconductors from the interfacial charge transfer processes [29, 30]. The determination of the SnO_2 and titanium dioxide (TiO_2) conduction bands from flat-band potential (E_{fbp}) obtained by Mott-Schottky electrochemical method was report elsewhere [39].

The semiconductor characterization in n-type or p-type has been made by electrochemical technique called Mott-Schottky through the electrochemical cell with three electrodes and an electrolyte [20,23,36,40-44]. The electrochemical capacitance (C) of the semiconductor/electrolyte junction as function of potential applied (E) is given by the Mott-Schottky equation (7) [36,40-44].

$$\frac{1}{C^2} = \frac{2}{\varepsilon_\infty \varepsilon_r A^2 N}\left(E - E_{fbp} - \frac{k_b T}{q}\right) \quad (7)$$

where ε_∞ (8.854 x 10^{-14} F cm^{-1}): permittivity of free space, ε_r: relative dielectric constant of the specimen, A(cm^2): sample area, N (cm^{-3}): electrons donor (n-type semiconductor) or electrons acceptor (p-type semiconductor) density, E (V): applied potential, E_{fbp} (V): band potential, k_b (1.38 x 10^{-23} J K^{-1}): Boltzmann constant, T (K): absolute temperature and q (1.602 x 10^{-19} C): the electron charge.

The study of the influence of copper (Cu) atoms in the SnO_x: F sprayed film properties and their impact on photovoltaic characteristics of DSSCs has not been reported in the literature. From this scenario, the aim of this work is to divulge the results of the copper decorated SnO_x:F sprayed films obtained from the techniques cited in the review above. Also, sprayed films samples were used in the determination of photovoltaic parameters of DSSCs, including open-circuit voltage (V_{oc}), short circuit current density (J_{sc}), fill factor (FF), efficiency (η), shunt (R_{shunt}) and serial (R_{serial}) resistances.

II. Materials and Methods

a) Obtaining the sprayed films

A muffle furnace (EDG F-1800) with ceramic heater (220V/500W, Higher) was used for calcination. The heating rate was 7 °C/min and the work temperature at 600 °C. Microscopy glass were the substrates. The solutions were atomized into a fine droplet spray by nozzle (α4, APREX) with the help of an air carrier gas fed into the spray nozzle from the air compressor (Twister, SHULZ).

The starting materials were tin chloride II dihydrate ($SnCl_2.2H_2O$), ammonium fluoride (NH_4F), copper chloride II dehydrated ($CuCl_2.2H_2O$). All the reactants were purchased from Vetec. The solution with 10.00 g of $SnCl_2.2H_2O$, 1.65 g of NH_4F and 10.00 mL deionized water (H_2O) was named A and the sprayed product designated as SOF. The solutions with copper salt were designated as BX, where X = 1, 2, ... , 9 and the sprayed products obtained from the combination of the solutions A and BX were named as SOFC (Table 1).

For the formation of the SOFC products, the A and BX solutions were sprayed out of the furnace on the heated glass substrates, inside an exhaustion chamber. The spray was alternated (A,BX,A,BX,A,...) and after each spray the substrates were placed inside the furnace to apply the working temperature. The procedure was repeated until all the solutions were sprayed on the substrates. The SOF product was used as a reference sample for comparison with the ones modified by copper atoms.

Table 1: Chemicals and products.

$CuCl_2.2H_2O$ (g)	H_2O (mL)	SOLUTION BX	PRODUCT (SOFC)
0.10	5.00	B9	SOF C0.1
0.20	5.00	B8	SOF C0.2
0.30	5.00	B7	SOF C0.3
0.40	5.00	B6	SOF C0.4
0.50	5.00	B5	SOF C0.5
1.00	5.00	B4	SOF C1.0
1.50	5.00	B3	SOF C1.5
2.00	5.00	B2	SOF C2.0
2.50	5.00	B1	SOF C2.5

b) Sprayed films characterization

The phase identification of the materials deposited on the substrates was done by the X-Ray diffraction (XRD) technique with D8 Advance equipment (Buker). The measurement conditions were: copper (Cu) anode, radiation Cu-Kα λ = 1.54 Å, 40 kV, 45 mA, variation of 2θ from 5 ° to 100 °.

The films growth was characterized by the transversal area images obtained through scanning electron microscopy (SEM) using Quanta FEG equipment (FEI). The digital multimeter (Fluke) was used to measure the electrical resistance value (R). The electrical characterization by sheet resistance (Rs) was estimated from the two points method and Equation 1 using materials with dimensions about 2.50 cm x 2.50 cm.

The electrochemical characterization by Mott-Schottky (M-S) of sprayed films was done using a three electrodes electrochemical cell using the PGSTAT302N potentiostat/galvanos-tat (Metrohm, Switzerland). Work electrode was sprayed film; counter electrode was platinum (Pt) plate and silver/silver chloride (Ag/AgCl) as the reference. The sprayed films were about 2.50 cm x 1.0 cm with active area of 1.0 cm^2, which is the working electrode fraction in contact with the 50.00 mL aqueous solution of sodium hydroxide 1.0 molar (1.0 M NaOH).

The measurement conditions by the M-S technique were potential variation between -1.00 V up +1.00 V, 100000 Hz until 10 Hz frequency range, eleven points per decade and signal amplitude about 10.00 mV. Plots of the capacitance reciprocal against applied potential (1/C2 against E) were generated. The straight line inclination was used to classify the semiconductor in p-type (holes excess into valence band) or n-type (electrons excess into conductive band). The line extrapolation in the direction of the E magnitude was used to estimate the flat-band potential (Efbp).

For the optical characterization, it was used the UV-visible spectrophotometer (Cary 100, Agilent) in the transmittance mode between the wavelengths of 200 nm up to 800 nm. The determination of the thickness (t) and band gap (Eg) was obtained from the transmittance (T) against wavelength (λ) data. The t values were estimated using Equations 4, 5, and 6, while the Eg values were estimated from Equation 2. The adopted conditions for obtaining Eg were direct transition $(\alpha hv/t)^2$ against energy of the incident photon (hv) plot and data extrapolation to the condition $(\alpha hv/t)2 = 0$.

c) Photovoltaic characterization: electrochemical and electrical

i. *Dye-sensitized solar cell assembly*

Sprayed film substrates were cleaned by the same volume ratio of water and ethanol alcohol mixture; in ultrasonic water bath (Q3360, Quimis) for 10 min. Subsequently, 0.084 g of SnO2 (99%, M) and 10% (mass/mass) SnO2-CuO (99%, Vetec) mixtures were prepared. All materials were added into volumes with 10 mL distilled water, then ultrasonic water bath for 10 min and stirring. Sprayed film substrates were added into the colloidal solution and the evaporation by natural convection happened for 7 days. All photoanodes with 0.5 cm2 active area were calcined at 450°C for 30 min in air atmosphere (EDG F-1800).

Photoanodes were immersed in equal volumes of solutions prepared from ethanol (Vetec), Ruthenizer 535-bisTBA(N719) dye and chenodeoxycholic acid into closed containers for 24 hours. These solutions were obtained from 7.50 mL of ethanol with 3.0 mg of N719 and 12.00 mg of acid. Platinum on fluorine-doped tin oxide (FTO) glasses were used as counter electrodes. The iodide/triiodide (I-/I3-) electrolyte (Iodolyte AN-50) was added onto the DSSC sandwich structures. The N719 dye, chenodeoxycholic acid and counter electrodes were obtained from Solaronix, Switzerland.

III. Characterization

In order to study the photovoltaic characteristics as a function of the sprayed films, the devices were characterized in terms of current density (J)-voltage (V).

The characterization was done using PGSTAT302N potentiostat/galvanostat and light source with LED generating 100 mW/cm2 white luminous energy. The system was controlled by computer through the NOVA1.10® program. The system and software (Solaronix, Switzerland) was specifically designed for DSSCs. From J-V, Voc, Jsc, FF, η, Rshunt and Rserial values were obtained.

IV. Results and Discussion

a) DRX

The oxygen vacancies (Vö) provide electrons transport in pure tin dioxide (SnO2) due the stoichiometric deviation, where the electrons generation can be described by equation 8.1 The understanding of the structural, optical and electronic properties of SnO2 films was improved by comparison between pure and doped SnO2 films [1, 32].

$$O^{--} \rightarrow V_{ö} + 2e + 1/2O_2(g) \quad (8)$$

According to equation 8, when the oxygen anions escape as oxygen molecules (O2) out of the SnO2 from the oxygen anions (O--) occupied sites, it is created ionized vacant sites (Vö) and two free electrons. The Vö occurs due to the chemical diffusion process of the O-- in bulk stoichiometric SnO2 that results in SnO2-y, where y range about 0.02 until 0.034 from 700 K until 990 K temperature range 1. One other way, the pure SnO2 stoichiometric deviation can be described as Sn+4(1-δ)Sn+2δO-2(2-δ), where δ is the amount of vacant sites generated from the oxygen absence occupied by Sn+2 cations [32].

If we assume that the Sn+4(1-δ)Sn+2δO-2(2-δ) has doping by Sn+2, then it is valid the Sn+4(1-δ)O-2(2-δ):Sn+2δ formula. Thus, the SnO2-y and Sn+4(1-δ)Sn+2δO-2(2-δ) can be designated as SnOx for x= 2-y, as well as Sn symbol is a short representation for the Sn+4(1-δ)Sn+2δ with Sn+2 being the dopant of fraction (δ < y) or all (δ = y) of all oxygen vacancy sites. Besides the oxygen deficiency and Sn+2, dopants such as fluorine (F) [3-9], antimony (Sb) [8], molybdenum (Mo) [10], manganese (Mn) [11], copper (Cu) [12] and chromium (Cr) [13] have been used to modify the structural, optical and electrical properties of the SnO2 films.

The incorporation of Sb5+ in the Sn4+ sites and F-1 in the O-2 sites happens by substitution and it is accommodated in the SnO2 net. [1,8] It has been assumed that the fluorine doped-sprayed films identified by XRD as bulk pure SnO2 is an approximate measurement of the SnO2 films with presence of both stoichiometric deviation and fluorine into its structure [3-8].

In the fluorine doped stoichiometric deviation, SnO2 films obtained by spray pyrolysis from tin dichloride (SnCl2) and ammonium fluoride (NH4F) are generated from the tin oxide (SnO) and tin tetrafluoride (SnF4) transitory compounds [8]. Thus, the experimental data (Figure 1) obtained by X-rays diffraction (XRD) technique was used to identify the nature of the sprayed films called SOF and SOFC.

Figure 1 shows that the SOF and SOFC films have XRD peak distribution similar to the SnO2 and tin oxide fluoride (Sn4OF6) or SnO:(SnF2)3 equivalent, which are stoichiometric oxides. Both SOF and SOFC materials were identified as Sn4OF6 (ICSD 078356 sheet data) phase into $20^{o} < 2\theta < 70^{o}$ and into $60^{o} < 2\theta < 85^{o}$ as pure SnO2 (ICSD 039175 sheet data) phase. For SOF material, the similar XRD peak distribution in the $20^{o} < 2\theta < 85^{o}$ region was reported for SnO2 films with stoichiometric deviation and fluorine dopant obtained from $SnCl_2$ and NH_4F solutions using spray pyrolysis [7].

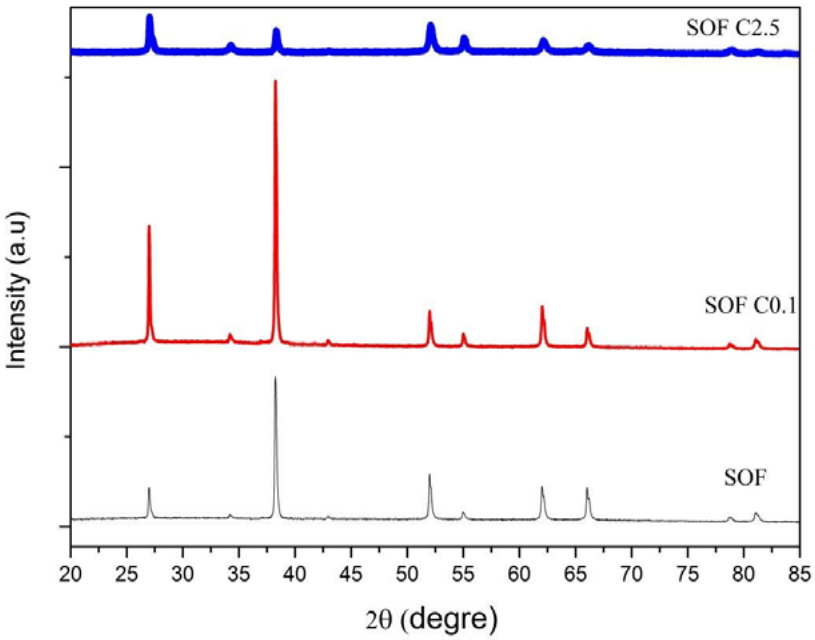


Figure 1: XRD of samples SOF and SOFC.

The spray pyrolysis creates oxides with stoichiometric deviation. Therefore, we can assume that SnO2 is an approximation of the SnOx:F, while that the SnO:(SnF2)3 could be replaced as SnOx:SnF2 or SnOx:(SnF2)y due to a stoichiometric deviation. Thus, SnOx:D is a general form for representation of SOF and SOFC materials, where D = F, SnF2 or (SnF2)y as possible dopants. The symbol "x" in SnOx:D identifies the stoichiometric deviation from the pure SnO2.

The dominant diffraction peak in ($37.50^{o} < 2\theta < 40.00^{o}$) region for the SOF material in Figure 1 was attributed to the fluorine dopant. The similar condition was reported for SnOx:F sprayed films [8]. But, such peak was drastically reduced in SOF conversion to SOF C2.5. One possible explanation for this would be the competition between the Cu and F atoms to occupy the vacancy sites in SnOx:D. As observed in Figure 1, the higher quantity of Cu atoms tends to induce the decrease in all peaks.

b) SEM

XRD has identified that the atomic arrangement of atoms in the sprayed films tends to form structures similar to the stoichiometric oxides structures of SnO2 and Sn4OF6 [SnO:(SnF2)3]. However, since the interfacial transfer process depends on the surface properties, SEM and energy-dispersive spectroscopy (EDS) were used to characterize the morphology and atoms distribution on the surfaces of the sprayed films. SEM images for a set of sprayed film samples are represented in Figure 2.

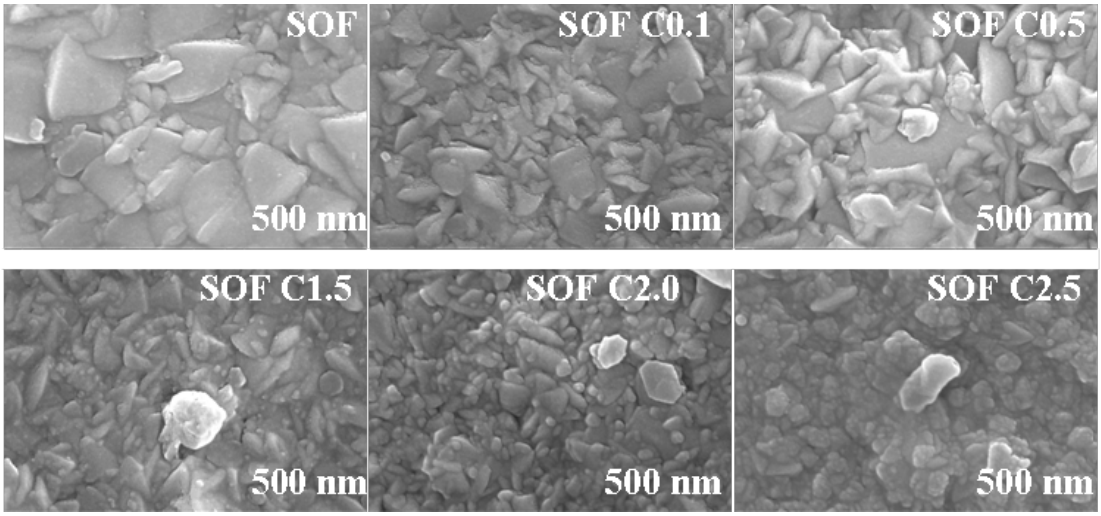


Figure 2: MEV images on the SOF and SOFC samples

For the SOF sample as a reference, from the MEV images can be inferred that the surface morphology of the products was altered when the mass of copper salts in the spray solution was increased from 0.10 g (SOF C0.1) to 2.50 g (SOF C2 .5). This change in morphology, which grains tend to decrease and become more compact, influenced the XRD profile (Figure 1). From EDS measurements, Cu atoms in the surface of SOFC materials were detected only for the SOF C2.5 sample, while the F atoms were detected in the surface of SOF and SOFC materials.

The sprayed films have heterogeneous growing, that is, material growth on a support. There is three possible paths for heterogeneous growth: overlapping uniform layers (Frank-van der Merwe), islands or agglomerates (Frank-van der Merwe) and layers and islands mixture (Stranski-Krastanow) [2,45]. Figure 3 illustrates the substrate/sprayed film interfaces obtained by SEM images. The sprayed SOF and SOFC films have the dominant Stranski-Krastanow growing.

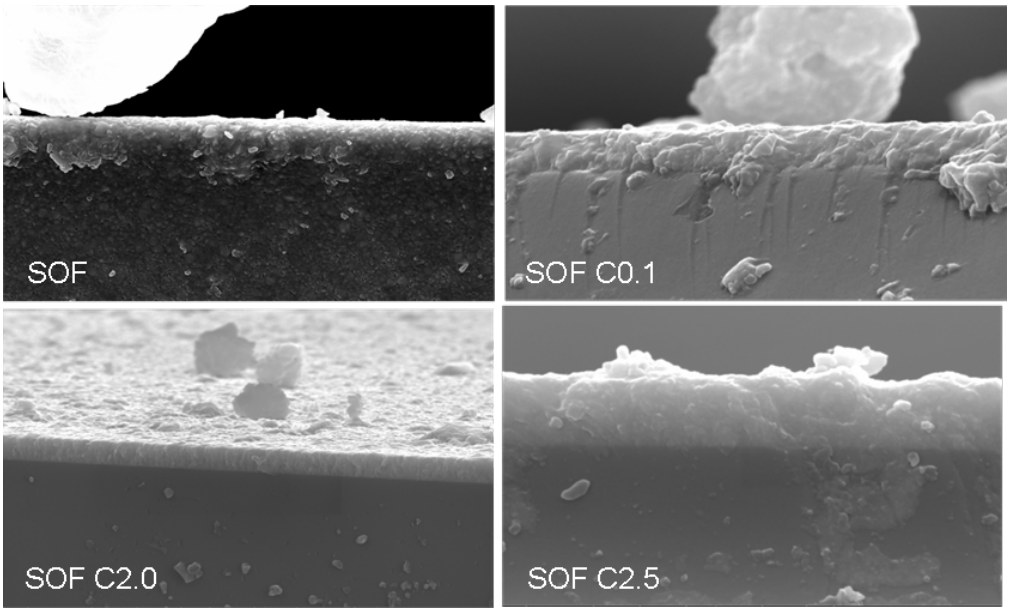


Figure 3: Substrate/sprayed film interfaces for the SOF and SOFC samples

The growing mechanisms of Frank-van der Merwe, Stranski-Krastanow and Volmer-Weber are complexes, but they are a function of the solution composition, driven thermodynamics, growing temperature and others [2, 45]. The observed growing type in SOF and SOF sprayed films was attributed to be a function of the deposition process adopted. The clusters happen when the bond energy between the superficial atoms and its neighborhood is stronger than between the atoms and the bulk layer.

c) *Mott-Schottky electrochemical technique using electrochemical cell*

The SnO2 films with both stoichiometric deviation and fluorine into its structure were characterized by the Mott-Schottky (M-S) technique, reporting as a n-type direct transition semiconductor [44] The n-type semiconductor has electron excess in the conduction band (CB), while the p-type presents holes excess in the valence band (VB) [1, 2, 46, 47]. As the SOFC materials have F and Cu atoms, the M-S electrochemical technique was used to identify the semiconductor type formed as a function of copper presence (Figure 4).

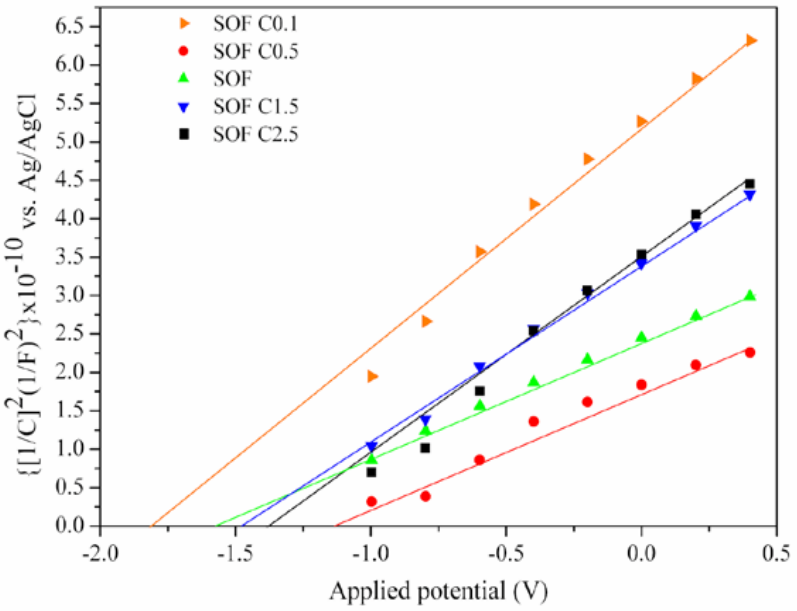


Figure 4: M-S plots for SOF e SOFC samples

Figure 4 illustrates the data obtained by M-S for the SOF and SOFC (C0.1, C0.5, C1.5 and C2.5) samples, which reflects the variation in the amount of copper atoms present in the sprayed films. The data described in Figure 3 shows that the variation of capacitance (C) of the semiconductor/electrolyte junction as a function of the applied potential (E) is a straight plot, which is typical of the M-S behavior. The SOF sample was used as standard reference.

The capacitance is typically a function of frequency (f) and the E. High frequency values have been used to eliminate the frequency influence on the capacitance in M-S plots [36,43]. The 1/C2 against E plots were generated using 1000 Hz as reference frequency [40, 42]. The illustrated data in Figure 4 was obtained for the 1000 Hz reference frequency. The slope of the straight lines (Figure 4) indicates the SOF and SOFC as n-type semiconductors. Table 2 illustrates the estimated flat-band potential (Efbp) values for the SOF and SOFC obtained from the line extrapolation forward the E axis.

Table 2: E_{fbp} and CB edge for the SOF and SOFC samples

Nº	NOMENCLATURE	E_{fbp} (V *vs* Ag/AgCl)	CB edge (eV *vs vacuum*)
1	SOF	-1.57	- 3.09
2	SOF C0.1	-1.82	- 2.40
3	SOF C0.5	-1.12	- 3.10
4	SOF C1.5	-1.45	- 2.77
5	SOF C2.5	-1.37	- 2.85

In the charge transfer process in the titanium dioxide (TiO2)/SnO2 junction, the Efbp values of materials obtained by M-S plots were assumed to be an approximate measurement of the CB edge of a n-type semiconductor [39]. Table 2 shows the CB edge values determined from Efbp values and converted to the absolute energy scale (vacuum). The CB edge change as a function of the copper atoms identifies an electronic distribution change into the CB of SOF and SOFC materials.

Regarding the materials from the SOFC group, the Cu atoms in the matrix seem to have contributed to the shift of Efbp to less negative values, but a non-linear increase of electrons in the CB, results in the shift of the CB edge. Such behavior is admissible, once the materials exhibit the n-type semiconductor behavior, which is associated with the electrons excess in the CB. In the CuFeO films, doped with calcium atoms, it was reported Efbp increase with the increment of the calcium (Ca) dopant from the Efbp= +0.70 V, for the pure film, and reaching Efbp= +0.93 V at 10% doping [40].

The Efbp value changes with the electrolyte composition. The increment in the Efbp value contributes to increase the charge transfer through the semiconductor/electrolyte junction [43]. Also, The Efbp interferes with the photovoltaic behavior of the DSSCs [20,23]. In TiO2-based dye-sensitized solar cells (DSSCs), the doping by ferric (Fe) dislocated the Efbp value to more positive potentials, Efbp (TiO2) = -0.73 V became Efbp (TiO2:Fe) = -0.55 V, and it increased the

efficiency of the cell due to the good charge separation between TiO2:Fe CB and the LUMO of dye [23].

For the SnOx:F/CuFeO2/dye/redox and (I-/I3-)/Pt-SnOx:F sandwich structure DSSC, the value of the open circuit voltage (Voc) was estimated from Efbp(CuFeO2) and Eredox(I-/I3-) using Voc = Efbp(CuFeO2) - Eredox(I-/I3-) [20]. From the Efbp(CuFeO2) the value converted to the standard hydrogen electrode (SHE) electrochemical scale and Eredox(I-/I3-) = + 0.32V vs SHE, was then Voc= 0.37 V, while the experimental value was 0.365 V. The Efbp (CuFeO2) value was estimated by M-S measurement in a 1.0 M NaOH solution with the aid of silver/silver chloride (Ag/AgCl) as reference electrode.

In relation to the dye-sensitized solar cells (DSSCs), the literature has reported that the theoretical Voc can be estimated from Voc = ECB - Eredox, where ECB is CB edge position of semiconductor. From this methodology, it is possible to infer that the approximation ECB~Efbp for the n-type semiconductor, which is a good tool in the characterization of materials for photovoltaic applications. Besides the knowledge on structural, morphologic and electronic properties of semiconductors, it is also important to determine the electrical and optical properties to understand the role they play in the photovoltaic field.

d) Sheet resistance (Rs)

SnO2 is an n-type semiconductor in which the presence of oxygen vacancies, cations and anions as dopants are responsible for the conductivity generated by the electrons transport [1]. SnO2 films synthesized by spray pyrolysis technique have been doped using manganese (Mn) [11], copper (Cu) [12] and chromium (Cr) [13] as source of cations doping. Titanium (Ti), zinc (Zn), tin (Sn), Cu, Mn, Cr and others are atoms that tend to form electrical insulating oxides [1]. Thus, research generally approached the influence of these atoms only as dopants on properties of bulk oxides.

For electrical characterization, the sheet resistance (Rs) has been used to measure the electrical resistance of materials in films. The two points method was reported for electrical characterization of SnOx:F films to the Rs measurement [5]. The sheet resistance (Rs) is the more adequate characterization for films due to the large area of the films that favors the capture of electrons by superficial defects [48].

In SnOx: F films from spray pyrolysis, Rs values were reported between 107.9 Ω/□ to 17.8 Ω/□ [5]. These values were obtained using the two points method with the aid of a digital multimeter. Table 3 illustrates the Rs values of the sprayed films determined by the two points method. For 35.80Ω/ □ to 17.60Ω/ □ (Table 3), the values agree with the ones reported for Rs of SnOx: F films obtained from the two points method [5].

The Rs values described in Table 3 reflects the dependence on the work conditions. For the SOF materials as referenced in Table 3, the increased number of copper atoms in sprayed films causes an obvious change in the resistance, which can be due to the transition from conductive to insulate phase or loss of oxygen vacancies or low F atoms into the SnOx: F matrix. A decrease in the number of oxygen vacancies, in SnO2 thin films, during the deposition, results in a reduction of the charge transporter concentration and, therefore, of the electrical conductivity [1]. In the self-doping of SnO2, the oxygen vacancies responsible for the electrical conductivity are occupied by the Sn+2 ions [32].

Table 3: R_s values of sprayed films by the two points method

Nº	Nomenclature	R_s (Ω/□)
1	SOF	17.60
2	SOF C0.1	20.20
3	SOF C0.2	24.50
4	SOF C0.3	24.60
5	SOF C0.4	24.90
6	SOF C0.5	20.70
7	SOF C1.0	25.70
8	SOF C1.5	28.40
9	SOF C2.0	35.00
10	SOF C2.5	35.80

From another approach, the increase in the Rs, with copper increase, is associated with the decrease of the prominent diffraction peak in $37.5^{o} < 2\theta < 40^{o}$ interval (Figure 1), morphology change in Figure 2 and formation of islands in Figure 3. Through transmission electron microscopy (TEM), it was found that the excess of antimony (Sb) dopant in the semiconductor creates agglomerates that increase the material electrical resistance [49]. The effects of copper atoms on the optical and structural properties of the SnO2 films have been reported [12], leaving out the electrical properties. Probably, the electrical characterization has not been mentioned previously because copper tends to make electrical insulators such as oxides.

From the electrical measurements in Table 3, it can be inferred that the copper (Cu) atoms act opposite to fluorine (F) atoms. By the size, the proximity of the F-ion with the O2- ion, the F- ions occupies the sites emptied by the oxygen absence [32]. Additionally, the antimony (Sb) ions, by being larger than the F-, substitute the tin atoms ions [8]. The electrical transparent conductors based in tin oxides made by spray pyrolysis presented Rs higher with Sb than with the F dopant [8]. Similarly to the Sb atoms, the Cu atoms in the SOFC can substitute the tin atoms in the tin sites (Sn+4 or Sn+2 or both) into the SnOx:F matrix.

Taking in consideration the crystal net, fluorine is a dopant which contributes to minimize Rs, because it causes less net deformation than copper. Copper increments Rs due to the deformation caused in the net. This decrease probably happened due to the diminution

in the quantity of extinct vacancies or increase in the quantity of generated agglomerates or both. The decrease of the peaks of diffraction (Figure 1) is the result of this behavior.

Not only the type of doping, also the process conditions affect Rs. The SnOx:F films obtained by spray pyrolysis at 400 °C from a solution mixture of acid, tin and fluorine salts presented Rs between 38.02 Ω/ □ to 300.02 Ω/ □ [6]. The SnOx:molybdenum (Mo) films produced by spray pyrolysis at 500 °C resulted in Rs between 39.81 Ω/ □ to 98.23 Ω/ □, while the pure phase had Rs equals to 109.81 Ω/□ [10].

Additionally, the spray pyrolysis is a technique capable of induce oxygen vacancies into oxides. It is a useful tool in the preparation of doped and pure oxide films with stoichiometric deviation from spray solutions with the salts and acids. This research showed that the spray solutions without the addition of acids produced materials with Rs varying between 20.20 Ω/ □ up to 35.80 Ω/□. These values agree with data reported in literature.

e) Transmittance, thickness and band gap from optical spectroscopy

The optical transmittance is one characterization technique that can be used in the study on the behavior of materials on ultraviolet-visible-infrared radiations. Figure 4 illustrates the transmittance of the samples SOF C1.5, SOF C2.0, SOF and bare glass into ultraviolet-visible radiations. From Figure 5, the transmittance of SOFC materials can be compared to the SOF matrix and bare glass transmittance. The presence of copper (Cu) atoms seems to affect the SOF matrix transmittance both decreasing (SOF C2.0) and increasing (SOF C1.5).

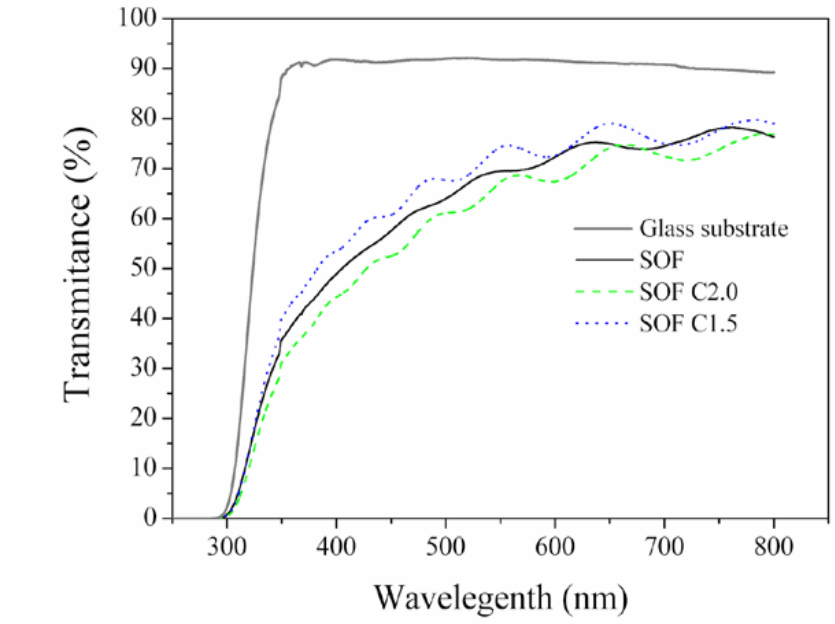


Figure 5: Optical transmittance values for samples SOF and SOFC

The transmittance value for SOF reaches close to 80% only at about λ = 800 nm, but transmittance decreases when the λ downwards, reaching values below 60% for λ < 500 nm. This behavior is similar for SOFC materials. For SOF matrix as reference, the increment in the SOF C1.5 can be attributed to a random distribution of copper atoms in the matrix. Such distribution may have helped to minimize the formation of agglomerates or impurities that induce the transmittance loss. The agglomerates were identified in SOF and SOFC materials (Figure 3).

The loss of transmittance in relation to the glass substrate may be related to a higher proximity between the atoms in the matrix. This approximation may have caused agglomerates capable of inducing absorption or reflection of the visible radiation or the incident luminous energy. Therefore, the transmittance seemingly increased when sprayed by a copper(II) chloride dihydrate (1.50 g) solution, which provides SOF C1.5 (Table 1). Possibly, the increase in transmittance was caused by a more efficient random distribution of copper atoms in the matrix with grains decreasing (Figure 2).

The loss of transmittance in a material can be attributed to the reflection and/or absorption phenomenon [50]. As mentioned previously, the film's dominant growth was Stranski-Krastanow. Possibly, the type of growth caused some loss in the transmittance. In the other side, in the SnOx:F from the spray pyrolysis technique, SnO, HF, SnF4 transitory composites are formed during the process and, due to the temperature effect, react with oxygen to form the SnOx: F product

[8]. Therefore, such transitory composites can be present in the SOFC materials as impurities acting to reduce the transmittance. From XRD (Figure 1), it was estimated the possible presence of SnF2 in SOF and SOFC materials.

Figure 5 illustrates peaks and valleys (interference fringes) in the optical transmittance spectrum. The peaks and valleys in the optical transmittance spectrum of film/substrate junction reflect a layer adherent to the substrate [34]. Also, the peaks and valleys generated in the spectrum of optical transmittance on a film/substrate junction have been used to estimate the film thickness (t) and band gap (Eg) [5,7].

The advantage of the optical characterization is the possibility of determining the t and Eg using only transmittance data. Table 4 shows the values for t and Eg for spayed materials, obtained only from optical characterization. The t values for SOF and SOFC materials were estimated through Equations 4-7, while the Eg values were specified using the Tauc relation, Equations 2 and 3.

Table 4: The t and E_g values of the SOF and SOFC materials

Nº	NOMENCLATURE	t^{op} (nm)	E_g^{op} (eV)
1	SOF	643.36	3.15
2	SOF C0.1	636.68	3.10
3	SOF C0.2	658.58	3.37
4	SOF C0.3	621.26	3.22
5	SOF C0.4	647.54	3.00
6	SOF C0.5	658.57	3.37
7	SOF C1.0	647.67	3.30
8	SOF C1.5	676.53	3.47
9	SOF C2.0	641.43	3.32
10	SOF C2.5	653.55	3.52

The random distribution of copper atoms (Cu), the preparation process and measurement conditions seemingly have influenced non-linear behavior of Eg (Table 4). The Eg variation as function of the preparation conditions and doping has been reported in literature. The Eg change on tin oxide materials was 4.0 eV for monolayer and 1.16 eV for three layers of deposited film [51]. Antimony (Sb), as the dopant, injects free electrons in the conduction band of the tin oxide, which causes an increase on the Eg [1] SnO2 films, Eg = 3.911 eV, while Eg = 4.011 eV with the increment of molybdenum (Mo) atoms in the matrix [10].

For semiconductors that behave as electrical conductors, the electronic conductivity is due to the oxygen vacancies and presence of electrons or holes from dopants into the energy bands of semiconductors. A transparent semiconductor as electrical conductor is a material with high electrical conductivity and band gap (Eg) higher than 3.10 eV (Eg > 3.10 eV) that provides low absorption in the visible solar radiation [1].

The inorganic semiconductors have the conduction band (CB) and valence band (VB) energy levels, while organic semiconductors have LUMO and HUMO, equivalent to CB and VB, respectively. The optical Eg and electrochemical HOMO values from the LUMO = HOMO + Eg were used to obtain LUMO [10]. Figure 6 shows the BC and VB edge position of the SOF and SOFC being as function of copper and obtained from the CB = VB + Eg, where CB is assumed as Efbp (Table 2) and Eg is illustrate in Table 4.

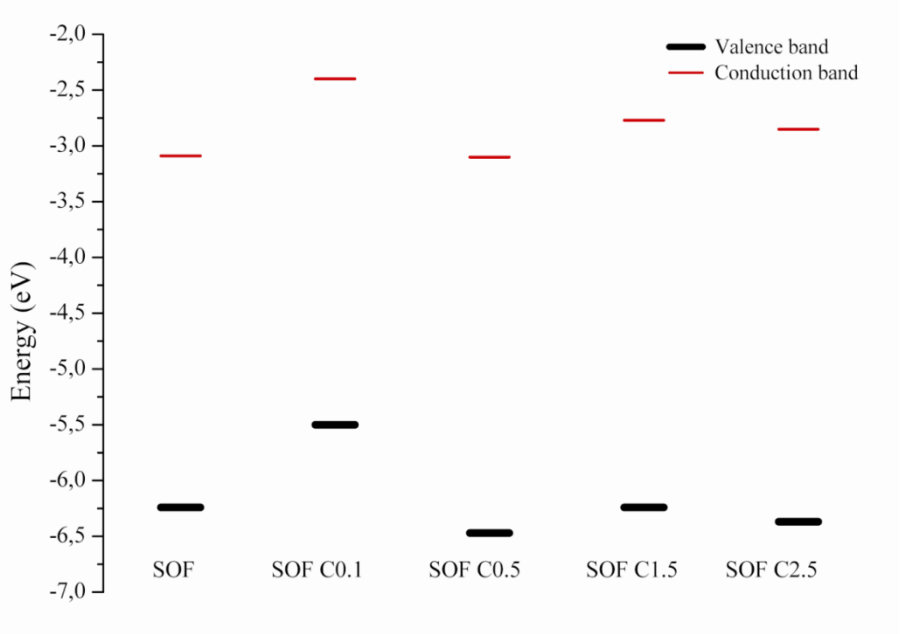
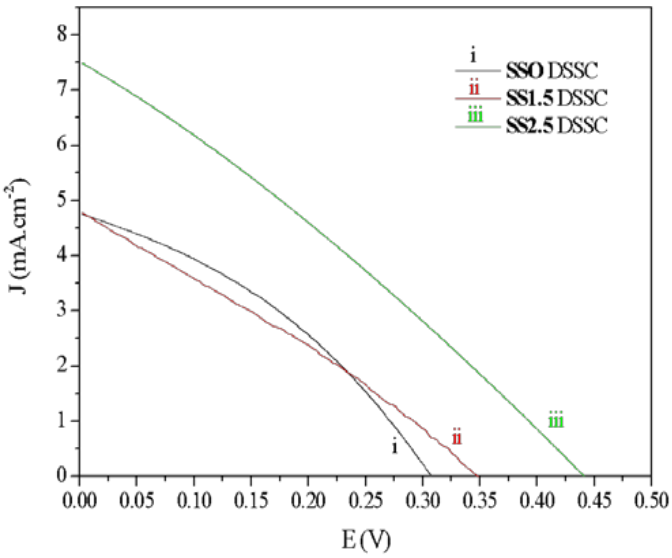


Figure 6: CB and VB edges for samples SOF and SOFC

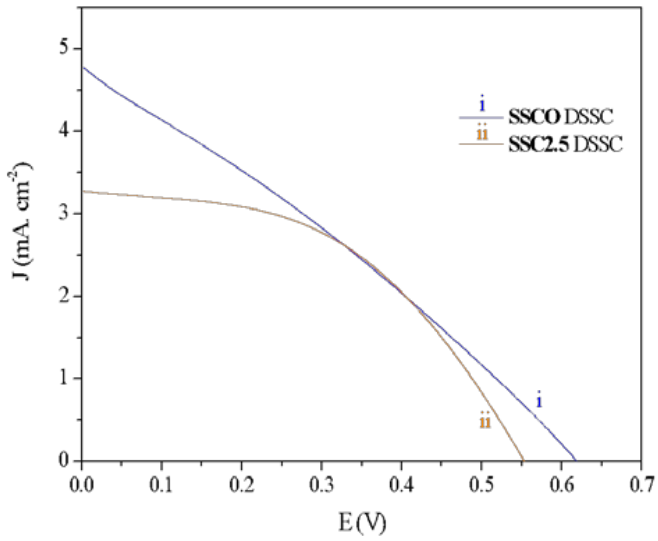
By previously exposed information about SOF and SOFC materials, it is possible to attribute that these materials are n-type semiconductors oxides, as well as transparent and electrical conductors and Eg > 3.10 eV. Once those photovoltaic solar cells use the visible region to generate electricity, the SOF and SOFC materials have potential for photovoltaic applications as collectors of electrons or in the form of conductor transparent oxide or counter electrode. Therefore, the SOF and SOFC materials were used in DSSCs as being SOF/platinum and SOFC/platinum counter electrodes.

f) Dye-sensitized solar cell (DSSC)

In DSSCs, the photovoltaic effect occurs by electron transfer at the surfaces of electrodes, the photoanode and counter electrode, from the photo electrochemical reactions. These reactions involve the charge transfer at the electrode surface, the electrolyte resistance, mass transfer from the electrolyte to the electrode surface and the electroactive species adsorption. The DSSC photovoltaic characteristics results from the net amount of the electron transfer processes into the cell. Figure 7 shows the photocurrent density-voltage (J-V) characteristics for DSSC with various photoanodes under a simulated solar light about 100 mW/cm2.



(a)



(b)

Figure 7: J *vs* V plots for the DSSCs: a) SnO_2 photoanodes and b) SnO_2:CuO photoanodes

All photovoltaic parameters are shown in Table 5. As Rserial is a resistance ohmic setup and Rshunt represents the setup of resistance to charge recombination in DSSC, then for ideal solar cell Rserial << Rshunt. Moreover, the results illustrated in Figure 7 and Table 5 are attributed to the effective influence of Rserial > Rshunt.

The fill factor (FF) indicates cell stability in face of energy generation. FF is given by a ratio between the maximum energy product (J.V)max and the ideal energy product (Jsc.Voc).Therefore, the closer FF is to one, the higher is the cell stability under luminous energy presence. The cell stability represents resistance to energy loss, which occurs when the cell is submitted to an electrical field induced by charge accumulation space (CAS), under the presence of the luminous energy.

Table 5: Photovoltaic parameters at 100 mW/cm^2 by various photoanodes of DSSC devices

Photoanode	DSSC	V_{oc}(V)	J_{sc} (mA/cm^2)	FF	η(%)	R_{serial} (Ω.cm^2)	R_{shunt} (Ω.cm^2)
SOF/SnO_2	SS0	0.31	4.75	0.36	0.52	1303.00	996.10
SOF C1.5/SnO_2	SS1.5	0.35	4.78	0.29	0.48	1113.80	993.50
SOF C2.5/SnO_2	SS2.5	0.44	7.49	0.28	0.93	1139.70	995.60
SOF/SnO_2:CuO	SSC0	0.62	4.77	0.29	0.86	1052.50	995.30
SOF C 2.5/ SnO_2:CuO	SSC2.5	0.55	3.28	0.48	0.86	1084.30	998.30

The low values of FF illustrated in Table 5 show high electrons concentration with lower energy than the electrical fields induced on SnO2 based photoanodes. But, the FF and Jsc values follow the literature for modified and unmodified SnO2 nanoparticles based photoanodes. For example, Jsc =2.45 mA/cm2 and FF = 0.5404 SnO2 photoanode [26]. Jsc =4.80 mA/cm2 and FF = 0.308 SnO2:ZnO photoanode [27], Jsc =9.2 mA/cm2 and FF = 0.332 SnO2 photoanode [30].

Among DSSCs, SS2.5 DSSC has an obvious increase in current density (Jsc) and open circuit voltage (Voc). But, photoelectrons have lower energy than the electrical fields induced by charge accumulation space into the solar cell, which from a specified voltage is captured by the charge accumulation space instead of the electron's acceleration. This process influences low Rshunt, high Rserial and low FF. Subsequently, the SnO2-CuO mixture on the SOF C 2.5 for the SSC2.5 DSSC provides Rshunt and FF higher than that of SS2.5 DSSC.

V. Conclusion

Copper decorated fluorine doped tin oxide films and its application in the photovoltaic performance of DSSCs was investigated in this study. From the characterizations, it is possible to assume that the properties of the material synthesized by the spray pyrolysis were influenced by copper concentration. However, the material keeps its characteristic as a transparent electrical conductor oxide. The composition of copper decorated fluorine doped tin oxide also facilitates the enhancement of the photocurrent and Jsc, and improves energy conversion efficiency of the DSSCs.

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Managing Sustainable Mobility: The Economics of Transport Externalities and Policy

By Ravinder N. Batta

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I. Introduction

Efficient transportation systems are necessary for providing access to resources, markets, and services (e.ghealth and education) alongside other amenities. Availability of cost-effective mobility options or the lack of it has not only direct implications on the economic efficiency, but also affects the overall well-being of the people. It is estimated (Lakshmanan 2007) that transportation interventions in production and supply chain generate types and sequences of consequences (such as expansion of markets, higher efficiencies through scale economies, economic restructuring through entry and exit of firms exposed to new competition) that enhance overall economic benefits. Thus, the contributions of transport to the economy are both direct (arising out of active use of transportation systems) and indirect (aggregate economic activity benefits related to changes in output, productivity and employment). These types of economic impacts occur in three forms: system performance and cost effectiveness, regional economic development, and liveability.

However, like all other good things in the world, transport also does not come without a cost. One of the major limitations of the road transport is that it requires a huge infrastructure before its product (automobile) is of some use to the society. Then on use, automobiles are associated with a number of externalities major among them are energy- and emission-intensity, congestion and road fatalities. It is for these unintended side effects that the governments world over are re-evaluating their policies to see if they could handle these problems. Several recent developments (e.g. global warming, spurt in oil prices leaving many countries in serious balance of payments crisis, urban grid lock, and rising road fatalities) make a case for reinventing transport policies. Several studies provide discussions on such externalities like Litman (2006), Parry, Kenneth, and Small (2005), Parry, Walls and Harrington (2007), Schafer 2012; and Zivin and Neidell (2013). While most studies conclude that reducing carbon intensity of energy and energy intensity of transport is a must, but some of them (e.g.Litman 2006; and Schafer 2012) conclude that actions on modal structure and volume of mobility (clubbed as behavioural approach) are also required.

From the policy perspective, ultimate objective is to achieve sustainable transport. The concept of sustainable transportation systems is defined as the one in which fuel consumption, vehicle emissions, safety, congestion, and social and economic access are of such levels that they can be sustained into the indefinite future without causing great or irreparable harm to the future generations throughout the world (Zivin and Neidell 2013). For achieving sustainable transport, it is essential to study the detailed implications of each one of these externalities and the current policy scenario as well as the possible solutions in terms of policy instruments. It may be useful to understand as to how to handle policy instruments when these externalities are affected by diverse factors for example, emissions vary with fuel usage, vehicle technology, vintage, traffic flow, and driving behaviour. Likewise, congestion may be affected by vehicle miles travel (VMT), insurance regime, siting of residential and commercial facilities, and timing of travel. Road safety is also a result of many factors like vehicle technology, insurance regime, and enforcement of regulations. Further complications are introduced in the presence of asymmetric information among the various agents.The challenge before the policy makers therefore is to control the four components through policy interventions: the carbon intensity of fuels, the energy intensity of mobility, the modal structure of mobility and the volume of mobility. In terms of Schafer

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(2012), the first two are classified as technology oriented and the last two are behavior oriented (often called Travel Demand Management TDM).

Most studies focus on the technological aspects of mitigation (on the energy intensity of mobility and carbon intensity of fuels) but tend to ignore the behavioural aspects(Schafer 2012) of mobility (e.g. volume of mobility and adoption of low carbon modes). A typical approach from the standpoint of technological approach for addressing the problems of transport is to build more roads and fuel-efficient vehicles. However, two major effects arise affecting volume of mobility: induced demand effect (Goodwin 1996) and rebound effect (Greening et.al. 2000). The induced demand effect arises as a result of infrastructure building or improvement leading to increased mobility. In the long run, it also changes the economic value of land affecting the location of activities and hence mobility needs. The rebound effect arises consequent to reduction in marginal cost of travel due to fuel economy (for a detailed analysis please see Gillingham 2020). Thus, instead of solving the problem, we end up aggravating it. Hence, it is argued (Litman 2006) that behavioural approaches have to be explored to find a sustainable solution. This paper is an attempt to highlight the need and importance of behavioural approaches in solving transport problems. In order to practically understand the dynamics of it, it takes up a study of transport policy of Himachal Pradesh - a province in the Indian Himalayas.

This paper is organized as follows. Section 2 presents discussions on transport externalities in alternate forms and dimensions. It also includes a literature review on the issue of externalities and their management. Section 3 is devoted to the study of transport sector in Himachal Pradesh. It highlights the current scenario in the sector, situation on externalities and presents analysis of the policy challenges faced by the state. Section 4elaborates the behavioural policy options available to the state and finally section 5 draws conclusions of the study. The study finds the transport policy in Himachal Pradesh fails to provide transport infrastructure of high standards, promote non-discriminatory competition within and between modes, and ensure tackling externalities. It is argued that the traditional approach of providing more infrastructure should be supplemented by behavioural initiatives to reduce the travel demand.

II. Transport Externalities

Among the major externalities are environmental emissions, energy security, congestion and road accidents. All of these are examined in detail as under.

a) *Environmental Externalities*

Among the major emissions caused by automobiles are Carbon Dioxide (CO2), nitrogen oxides (NOx), and hydrocarbons (HC). Each one of these has a different effect on human lives. For example, CO2 reduces oxygen supply to the bloodstream causing breathing difficulties and cardiovascular problems. HC and NOx react with sunlight to form ozone leading to smog and hence breathing difficulties among children and visibility issues. Besides, NOx and HC react to form particulate matter. Studying the health impacts of air pollution is complicated due the fact that these pollutants interact with each other and other atmospheric factors. For instance, ozone pollution is not directly emitted but forms as a result of complex interaction between two other emitted pollutants namely nitrogen oxide (NOx) and volatile organic chemicals (Deryugina et. al. 2019). The actual impact is also dependent on exposure. Deschenes, Greenstone and Shapiro (2012) examine the impact of NOx on mortality, hospitalization, and medication expenditures. The study finds that reduction in NOx emissions led to a significant decrease in ozone pollution. It is estimated that the transport sector is responsible for about 25 percent of emissions of the gases contributing to global warming in industrialized countries, but only about one-half of this amount in developing country cities. While the proportion appears to have been stabilized in the Organisation for Economic Co-operation and Development (OECD) countries, it is still growing in the developing countries as motorized transport increases (OECD 2011).

There is often an observed synergy between Green House Gas (GHG) reduction and local environmental and economic interests. The GHGs that most contribute to global warming in the transport sector include carbon dioxide (CO2), methane, and nitrous oxide (NOx). Emissions of CO2 are directly proportional to the quantity of carboniferous fuel consumed. Fine particulate matter PM 2.5 (also associated with fuel consumption), is a mixture of various particulates with a diameter of 2.5 micrometres or less, including nitrates, sulphates, ammonium, and carbon (Kundu and Stone 2014). It could be both locally produced as well as transported from other locations through wind. Other things being equal, reduced fuel consumption will reduce economic costs and global pollution simultaneously (Heal 2017). Better traffic flow conditions typically reduce fuel consumption per kilometer. Thus, while diesel is a particularly in-efficient fuel from the point of view of reducing GHG emissions, only the new generation of clean diesels should have a role in GHG strategy (Parry, Walls, and Harrington 2007). Furthermore, mitigation measures for local pollution focus on emissions of vehicles in use, whereas the entire life cycle (from well to tailpipe) is relevant for analysis of GHG emissions (Greenstone and Jack 2015). Some emission reduction measures in fuel quality also lead to green-house gas emissions.

The generation of these pollutants can be curbed by reducing the vehicle miles travelled (VMT), improving average of vehicle, using technologies that reduce emissions per gallon of fuel, and retiring the obsolete fleet that is more polluting. It therefore makes a strong case for environmental regulation. Studies have concluded (e.gZivin and Neidell 2013; Deschenes, Greenstone, and Shapiro 2012; Dittrich et. al. 2012) that as environmental regulations contribute to productivity, they should be treated as an investment in economic growth. A large volume of literature explores mitigation options and policies in the transport sector at various levels.The most insightful among them are:IEA 2009; Parry, Walls, and Harrington 2007 (at the global level), Banister, 2000 for Europe (at the regional level), Bristow et.al. 2008, for UK; Greene and Plotkin 2011, for US; and Greenstone et.al. 2015, for India (at the national level), and Hickman et.al 2011 for London and Delhi (at city level).

b) Energy Security

Automobile use consumes a lot of fossil fuel. International Energy agency estimates that transport accounts for more than half of the primary oil demand and due to its limited substitution and short run price inelasticity (Dahl 2012), the sector will account for three quarters of the projected increase in oil demand (IEA 2009). Excessive dependence on imported oil exposes the countries to energy price volatility and price manipulation that could even compromise national security interests of the country (Parry, Walls, and Harrington 2007). While, the market shocks could be absorbed if the prices reflect the true cost of production and there are no hidden subsidies, the chances of macro- economic disruptions getting accentuated is enhanced in the wake of market failures (For instance, price and wage rigidities, underinvestment in fuel efficient technologies, inadequate investment in oil explorations).Oil dependency ultimately results in higher military and political costs (Delucchi and Murphy 2004).

c) Congestion Costs

Congestion is basically a by-product of a mismatch between road capacity and vehicle use. Owing to the land constraints and heavy investment in creation of road infrastructure, the road capacity enhancements are not able to keep pace with the vehicle use. Gridlocks are therefore the natural outcome of such a mismatch. Congestion imposes costs for vehicle users (direct costs) as well as non-users (indirect costs). While user costs are in terms of enhanced fuel consumption, pollution, and travel time, the non-users cost are manifold: additional costs are imposed in terms of reduced service areas for work force, suppliers and customer markets. The phenomenon has three different dimensions of variation: traffic congestion may vary area wise (spacial pattern), occurring at various points of time during the day (temporal patterns), and it could be predictable or a random event (stochastic element).

There are following five elements of factors that affect congestion and its economic impacts (Transportation Research Board 2001).

(i) Transportation related investments and pricing affecting the capacity of the facility;
(ii) Transportation systems performance measured in terms of network demand and congestion levels;
(iii) Business market accessibility and location costs measured in terms of operating costs related to accessibility of various locations;
(iv) Productivity effects considered in terms of output levels and cost economies of scheduling and market scale;
(v) Economic growth effects entailed in adjustments in response to changes in the cost competitiveness of business location in various urban areas.

The last three costs are indirect costs of congestion. These essentially arise due to the cost escalations of delivery of goods and services, limitations caused in accessing the markets and inability to expand businesses and derive benefits of economies of scale. This in turn affects economic growth. Correcting this external effect generated by urban density and making the best use of agglomeration economies is one of the main challenges in urban and transport economics (Proost, and Thisse 2019). NITI Ayog (2019) assesses the cost of congestion in 4 major metros in India as $ 20 Billion per annum across the four metros (figure 2).

Figure 1: Avoidable Social Cost of Congestion

Although the costs of travel delays are borne by drivers collectively, yet each individual driver neglects the external cost imposed on others and the consequence is excess travel at inefficiently low speeds. Consequent upon the pioneering work by Pigou (Pigou 1932), the often-recommended solution to the problem of congestion is road pricing (Parry, Walls and Harrington 2007; Proost and Thisse 2019). Subsequent models (e.g.Small, Winston, and Yan 2005; and Koster and Koster 2015) exploit the heterogeneity among drivers for their travel time values. This approach makes road pricing a dynamic tool that substitutes high value trips (e.g. business trips, and highly skilled commuters) for low value trips and thus generate additional benefit of increasing productivity. Likewise, drivers have varied preferences for schedule delays. Studies (e.g.van den Berg and Verhoef 2011) show how by imposing a time varying toll heterogeneity of preferences can be exploited. This aspect is considered important in the light of evidence (van Ommeren and Gutierrez-i-Puigarnau 2011) that workers who must travel more for work are prone to being absent, tend to arrive late, and are less productive.

d) Road Accidents

Safety of human life has also become a major concern in transportation especially in the developing countries. As per World Health Organization (WHO) Global Burden Disease study (IHME 2017), road traffic injuries in developing countries are the cause for one fourth of injury-related deaths. It was ranked ninth in the overall cause of death in 1990, which has risen to the sixth rank by 2020, with India bearing most of the burden. One of the most dangerous aspects of the road traffic injuries is the profile of the victims. As per IHME (2017) estimates, over 90 percent of deaths and injuries occurred in developing countries, with children accounting one in every five fatalities. It concludes that the road traffic injuries are now one of the leading causes of deaths among children in the age group of 15-19 years.

The accident costs are often measured in two types: ex ante and ex post costs. The ex-ante costs are basically assessed by undertaking willingness to pay surveys. The underlying assumption is that people do not value their lives for its utility to the society, but because of its intrinsic value to them and their families. This value, often referred to as Value of Statistical Life" (VSL), can be estimated by determining the amount that people are willing to pay to reduce the risk of being killed in an accident. However, a major limitation of the method is that it could lead to low estimates of VSL in developing countries where both average wages and life expectancy are low. Besides, additional factors (like assessing intangible losses such as pain grief and sufferings) add further difficulty in imputing the true cost levels. The ex-post costs, on the other hand, are costs in the form of medical bills, property damages, production loss, travel delays, insurance and legal costs.

Further, like other externalities, road safety also entails many vehicle and non-vehicle characteristics (White 2004; Gayer 2004). Vehicle characteristics comprise of type of vehicle, size/weight, vintage, and maintenance status. For instance, study by White (2004) concludes that the chances of death are 61% higher if the other vehicle is a light truck than if it is a car. Vehicle technology also has a direct impact on the road safety: technological choices range from driving assistance to autonomous vehicles. A similar situation exists with reference to maintenance of vehicles: the more the maintenance the lesser are the chances of accidents and injuries. As both technology and maintenance (including refitment) entail a cost for the vehicle owners making it a policy challenge as to what kind of policy regime should be put in place that encourages adoption of safer vehicles and their maintenance.

The non-vehicle characteristics are driver's age, gender, region, speed, negligence, weather and road conditions, insurance regime, and behavioural aspects (like risk averse or risk preference driving). Vehicle Insurance regime particularly affects the choices and behaviour of individuals (Tooth 2017). Through the vehicle insurance, the drivers are largely protected from the significant financial liability. This in itself poses a serious problem of moral hazard: there is no incentive to the drivers to adhere to safer road use. If the insurance premiums are not based on driving characteristics, the premium will be the same regardless of whether the insurance covers a heavy or a light vehicle and older (generally risk averse) or a younger driver (risk prone). Unless the premiums vary with the expected cost of claims, regulation has the effect of increasing premium of low risk drivers and reducing premium of high-risk drivers (in other words, taxing the safe drivers to subsidize the risk prone drivers). In India (as in the case of most countries in the world), the premium is the same regardless of age, driving skills and driving behaviour of drivers. It therefore subsidises high risk drivers and penalises the risk averse drivers (figure 2). The latest trend is towards usage-based insurance (UBI) where the premium value is directly related to the vehicle miles travelled.

Other externalities mostly relate to noise pollution caused by the vehicle use, infrastructure maintenance costs, parking requirements, and urban sprawl.

e) Information Asymmetries

A situation of information asymmetry is created when one of the parties involved in a strategic relationship has private information about some important element relevant to the relationship. While considering each of the above externality, it is presumed that there is no interaction among them and there is a

perfect flow of information. However, it is not a realistic assumption. There are many problems with information that arise in an economy: employers want to know the productivity of their employees, investors want to know the return on various investments, and insurers want to know the likelihood that various people that they might insure have an accident. All these problems ultimately lead to incentive problems also known as moral hazard (Stiglitz 2000; Bowles 2016). Lack of information also leads to *adverse selection*. In other words, when private information held by the agent is endogenous variable such as agents' discretionary actions (e.g.taking safeguards against risk), it is situation of moral hazard. However, if it related to some exogenous variable (like technology or cost of production), it is a case of adverse selection. Both moral hazard and adverse selection represent a market failure.

Typically, moral hazard arises when the actions of one person are unobservable to another and the adverse selection arises when one person cannot identify the type and character of another person. *Moral hazard* in the transport context arises where the damages caused by a vehicle to the society are insured by the insurance company so that the firm has no incentive to mitigate the damage. More complete the cover and the lower the psychic loss from the insured event, the less firms have to bear the consequences of their action and less therefore the incentive to behave as they would if they had to bear the loss themselves. Another form of moral hazard arises when the insured person can influence the expected loss at a cost lower than the expected gain. Despite the insurance cover requiring the firm to invest in preventive activities thereby reducing the probability of occurrence of the insured event, if the losses are fully insured and the insurance company cannot monitor individual preventive activities, the extra spending by a firm reduces its premium marginally. As a result of this type of externality, firms face private incentive to under invest in preventive activities.

Adverse selection in the transport context is manifestation of a situation where the service provider is aware of the external effects of the operation, but is able to conceal it from the users (for example, plying a vehicle without the same being mechanically fit for roads).

Information asymmetries play an important role in environmental policy making. There are two different hypotheses on the impact of asymmetric policies: pollution heaven hypothesis and Porter hypothesis. The pollution heavens hypothesis predicts that more stringent regulations increases costs and overtime tend to shift pollution intensive industries to low investment cost regions causing pollution heavens and policy induced pollution leakages (Levinson and Taylor 2008). In contrast Porter hypothesis argues (Porter and van der Linde 1995) that more stringent environmental policies can have positive impact as these policies promote innovation and cost cutting improvement. Dechezlepretre and Sato (2017) conclude that there is a strong evidence that environmental regulations induce innovation activities in cleaner technologies.

III. Transport Sector in Himachal Pradesh

a) *Current State*

Owing to its geo-political conditions (as most parts of the state are remote and inaccessible), road transport is, the only mode of communication and hence is of utmost importance for the state. Being so, the sector makes substantial contribution to the state economy both directly and indirectly. Directly, its contribution comes in the form of value of services generated by the sector and the employment opportunities generated in the sector. Its contribution in the form of value addition made in the goods and services produced by other sectors is its indirect contribution. The sector is growing at the rate of over 6% per annum and is expected to contribute more with increased transport demand led by the rising incomes.

The vehicle population in the state has shown a phenomenal growth over the past few decades. From an average growth rate of 2.7 % during 1980-85, growth rate of vehicle population in HP increased to 7.8% in 1995-2000.After 2007, the vehicle population has grown at an average rate of nearly 17%. The total registered motor vehicles in the state have been reported to be 1.6 million as on 31st March 2019 that is a 28.5 % increase over total vehicles registered in 2011.Out of the total vehicles, non-commercial vehicles accounted for nearly 80 % of the total vehicles in 2019. The commercial vehicles are nearly 20% of the total vehicles in the state. Two wheelers and cars dominate the vehicle composition, accounting for nearly 51% of the total vehicle population. An average growth rate of nearly 15.5% was observed in case of two wheelers from 2007-19; cars indicated a further higher average growth rate of nearly 20% over the same time period. Apart from the above, nearly 0.4 million vehicles registered elsewhere enter the state during the tourist season that lasts for 9 months a year.

This clearly indicates an exponential growth in traffic volumes particularly personal vehicles in HP. This in combination with slow growth in road infrastructure and services has led to the rising problems of congestion, pollution, and depleting air quality over the years. Easy availability of finance, rising affordability, and lack of adequate public transport systems; have all led to the increasing preference for personalized modes. It therefore, calls in for a need to promote measures that wean people away from personalized modes and help promote more sustainable modes especially the public transport.

While the growth of private vehicles has been phenomenal, the growth of public transport is negligible. In the absence of a maximum life span of vehicles under the statute, obsolete technology vehicles ply on the roads, leading to the problems of pollution and road safety. Petrol and diesel are the dominant sources of energy for the vehicles, as CNG and electrically propelled vehicles are yet to be introduced. For these reasons, the transport sector in the state was also chosen to be the focus area for the green growth initiative.

b) Infrastructure Development Trends

Road transport forms the backbone of the transportation sector in HP. The role of roads in movement of people and goods is therefore critical in the overall growth and development of the human settlements in Himachal Pradesh as they stand today. Contribution of roads has not only been in making the isolated regions accessible but has also improved the overall quality of life of the people by enabling and improving the overall movement of goods and services across the state. There has been a phenomenal growth in road network in the past few decades. The state had only 288 kilometres of motorable roads in 1948 which has now grown to 37,460 kilometres and nearly 90 %of these are single lane roads. While motorable single lane roads have grown at an average rate of 5 % per year; motorable double lane roads have grown at an extremely slow rate of less than 1%.Data indicates that the primary focus of the government has been on providing access to the inaccessible villages/habitations in the state followed by conversion of existing nonmotorable roads into motorable roads. The presence of Railways and Air transport in HP is negligible. At present there are three airports in HP, in Shimla, Kangra and Kullu. Apart from that, there are 68 operational helipads. To provide better connectivity and open up remote and tribal areas to the tourists, the state government has introducedheli-taxi services in the state.

One major limitation of the sector is a lack of institutional set up to coordinate the activities of all the stakeholders. Transport systems require several functions to be performed in a well-coordinated manner for seamless and comfortable travel experience for commuters, for instance, the road management, land use planning, development of industrial areas, and urban development. Transport planning has to be integrated with land use planning right from the beginning to ensure provision of services. Currently, there is no synergy between urban development and transport planning. Transport planning is undertaken independent of the development of commercial and residential areas. Such a scenario has led to a situation where many new residential and commercial areas are planned without transport network. This has resulted in crowding in of para transit vehicles like autos and increased trend towards private car ownership. There is no formal mechanism of sharing new developments including industrial areas with the transport department.

Non availability of land is another major bottleneck in expansion of transport infrastructure. A peculiar situation is created in Himachal Pradesh since 66% of land in the state has been classified As forest land which cannot be put to any other use. As regards private land, very high costs of land acquisition along with arduous and time-consuming processes are a major barrier for planning integrated transport infrastructure. About 70 per cent of delays in all infrastructure projects are due to problems related to land acquisition. One of the factors is the heavily distorted land market, caused by zoning and development control rules that limit the supply of land that can be devoted to commercial, industrial or residential use. Significant amount of public lands keep large portions of well-located land outside markets. Cumbersome and time-consuming forest to non-forest land conversion rules increase cost of land. The Floor Area Ratio (FAR) and Floor Space Index (FSI) regulations as espoused in the Development Control Regulations (DCR) are too low compared to international benchmarks. Exceptions to these rules are traded on a highly selective and non-transparent basis, offering little incentive for land owners to surrender their lands for infrastructure development.

Common standards for design, operation and maintenance of transport infrastructure and rolling stock are relatively absent in the state. Till recently, bus bodies were being built by the local vendors and this had serious limitations in terms of passenger comfort, safety and vehicle efficiency. In a study on the road accidents that had taken place in the past five years, it was concluded that the defective bus bodies were responsible for larger number of deaths in bus accidents as the bus bodies used to fall apart throwing passengers out of the bus. Thanks to the amendment in the Central Motor Vehicles Rules which had made it compulsory to build monocoque bus bodies. However, truck bodies are still being built by the local vendors. Similarly lack of uniform guidelines on terminal facilities has resulted in bus terminals with bare minimum facilities and completely absent IT related infrastructure for passenger information.

c) Public Transport Services

Public transport in Himachal Pradesh is mostly conducted through the Himachal Road Transport Corporation and is fully owned and managed by the state. Constituted in 1974, the Corporation has a fleet of 3100 buses and operates the same both within and outside the state. A study discovered that there were at least 294 new roads opened in the last few years, but no service has been provided by the HRTC so far (Batta 2016). Public transport is subject to a very high tax

regime. These vehicles pay taxes on a monthly basis compared to the one-time, nominal tax levied on private vehicles. Even the taxes levied on the interstate routes are very high—almost double the normal Special Road Tax (SRT). In addition, inter-state movement of public transport in India (both buses and trucks) is subject to a severe problem of "tax exporting". This arises when governments tax the non-resident population on arrival to its territory, as corridor states levy high rates of tax on a competitive basis on the entry of outside vehicles. Even though the Motor Vehicles Act (which is a federal legislation applicable to all states) has a provision for scrapping vehicles based on age, it does not specify any age limit. Because of this, there is a "free rider" problem with owners of antiquated vehicles plying highly polluting, unsafe vehicles with old technology having to pay less private marginal cost at very high social cost. The externalities in the form of pollution, road accidents and congestion enhance the marginal social costs. Data shows that buses up to 20 years of registration age are still in operation, while trucks of more than 30 years registration age are still on roads.

With increasing mobility needs, a phenomenal increase in the segment of private run contract carriage vehicles (tourist taxis) has been observed in the segment of contract carriage vehicles in the state. The total number of light motor vehicles carrying passengers in the state has increased by more than 61 % in the last ten years from 2009 to 2019. However, there are serious concerns in terms of quality of services and passenger security in these vehicles (GoHP 2014).In absence of adequate public transport services, the dependency on personalized modes has also increased over time in cities in HP bringing along problems of congestion, rising pollution levels, and others.

In this segment, an additional complication is introduced by its overlap with the stage carriage operation. There is a rather thin distinction between the operational parameters of stage carriage and contract carriage operation. Ideally, the contract carriage operation should be limited to taking passengers from one place to another with no stoppage for boarding and alighting the passengers en route. The stage carriage operation on the other hand is operation on affixed route, from stage to stage, and committed regardless of pre-booked passengers. In the absence of enough tourist business throughout the year and in all places, the contract carriage vehicles (both buses and taxis) start operating on a fixed route taking passengers from place to place en route. It often leads to violent conflicts with stage carriage operators and instance of legal action for violation of the Act.

With market being supply driven dominated by small operators, there is a cutthroat competition in busy places and instances of over charging in remote localities. It has seriously affected the vehicle maintenance leading to problems of pollution and road accidents. Frequent problems of mixing kerosene with diesel are also reported. Transportation is a complex system as it constitutes several activities, stakeholders and processes. Unfortunately, the capability for undertaking a coordinated approach along with a holistic understanding of transport issues and their causes involved is generally lacking at the state government and city level. This is attributed to a lack of transport management skills amongst city and state officials. In most cases, state and city level agencies dealing with transport planning and provision have typically suffered from overstaffing with people with homogeneous skills consisting of largely untrained and unskilled manpower on the one hand and shortage of qualified technical staff and managerial supervisors on the other (Batta 2016). It is a major reason that they have not been in a position to deliver the current demand for transport services, let alone plan for the growing needs of cities and peri urban areas. The staff and management at these agencies are typically not accustomed to innovation and taking up new tasks, and are more comfortable opting for traditional methods of procurement and working with government grants and loans.

d) Freight Transport

The state has had a huge and ever-growing demand for movement of goods ever since its formation. With opening of new areas with development of roads, industrial and tourism development; need for movement of goods has increased phenomenally. The goods transport is also dependent on road transport in HP further adding onto extreme pressures faced by the road network. The number of goods carriage vehicles (including trucks, lorries and light motor vehicles carrying goods) in the state have doubled up since 2007. The total number of goods carriage vehicles registered in HP in 2019is 1,62, 849. The number has grown at an average rate of growth of 26% per year since 2010.

The state's transport policy clearly states that the freight segment in Himachal Pradesh is characterized by proliferation of small operators with high operating costs in the absence of economies of scale, dominance of old and polluting fleet, cartelization of operators to enforce rates and terms as per their choice, and problems of overloading associated with ill effects in the form of accidents and damage to the roads. In the absence of ample employment opportunities in other sectors, the transport sector has by default absorbed a large chunk of manpower which is now totally dependent on it for livelihood. It therefore presents a delicate politico-economic policy problem and the challenge to find an easy solution is difficult to the extent of being infeasible. Further, it is realized that the goods transport has not seen any new innovation in technology and operation in the past many years due to

which the transportation of farm produce and industrial products at competitive fares remains an area of serious concern (GoHP 2014).

e) Externalities

i. *Road Accidents*

Road safety is a major concern in the state. In 2018, the total number of road accidents reported in the state were 3017 and fatalities reported were 1168 and it showed an increase of nearly 30% over 2005. The total number of accidents per 100,000 population reported in HP in 2013 were 42.4, which is higher than the national average of 38.9 accidents. Similarly, the total number of road fatalities 100,000 population in HP in 2013 were 15, which was also higher than the national value of 11 fatalities (MoRTH 2013). The above statistics indicate that though the growth in accidents and fatalities over the years has been slow, but still the number is higher than the national average and needs immediate attention.

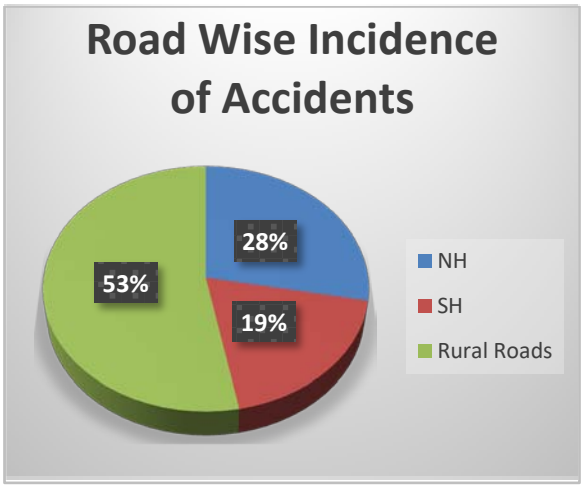

Figure 3: Road wise incidence of Accidents

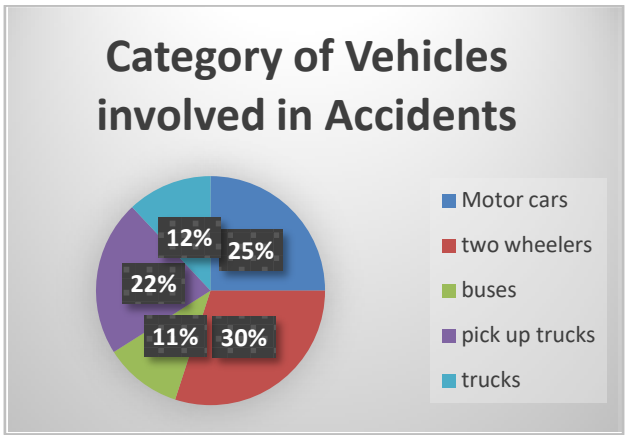

Figure 4: Type of vehicles involved in accidents

As per the road accident statistics maintained by the Department of Transport Government of Himachal Pradesh, on an average, around 3000 accidents take place every year in which 1100 deaths are reported. Most of the victims are in the age group of 21-35 years of age and 81 percent of them are males. Over 40 % of vehicles involved in accidents are motor cars and two wheelers, with over 50% accidents occurring in the rural roads. There are four main actors involved in the traffic operation: vehicle, driver, road, and passenger (Batta 2008). There are different concerns in each of them which are discussed as under.

a. *Vehicle Related Concerns*

Vehicle related concerns are often divided in three parts. First, relate to the machinery itself. The technology used, the road safety devices provided and the maintenance regime for vehicles. The older the model of the vehicle, the more it is likely to be polluting, unsafe and breakdown prone causing traffic hazards. Second, concerns the operational aspects of vehicle. These mostly relate to route planning, putting in use intelligent transport systems to regulate traffic, and policies of the government relating to vehicle use and technology. For instance, with government policies

encouraging safe vehicles by reducing taxation and promoting non- polluting vehicles like the electrical vehicles, the pollution and road safety are both attended to. Third, relates to the vehicle density and carrying capacity of roads. It is here that the role of two and four laned roads gets important.

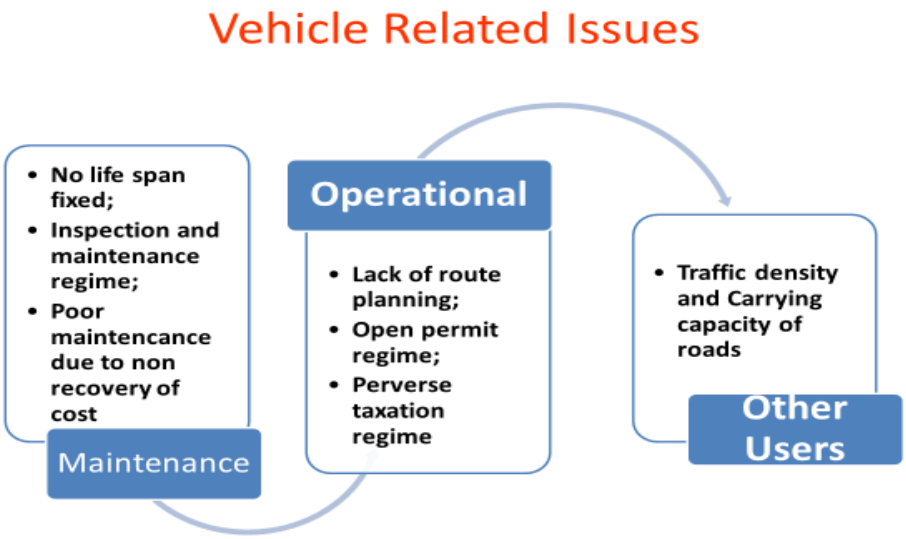

Figure 5: Vehicle Related Issues

When seen with reference to the state, there is no life span prescribed under the law for scrapping of vehicles. As a result, vehicles aged over 30 years are still plying on the roads. With their capital cost being zero and minimal insurance premiums, the owners are able to free ride by operating on nominal variable costs and with high marginal social costs loaded on to the society. Even the inspection and maintenance regime is also faulty as all inspections are carried out visually (without the help of machines). Further, there are serious issues of spurious parts being sold in the markets at low prices incentivizing the operators to get repairs done from the open market rather than the authorized dealers. All this put together results in highly polluting and unsafe vehicles being plied on roads. Further complications are introduced in the absence of appropriate route planning and perverse taxation regime favoring old vehicles. Even the roads being narrow with high vehicle density (especially in major district roads), the congestion and accidents are a common phenomenon.

b. *Driver Related Concerns*

Driver related concerns relate to level of education and training of the drivers, the licensing regime, their mental and physical condition, their driving behavior, insurance regime, traffic management practices in vogue, and policies relating to these aspects. The more stringent is driving licensing regime, educational and training requirements, driving behavior related insurance premiums, and intelligent transport systems keeping an eye on the driving practices by each driver; the safer the roads are likely to be.

The current licensing regime and the extant laws do not repose much confidence on the driver's capability to offer safe driving. Licensing applicants are subject to a routine test for a short while and with large number of applicants in a day and the inspector being under pressure to pass vehicles and conduct driving tests of a large number, the driving skills of the licensed drivers is always in doubt especially during the odd situations like fog, heavy rains, snow, and in the presence of heavy traffic. The insurance system is administered premium based and not linked to the driver's behavior which encourages risky behavior (one of the reasons of high death rate among the young drivers is this faulty insurance regime).

c. *Road Related Concerns*

Road related concerns pose another serious challenge. Major road related concerns are size, quality and technology in use (bitumen or cement concrete roads), traffic density on roads, maintenance of roads, and regulatory regime to enforce road quality and standards. The problem emanates from the very construction and passing of roads. Being a hilly area, most roads are constructed by cutting on the hillside and filling on the valley side. Most of these roads are prone to landslides and collapsing of retaining walls (Bayan 2013). In its endeavor to connect more and more villages, there is always a possibility of negotiating the quality standards to save costs. Even the road fitness regime is also not accurate as the committee responsible for this does not have any technical member (Batta 2016). There are serious issues in terms of road management and quality maintenance as several agencies are responsible for road construction (e.g. Public Works Department, Forest Department, and Rural Development Department) and none has

adequate resources for maintenance of roads. All user charges collected are deposited in the government receipts and the money is not available for the agencies charged with the responsibility of maintenance. Even the crash barriers are not installed on all roads as there is no law for enforcing of road standards.

d. *Passengers Related Concerns*

Passenger related concerns basically relate to the availability of passenger information systems, willingness on the part of the passenger to pay cost-based fares, road safety improvements, and adherence to traffic regulations.

Overall, the major factors contributing to road accidents could be divided in two parts (figure 6): policy related and legal. Policy related factors are further divided in two parts namely legal and institutional. Major legal factors emanate from the provisions of the Motor Vehicles Act, insurance regime encouraging free riding, open permit regime, lack of data and scientific investigation of accidents. The institutional factors are lack of road management and certification systems, and absence of an effective mechanism for cost recovery. Unemployment is the major social factor leading to over-crowding of commercial vehicles.

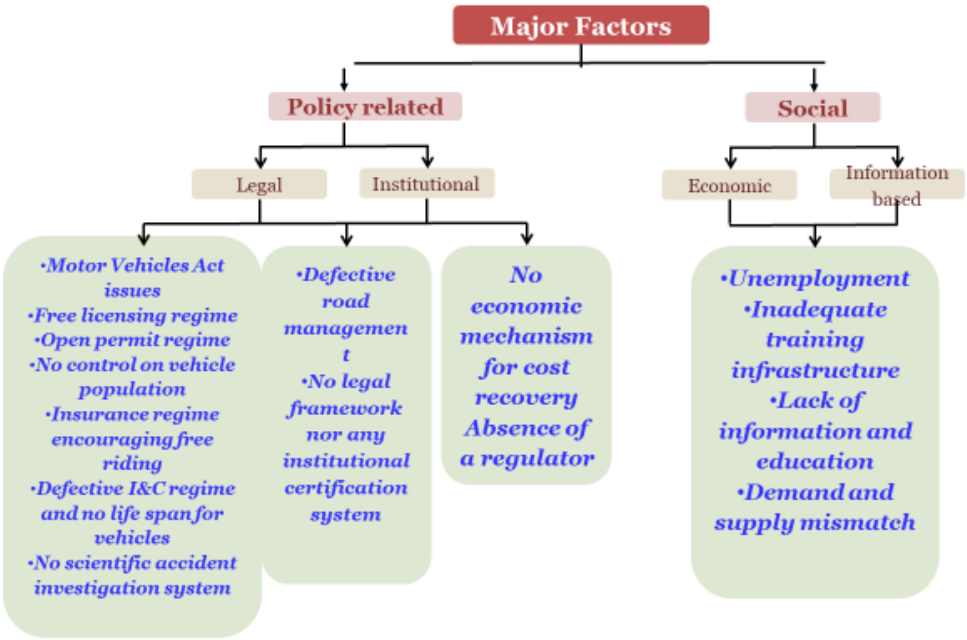

Figure 6: Major Factors Affecting Road safety

ii. *Pollution*

The major concern in terms of air pollution is unsafe levels of PM2.5. HPPCB (2014) notes that increases in the values of PM2.5 is a matter of concern. As there is no exclusive study on air pollution in the state as such studies considering the country as a whole have to be relied upon. Greenstone et al. (2015) estimates for India (including Himachal Pradesh) find that 660 million people in India (54.5% population) live in regions that do not meet the 40 µg/m3 National Ambient Air quality standard (NAAQS), and 262 million people live in regions with levels twice this standard. They further observe, "Nearly every Indian (99.5% population) lives in an area with PM2.5 pollution above WHO's 10 µg/m3 guideline (Greenstone et al., 2015: 42). All major towns of the state fall within the category of 40-60 µg/m3. HPPCB (2014) attributes this increase in the values of PM2.5 to the increased vehicular pollution. The loss of quality of life due to the increase in air pollution is estimated to be an average 3.2 years (Greenstone et al. 2015).

As ecosystems in the state harbor a wide range of natural resources, they are particularly sensitive to change. Regional changes in climate have already affected many physical and biological systems in the mountains. Analysis of temperature trends in the Himalayas and vicinity shows that temperature increases are greater in the uplands than the lowlands. Climate change impacts include movement of apple orchards to higher altitudes, loss of various tree species, drying of traditional water sources, change in bird types and population, reduction in crop yields, and increased vulnerability of winter cropping due to changes in rainfall patterns and planting dates (MOEF 2009). Projections by the Government of India (MOEF 2009) are even scarier: the annual temperature in the state is projected to increase up to 2.6±0.7℃by the 2030s and the annual rainfall upto 1604±175.2 mm. The projected

precipitation is likely to increase by 5% to 13% by 2030s as against 1970s levels (GFN and CII 2008). For a state like Himachal Pradesh heavily dependent on agriculture for livelihoods and GDP, the impacts of Climate Change on water resources are of critical significance.

iii. *Congestion*

The state has experienced a rapid urbanization and income growth led vehicle population explosion. Most of the cities have seen adjoining villages getting converted into dense localities. The trade-off between urban agglomerations and urban mobility is quite apparent as most urban areas face acute congestion during the peak hours and during the peak tourist seasons. Peak hour traffic delays and huge demand for services poses serious challenge to the service providers to meet the demand for services. As the supply gets further constrained due to congestion led delays (buses make lesser number of trips), there is often a problem of overloading of buses. Besides, being a tourist state, the traffic flows during the tourist seasons increase manifold due to large scale influx of outside vehicles. Hence, the urban transportation offers a major challenge to the transport planners and policy makers.

Apart from the rising vehicle fleet and increased mobility, roadside parking and encroachments have further reduced the capacity of the existing roads to take traffic as per design. On several occasions, this reduced capacity has led to serious accidents. Congestion has affected pollution levels as well as road safety in the state. The normal response has been to build bypass roads (the state has built bypasses in all the cities), however, these bypasses have also been taken over by the ribbon developments along the road causing traffic delays. The issue of congestion has been a hotly debated topic which has even attracted the intervention of the High Court of Himachal Pradesh. On several occasions the High Court has passed directions to the civil administration to ensure free flow of traffic.

f) Information Asymmetries and the Transport Externalities

i. *Road Accidents*

We have noted the concerns with respect to all the stakeholders in the transport management. In the situation where there is no life span prescribed for vehicles, perverse taxation regime encouraging old vehicles, imperfect licensing systems, untrained drivers with gross mismatch of skills with the vehicle technology requirements, no age limit for drivers, roads neither support the latest technology nor are well maintained, and passengers not willing to afford cost of operation; the likelihood of accidents is much more. When the element of information asymmetry is introduced, the driver does not know the road as well as the bus condition, the owner does not know the driver's skills, the passenger does not know the road, bus and driver's status and is also unaware of the next bus timings, there is every likelihood of accident which results in a death trap' (figure 7).

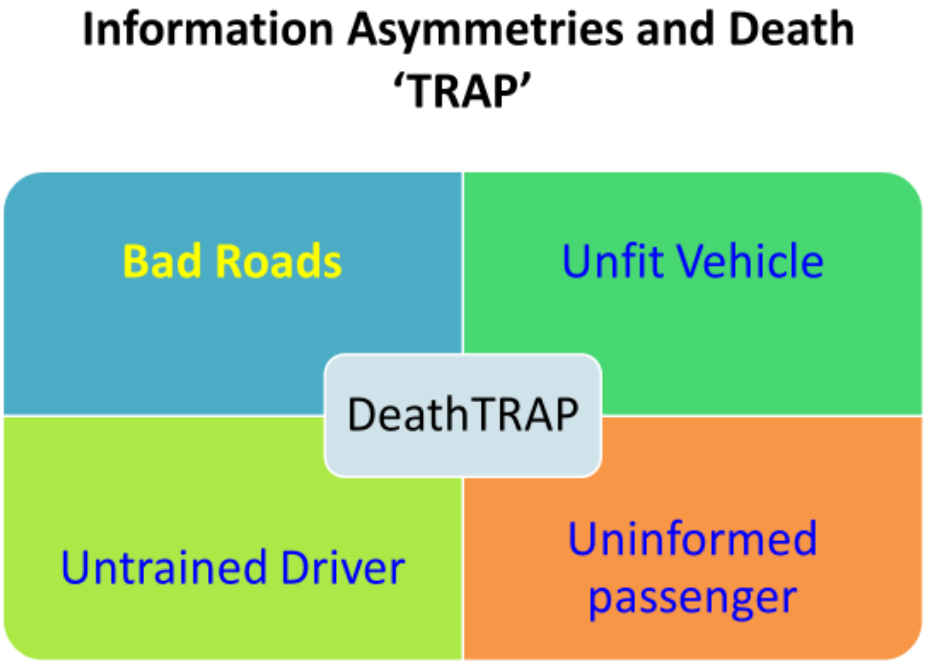

Figure 7: Information Asymmetries and Road Safety

With a view to actually find out the effect of asymmetries in the road accidents, accident inquiry reports maintained by the transport department were examined and the following facts came out.

Table 1: Information Asymmetries and Road Accident

Vehicle Details	Date of Accident	Driver	Bus	Road	Passenger	Fatalities
H.P. 65 7065	20-06-2019	Driver not fit to drive	Mechanically Defective bus	Steep curve, no crash barriers	Overloaded with 87 passengers	45 dead 17 injured
H.P. 03B 6205	01-06-2018	Over speeding	Defective bus Being Illegally plied	Steep un-mattled road	nil	09 dead 21 injured
H.P. 47 2477	20-05-16	Not fit to drive	Defective bus	Defective road	Overloaded	10 dead 30 injured
H.P 14A 4256	25-02-2016	Driver no holding license	Defective bus	No crash barriers	nil	8 died 22 injured
H.P. 86 0957	21-06-2018	Minor and without license	Unfit vehicle	No crash barriers	Overloaded	1 dead 11 injured

Almost all the inquiry reports have pointed out the road shortcomings and defective vehicle inspection regime declaring vehicles fit without any mechanical inspection.

ii. *Congestion*

Information asymmetries result in two-fold effects. First, it is difficult to know the marginal cost of congestion and the marginal benefit to the drivers. It is therefore often difficult to levy an appropriate congestion toll. This is especially true for the tourists visiting the state during the summer season. Second, while the congestion is highly variable over time and space, it may not be only due to the inadequate capacity of the road (it may even be due to some bottleneck occurring elsewhere). Therefore, estimation in such a dynamic scenario is all the more difficult when there is no system of collection and release of information.

The asymmetry of information also plays a serious role in public transport infrastructure management like roads, parking, and the rolling stock. The problem is that it is difficult to know the marginal benefit derived by each consumer using the infrastructure hence, either the transport infrastructure would be undersupplied (if it is left to the market mechanism with private capital to take the investment initiative), or the cost would not be recovered even if the state intervenes by augmenting the capacities to facilitate deriving benefits from forward and backward linkage effects. The social distributive consideration often leads to under pricing of such services vis-à-vis normative costs. In the context of the state, subsidized or free use of road and transport services have resulted in under pricing, poor maintenance and delayed augmentation of capacities. That is why not only the Himachal Road Transport Corporation is running in losses but it is true for all state PSUs in the road transport. It is for this reason that public transport services are subsidized by governments world over (Chandler 2014). Challenge therefore is to put a system in place that while protecting the interests of the poor also supports the public transport operation to fund the gap.

iii. *Environmental Management*

Information asymmetries plays an important role here. First, one major limitation is that often consumers undervalue new vehicle fuel economy because of the short planning horizons and have greater appreciation for other attributes (like sports utility functions and horse power, especially in the hilly terrain), and do not expect savings to be reflected in used vehicle prices. Therefore, the policy tools may not bring the desired results. Second, it is difficult to assess damage caused to the environment especially as there are other factors also contributing to the pollution.

IV. Travel Demand Management

Travel demand management (TDM) seeks to reduce externalities by reducing single occupant vehicle trips as well as shifting the travel to non-peak hours of the day. The TDM strategies mainly aim at: moving more people in fewer vehicles by using transportation that does not contribute to congestion and pollution (public transport/mass transit), reducing the number of people travelling during the rush hours (congestion pricing), and eliminate the need to commute to work (transport efficient land uses and Information technology).

a) Public Transport Management

The model structure of mobility breaks down between carbon intensive (e.g passenger cars, trucks) and low carbon intensive options (e.g. public transport and non-motorized transport). The expansion of the latter requires huge investment in infrastructure to ensure efficiency, reliability and coverage. One of the major limitations in the state is neglect of the public transport. The services are neither reliable and nor comfortable. The data maintained by the Corporation shows that on an average 30% of services face

problems of breakdowns and non-completion of trips for various reasons (Batta 2016). Even when road transport is the only mode of transport, there are no luxury services connected the state headquarters with districts and inter district traffic. One of the reasons of morning jams is school traffic which again due to the inability of the Corporation to provide services connecting all places, people are forced to bring their wards on personal vehicles. The recent success of Volvo services to Delhi shows the public preference for comfort and their ability to pay more if quality services are provided.

Promotion of public transport is also essential from the equity considerations. Transport having more of the character of a necessity in the basket of a poor man's consumption, the utility function of the poor will involve inelasticity of substitution between a transport and a non-transport goods. Since variation in prices facing the poor would have both an income and a substitution effect, a higher price of transport would have an adverse effect on real income as also on social welfare level. This leads often to the argument that ideally society should resolve such distribution problem by income transfers through lump-sum taxes and subsidies independent of the regime of the relative prices, as this would not cause any distortion in the allocation of resources. However, often the political-economic transaction cost of implementing such policies of income transfer becomes too high, reliance by default, has to be placed on the use of prices as instrument of resolving the distributive problems through subsidy in consumption of the necessities.

For promoting public transit services, appropriate pricing strategies are essential so that transport business is kept sustainable. It is also important for promoting pollution abatement technologies and road safety. The growth of the transport sector and the consideration of allocative efficiency would require the pricing of any mode of transport to follow the long run marginal cost pricing principle (Sengupta 2001). Unfortunately, it is not a practical solution for two reasons: market failure and distributive considerations which create problems. First, the ground-fixed infrastructural items (like roads and bus terminals, etc.) have 'public good' character so that it is not possible to apply the pricing principles as applicable for private goods. Second, on the operation side, the transport operation exhibits tendencies of vertical integration and large-scale economies leading to a natural monopoly situation. Simultaneously, there are both negative and positive externalities generated by transport again leading to market failure. Besides, income inequalities make a case for government intervention to provide access to the poor.

The state needs to correct its taxation system, review the current fare fixation system to enable the operators to recover the costs, and promote technology centric replacement of fleet. Adequate services of budget travel as well as luxury travel need to be promoted to provide substitute to the personal vehicle use. The recent initiative of adding electric buses using a national program funding should be further expanded to cover the entire state. Private sector participation should be earmarked for certain sections and be encouraged by tax concessions and appropriate pricing regime.

b) Emerging Pricing Policies

Over the years, with the introduction of electronics and telecommunications, many developments have led to development instruments for addressing congestion and accidents that complement the fuel taxes. Using pricing as a tool, behavioral change among the users is sought to be made. Discussions hereinafter examine the ways how pricing could resolve some of the congestion and accidents related problems.

i. *Congestion Pricing*

The basic premise of the congestion tolls is to charge motorists the difference between their marginal cost to all drivers and average travel cost to the individual drivers. Even though, there is ample scope of controlling congestion and mobilizing resource by using this tool, but the main limitation is that the current collections of state entry tax (a kind of toll tax charged for entering the state. It is a fixed charge that does not vary with the time of the day.), are all credited to the state exchequer with not a single penny used for the maintenance of roads. It therefore creates political as well as public opposition against any increase in toll. One important, and probably effective way of making this tool useful in managing congestion is by judicious use of revenues from congestion tolls to create a broader coalition of winners from the policy change (Parry, Wall and Harrington 2007). A review of literature shows (e.g. Small 1992; Goodwin 1995; Harrington, Krupnick, and Alberini 2001; and Transportation Research Board 2006)that mixed spending on road improvements, transportation alternatives, and road safety bring good results. Studies like Harrington, Krupnick, and Alberini (2001) finds discernible increase in support for congestion tolls when the revenues are recycled for reduction in local taxes or benefits from the toll collection are visible.

Congestion pricing often results in timing adjustments and car pool. It is often seen that as all offices and business establishments open at the same time, there is a peak time travel rush causing congestion. Flexi working hours, working from home, and compressed working weeks are some of the options to reduce travel demand during the peak hours. However, it requires employer employee adjustments and all places and establishments may not be amenable to such adjustments. Though staggering the opening timings of educational institutions, shopping malls, and

entry of goods vehicles could be easily done. Likewise, encouraging car pools and park and ride also reduce number of SOV (single occupancy vehicles) on roads. These car pools could be informal or even under some formal arrangements. Under the dynamic ride sharing prevalent in some countries, an independent organization matches the passengers and drivers for individual trips. Park and ride is basically used to provide last mile connectivity and connecting people with HOVs.

ii. *Parking Fees*

Parking management is an equally important element in the TDM strategies. Parking practices and prices have a substantial impact on the car use. For instance, free or inexpensive parking encourages car users to undertake long trips by car rather than use bus or rail link. Such parking facilities incentivize long time parkers at the expense of those undertaking short trips for shopping or other short-term users (like for healthcare and medical services).Most effective parking strategies apply cost-based pricing measures that fix demand-based parking rates with incentives to car pools and short term parkers. It has an effect of reducing total parking demand and tends to shift travel to other modes. One of the serious limitations in Himachal Pradesh, is that the entire road space is used for parking. It not only reduces the available road space for plying of vehicles, but has rendered the commercial parking non-viable. The state has tried to mobilize resources for parking and bus stands under public private partnerships (PPP), however, all these are running in losses due to this factor. While PPPs have inherent advantages of providing private finance, expertise, and management; but the economic characteristics of transport infrastructure is exogenous demand risk (Engel and Galetovic 2014) whereby predicting initial use and growth rates is very difficult. Both macro-economic cycles and demand uncertaintiespose a serious threat to such projects and if the demand is further curtailed by open free parking policies like this, then the very purpose of having PPP is defeated.

c) *Planning for Low Traffic Neighborhood*

Transport efficient developments are characterized by higher density and mixed and uses. Reorientation of investments towards public transport is possible if density of settlements is enough and for doing so land-use policies and fiscal policies handling control of land markets become important. Similar is the case with policies aimed at reduction of demand for travel as it entails some degree of reorganization of firm's production and distribution processes and households' pattern of consumption. Studies supporting this hypothesis have highlighted by concluding that energy consumption from transport and CO2 emissions are dependent on population density (Grazi et.al 2008), compact cities as sustainable urban forms (Holden and Norland 2005), and association between land use planning and automobile dependence (Glaeser and Kahn 2010).

It is a known fact in the state that in most of the urban areas, expansion of settlements has taken place horizontally rather than vertically. It has posed serious issues not only in terms of provision of public transit services but also in terms of provision of other civic amenities like water supply, solid waste management and public health facilities. It has also resulted in escalating the prices of scarce land and is often held culprit for visual pollution (Batta 2000). Thus, there is a strong case for integrating complimentary policies on the demand side such as infrastructure policies, land-use policies, building regulations, and in addition to these physical policies, the soft policies (telecommunication) that reduce the need for travel.

d) *Using Emerging Technologies in TDM*

Our analysis so far has revealed that the transport sector faces information asymmetries in both the forms: one party lacks the information about quality of other party (e.g. the standard of bus, quality of road and skill level of the driver) and behavioral aspects of a driver (principle agent problem between bus owner and the driver and driver and insurance company leading to moral hazard). Use of information technology is critical in maintaining and dissemination of vital information. The current impacts of intersecting physical and digital technologies are unprecedented: with convergence of developments such as machine learning, real time data, and artificial intelligence has increased automation in multiple areas from traffic and network management to autonomous vehicles. This will provide ways to not only improve infrastructure, but will also have a substantial impact on transport demand and information dissemination.

V. Conclusion

Externalities caused by transport are very significant and could potentially be very costly if not contained by appropriate policy interventions. It needs to be appreciated that transport sector reforms have co-benefit features in the form of increased incomes and leisure time, cost savings, and enhanced competitiveness all of which have bearing on the quality of life. Similarly, investments in public transportation, besides expanding service and mobility, help boosting the economy as a whole in many ways. These could occur in the form of saving in the cost of travel as well as vehicle ownership cost avoided by those travelling by public transport or shifting to public transport from the private modes. It also results in reduced traffic congestion, caused due to decreased personal vehicle use, often leads to travel cost savings for businesses and households through operating cost savings

associated with worker's wage (i.e. less time spent by a worker on travel during a business trip).In addition, business productivity improvements due to access to broader labour markets with more diverse skills is enabled by reduced traffic congestion and expanded transit service areas.

However, the sustainability considerations require that the pricing of transport services is pursued in a scientific and professional manner. It needs to be appreciated that transport input costs (e.g. wage rate, interest rates, and exchange rates) have all moved from the administered price regime to the market determined prices, but the fare fixation has still remained in the administered price regime in the garb of equity. The fare rates are often revised by the governments after long intervals while the input costs increase almost on weekly basis. It is therefore difficult to match the costs with fares leading to implicit subsidy being transferred to the users of services. It initially affects quality of services and ultimately the quantity of the service supplied. It therefore makes a case for public funding of transport services. It is a known fact that governments world over fund public transit services through subsidies and tax credits (Chandler 2014). This public intervention is warranted to discourage negative externalities caused by cars (Parry, Walls, and Harrington 2007; Erutku 2020). Studies (Anderson 2014;Andler and Ommeren 2016; Bauernschuster, Hener, and Rainer 2017) have found increased pollution and congestion during the strike by public transit operators.

Seen from the perspective of TDM, it needs to be appreciated that two distinct changes are taking place in the current evolution of traditional TDM programs. First, the changes in technology are affecting both supply (road pricing, intelligent corridor management, dynamic ride sharing) and the demand (changing travel behavior relating to telecommunications and improved information on travel choices) for transportation. Second, is the demographic transition taking place in Himachal Pradesh that is likely to affect demand for travel. Therefore, any successful TDM program has to focus on understanding the changes in demographic characteristics like income, age and place of residence and develop tools for projection of travel demand.

The state faces serious issues on the road safety front: the current policy regime views the problem of road safety in isolation from the broader context. There has been increased recognition that combinations of interventions demonstrate greater cost effectiveness. This requires focus on systemic issues and simultaneous interventions at multiple levels. For effectively controlling traffic injuries and deaths, the state needs to put in place a strict licensing regime where by no unfit person could obtain a license, maintain data to keep track of the driving behavior of the licensee, thoroughly revamp the inspection and maintenance regime by putting up fitness centers across the state, enforcing permit conditions effectively and cancel permits in case of major violations, introduce tax reforms for disincentivizing unsafe vehicles, reconsider road inspection committees by putting independent professionals therein, and have effective accident enquiry systems that contribute to identifying appropriate changes in policies and procedures across the sectors. Besides, other interventions like improvements in land use and built environment (land zoning, traffic calming measures), improved quality of public transport, improvements in information dissemination, legislation and enforcement of traffic regulations, and improved quality of roads with a well-designed enforcement mechanism for ensuring quality; would also help. It is often seen (Wales 2017) that lack of accurate data on accident causes, damages, and costs to humanity has led to low political saliency and failure to fully implement reforms.

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Optimizing Bio-Sand Filter (BSF) for Maximum Thermotolerant Coliform (TTC) Removal from Drinking Water in West Bank

By Ahmed I. A Saya'Ra

Al-Quds University

Abstract- About 297,900 Palestinian who lives in 532 residential areas in Area c of Palestine (Jarrar, 2019). Many of them rely on rain harvesting into cisterns during winter to fulfill their needs of drinking water. For instance, in Massafer Yatta, results of water quality from cisterns showed contamination levels that are ranging from 20-100 CFU/100ml. The Bio-sand filter (BSF) has been prompted extensively for water treatment in households in developing countries. In the present study, we investigated the influence of 9 operating parameters on BSF efficiency for Thermo tolerant coliform (TTC). Results analysis showed that five h residence time and media age more than one month were significant with P-values of 0.0439 and 0.0089, respectively. Although the fiveh residence time was insufficient to minimize TTC below the drinking water permissible level of 10 CFU/100ml when influent water had 500 CFU/100ml TTC. In addition, the use of five h residence time may have reduced the filter age and efficiency in removing TTC. Charge volume, turbidity, and using different cistern to fill BSF had no significant influence.

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I. Introduction

There are around 1.1 billion people worldwide who lack access to safe drinking water. This lack of access, combined with insufficient water supplies, is responsible for the occurrence of 4 billion cases of global diarrheal diseases (Sobsey et al., 2008). More than half a million children die from diarrhea each year (Kumar et al., 2020).In the occupied Palestinian territories, about 12.3% population isoff access to public water supply(Mahmoud et al., 2018). Diarrhea in the territoriesis a major cause of outpatient visits and hospitalizations (Elamreen et al., 2007). According to the Vulnerability Profile Project (VPP), there are about 297,900 Palestinians in 532 residential areas in area c lives without access to public water grid (Jarrar, 2019). Residents of these areas subsist on herding and non-mechanized agriculture; they rely on rain harvesting into cisterns during winter to fulfill their needs of water that is contaminated with domestic animal's organic wastes. The available database from Comet-Me(Community Energy Technology-Middle East) has shown Thermotolerant Coliform (TTC)water contamination levels, ranging from 20-100 CFU/100ml in drinking water cisterns.

The Bio-sand filter (BSF) is prompted extensively for water treatment in households in developing countries. It has been introduced in at least 36 countries worldwide, with more than half a million people using this technology (Elliott et al., 2008).This filter is easy to operate, maintain, affordable, durable, manufactured using local materials, zero energy consumption, and sustainable (Kubare & Haarhoff, 2010).BSF seems to be an appropriate technology for biological water treatment in residential areas of Palestinian territories. In this paper, BSF operation conditions were characterized and optimized based on the design of the experiment (DOE) provided by Design-Expert software. We investigated the influence of 9 operating parameters on BSF efficiency for Thermotolerant coliform (TTC) removal. These parameters were residence time, charge volume, media age, turbidity, changing water source, temperature, sand size, influent TTC counts, and inflow rate.

II. Methodology

As per the Center for Affordable Water and Sanitation Technology (CAWST) specifications, the following (Fig.1) show the BSF design. The filter is a cylinder pipe of 90cm height and 25 cm. diameter. At the bottom, 10cm layer of small gravel is installed, followed by another 10cm larger gravel layer and a 40cm layer of sieved and treated sand.

a) Residence time, charge volume, media age, water source, and turbidity characterization experiment

In this experiment, we used Regular Two Levels factorial design 25-1 with four center points to

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characterize the influence of residence time, charge volume, media age, water source, and turbidity. We assigned the residence time low level as 1h,the high level 5h, and the center as 3h.We selected the charge volume low, center point, and high levels as 4, 6, and 8L. Media age levels were 1, 37, and 73 months. Turbidity levels were 1, 10, and 20 NTU. Two different cisterns of harvest one and harvest two were included to characterize changing water sources influence on BSF treatment efficiency.

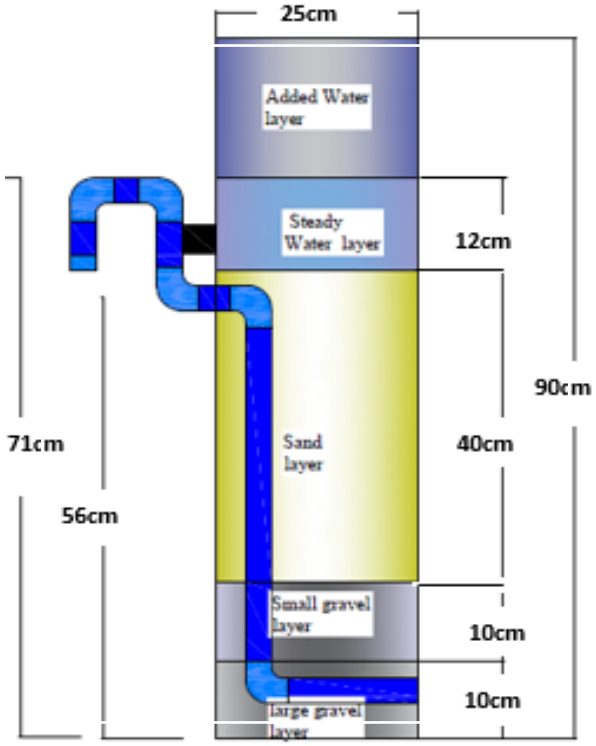

Fig. 1: BSF design

b) Temperature, residence time, charge volume, effective size, and inflow rate characterization experiment

In this experiment, we used a replicated Regular Two Levels factorial design 25-1 without center points. For temperature, we have chosen a constant low level of 25 °C inside the cave and a fluctuating high level of average 33°C outside the cave. The low and high levels of sand size were 0.18 and 0.23mm. Inflow rate levels were irrigation meter as low and manual charge as high levels. The residence time low level was 2h while the high level was 4h. The charge volume low and high levels were six and 8L.

c) Residence time optimization with influent count and media age

We used Response Surface Method (RSM) and Behnken Box Design (BBD) in this experiment to obtain a mathematical equation that can be used to inform farmers how many times they should fill the filter per day and how long they should wait before complete water treatment is ensured based on TTC concentration in their cistern. Residence time had three levels of 1, 12, and 24h. Media age levels were 4, 40, and 77 months. Influent TTC counts were 10, 500, and 1000 CFU/100ml.

III. Analytical Methods

TTC analysis was performed using the Del Agua kit (manual version 5.0). This analysis is based on the membrane filtration method of TTC specified by the WHO in annex 6 of guidelines for drinking water quality. Turbidity was measured by nephelometric tube method provided with the Del Agua kit.

Porosity, pore volume of the filter sand, and sand size and uniformity coefficient (UC) were measured based on CAWST guidelines.

IV. Results and Discussion

a) Residence time, charge volume, media age, water source and, turbidity characterization experiment

The analysis of results using design expert software (Analysis of Variance ANOVA) showed that only residence time and media age were significant with P-values of 0.0439 and 0.0089, respectively. Charge volume, turbidity, and changing water source had no significant influence (Fig.2).

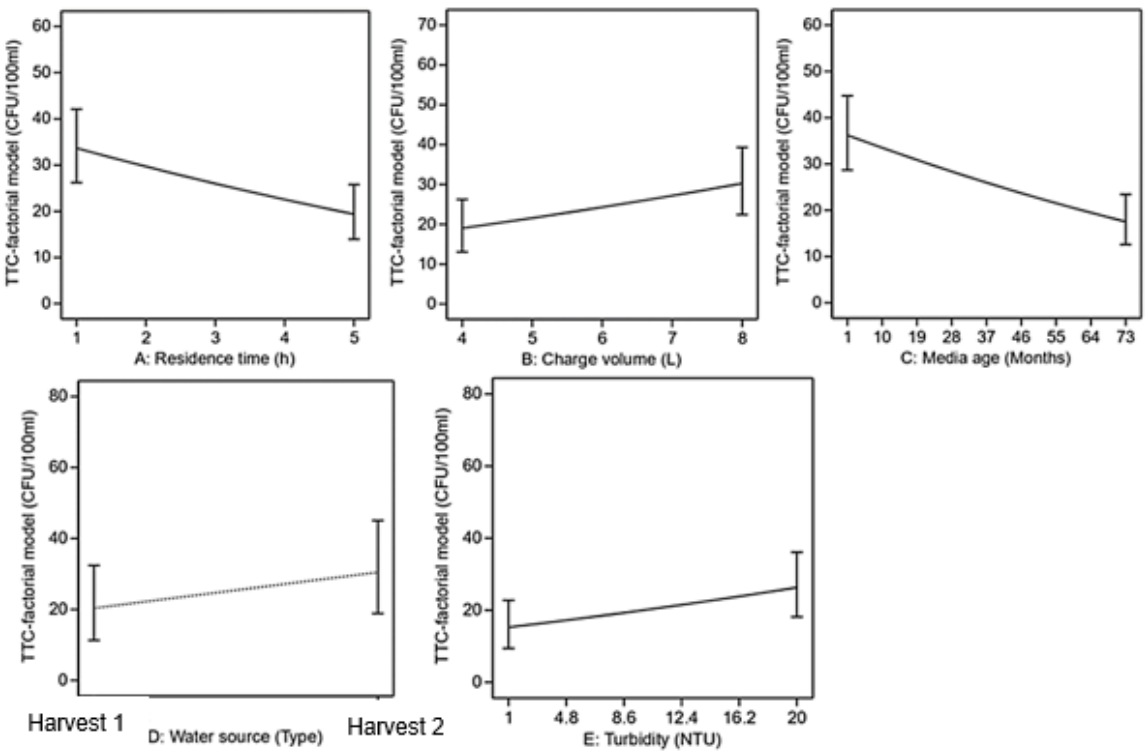

Fig. 2: Residence time, charge volume, media age, water source and turbidity influence on TTC removal from BSF

In this experiment, residence time was compared for the levels of 1, 3, and 5 h. CAWST recommends BSF operation with a minimum of 5 h after each fill. The BSF elimination of pathogens is based on their contact time with sand particles. The longer water retention in sand media increases the opportunity to adsorb or trap more pathogens. Despite that, when the water source had TTC concentration up to 500 CFU/100ml, the 5h residence time operation format was not completely effective. In this experiment, the results of TTC after BSF were higher than the reasonable water quality limits of 0-10 CFU/100ml. The average TTC in effluent samples was 22.62 ± 4.3 CFU/100ml.

Although increasing charge volume did not show a significant change in TTC removal, this was not a contradiction to its significant role in the filtration process that have been described by previous studies. On the contrary, referring to the current BSF design in the methods, the total sand volume in BSF can be approximately 19.6L. At the completion of all experiments, sand porosity for each filter was measured after completely drying sand samples. The average filter porosity in this experiment was 0.43; this is about 8.5L water that can be retained in 19.6 L of sand. This explains the insignificance of charge volume in this study. When the filter is filled 4, 6 or 8L, the whole charged volume was, approximately speaking, contained in the BSF sand layer.

The media age was also significant with a P-value of 0.0089. Most previous studies investigated this factor in the range of 1 to few months. This study has compared the media age up to 6 years. The findings here were consistent with most previous works, which emphasized an increased BSF efficiency after one month of operation. BSF is assumed to remain effective up to many years. In the current study we found that BSF of 28–46-months as the most effective to reduce TTC by 96% and produce reasonable water quality. However, further investigation is required to ensure the efficiency of BSF beyond this age when it is being operated in intervals of 1-5 h residence time (Fig.3).

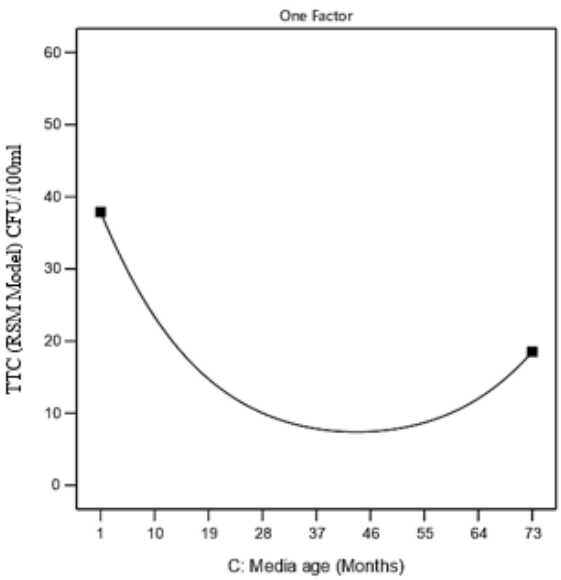

Fig. 3: Influence of media age on TTC Removal when residence time is 1-5h

There were no significant effects that resulted from changing the water source to a different cistern as long they have relative TTC concentration (about 500 CFU/100ml in this case). This factor was included because farmers in area c usually have few cisterns to fill during the rainy season. The main cistern near the household is filled with other cisterns when it is empty.

There was no significant influence for turbidity in the range of 1-20 NTU on BSF removal efficiency. However, turbidity reduction to acceptable limits (< 5 NTU) by BSF is important to ensure water is safe to drink.

The Design-Expert software helps to predict optimal values of factors based on the regression model generated from results analysis. By using this feature, the most optimum solution was suggested as 5h residence time, 7.77 L charge volume, and 53.3 months media age.

b) Temperature, residence time, charge volume, effective size, and inflow rate characterization experiment

The analysis of variance ANOVA showed that effective size and residence time had a significant influence on BSF TTC removal with P-value of 0.0016 and 0.0238, respectively. While temperature, inflow rate, and charge volume were insignificant factors (Fig.4).

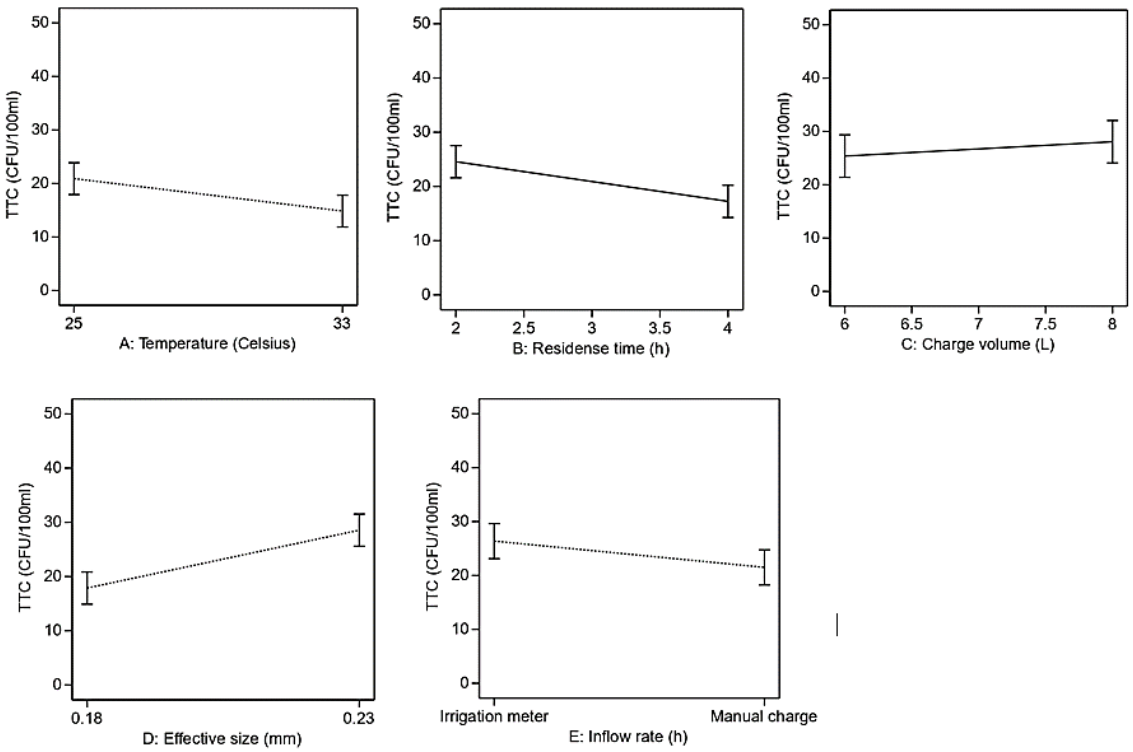

Fig. 4: Temperature, residence time, charge volume, effective size and inflow rate influence on BSF TTC removal

Temperature influence on BSF was investigated as constant and fluctuating in this experiment. Whether filters were operated at a constant temperature of 25 °C or a fluctuating average 33°C, there was no variation on BSF TTC removal. While the temperature itself was not significant, it showed an interaction with effective size (Fig.5). At 25 °C, both 0.18 and 0.23mm had the same influence on TTC removal. On the other hand, at 33 °C, 0.18mm was significantly more effective to remove TTC. (Bai et al., 2016) investigated the effect of temperature on the transport of suspended particles in the pore space of material. They found that when temperature increases, it accelerates the irregular movement of suspended particles and reduces their migration velocity; this can be attributed to the narrower pores in 0.18mm than 0.23mm.

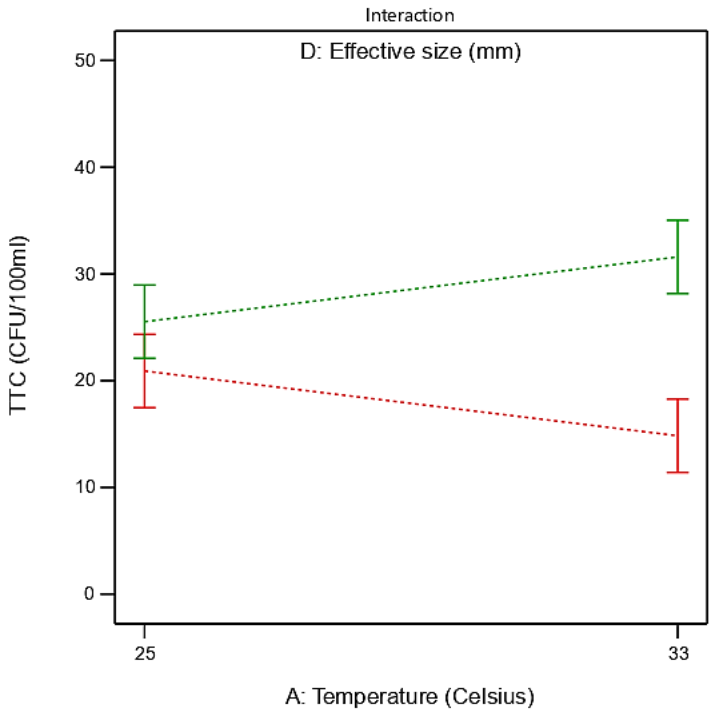

Fig. 5: Temperature and effective size interaction

The residence time was a gain significant when it was increased from 2 to 4h. The reason behind using these two levels in this experiment was that 1 to 5h is considered long for a nonlinear factor without a middle point. Charge volume significance did not appear as well; this is due to the sufficient sand pore space that can contain six and 8L.

Finally, changing the inflow rate of water into the BSF from manual charge to automatic irrigation meter did not produce any significance. This is probably due to the mechanical action of diffuser placed above the standing water layer, which maintains regular water flow on the BSF top layer.

c) *Residence time optimization with influent count and media age*

In the first experiment, it was concluded that residence time of 5 hours and media age over one month has a significant influence on BSF TTC removal (minimized TTC by 50 Δy). The significant model calculated desired charge volume as 7.77 L. It was also concluded in the second experiment that finer sand of 0.18mm effective size improves TTC removal. In this experiment, the previous significant findings were taken into consideration. The charge volume was adjusted at 7 L, the 0.18 mm effective sand size was selected, and media age was upgraded to four, 40, and 77 months.

Seventeen runs were designed in this experiment to mathematically model the influence of influent TTC count, media age, and residence time on BSF efficiency. In this case, residence time, Influent TTC count, Residence time-influent count interaction were significant model terms with P-value 0.0006, 0.0004, 0.0006, respectively. The influence of media age was insignificant with a P-value of 0.4295; this is due to including filters older than four months. The RSM graphical presentation (Fig.6) shows the interaction of residence time and influent count. The graph surface slice shows that increasing residence time to 24h was necessary to keep high BSF efficiency to remove the TTC count of 1000 CFU/100ml. The color of the surface slice changed from blue to green at that point to visualize the difference. Fig.7 presents the interaction of media age and influent count; there was no clear variation on the slice surface or color. Fig.7 is also driving the conclusion that media age more than one moth will have same efficiency of TTC removal when selected residence time is up to 24h.

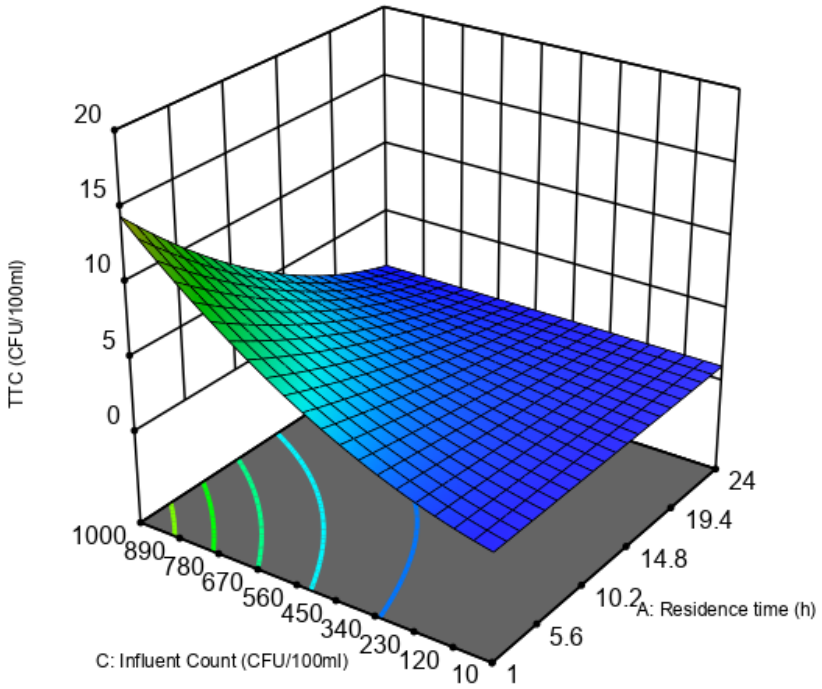

Fig. 6: Interaction of Influent count and Residence time

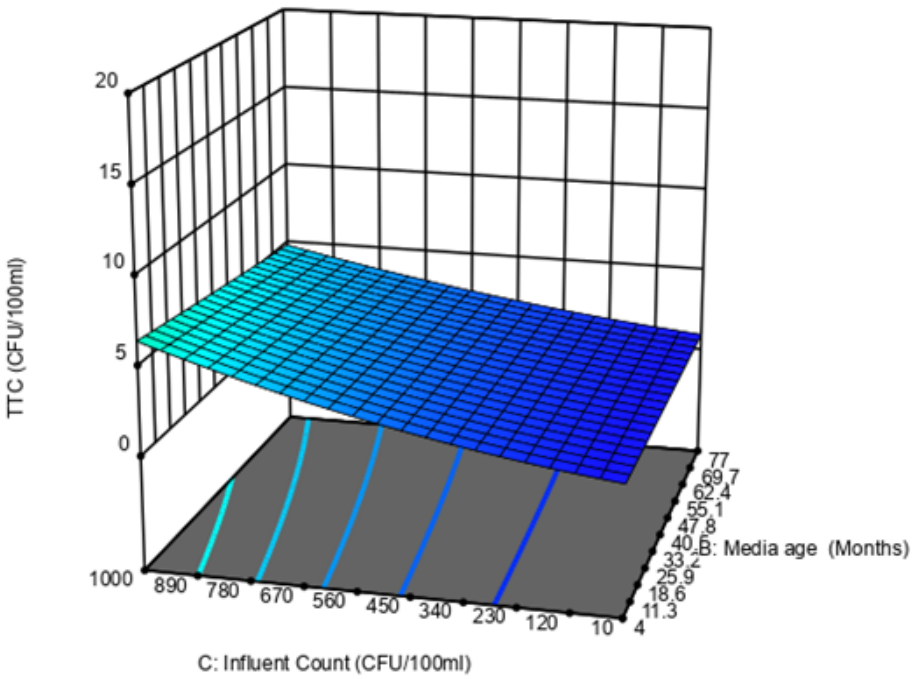

Fig. 7: Interaction of influent count and media age

The review of fit statistics and diagnostics of this experiment showed an R2 value of 0.9224; this means that the RSM model is well explaining the data. Adjusted and Predicted R2 were in reasonable agreement of 0.8758 and 0.7652. Their difference was less than 0.2. The RSM model of this experiment specified optimum conditions to maximize TTC removal by BSF as the following: residence time of 23 hours, media age 29.9 months, and influent count of 475.9 CFU. The result is 99.8% TTC removal as the response TTC result under these conditions is 0.953 CFU/100ml.

V. Conclusions

1. The five-h residence time was enough to produce Δy change of 50 CFU/100ml. Despite that, when the water source had TTC concentration up to 500

CFU/100ml, the five-h residence time was not completely effective. In this case, the results of TTC after BSF were higher than the reasonable water quality limits of 0-10 CFU/100ml. The average TTC in effluent samples was 22.62 ± 4.3 CFU/100ml.

2. BSF media age is more efficient for TTC removal after one month of filter setup. The BSF operation format of once every 1-5 hours residence time may result in filter age reduction to less than 4-6 years. On the contrary, the BSF operation format of 12-24 h extends filter age to more than six years. This is due to the operation of the BSF less frequently (1-2 times per day).
3. There is no significant effect on BSF TTC removal when it is filled from a different water source as long they both have relatively equal TTC concentration.
4. BSF is excellent for turbidity removal in the range up to 50 NTU. Turbidity of 1-20 NTU is within filter capability for this purpose.
5. The optimum charge volume of BSF is the volume of sand pore space. BSF media should be designed to contain approximately all charged water volume to ensure complete water treatment.
6. Smaller effective sand size has expressed a significant effect on TTC removal from BSF. Together with uniformity coefficient should be considered among critical factors to improve BSF efficiency.
7. Whether BSF is filled manually or using an irrigation meter, this should not be of great concern when operating the filter in rural areas that lack electricity or water grid infrastructure.
8. Sand effective size of about 0.18mm is necessary to maintain high BSF efficiency when temperature rises to 33 °C. Filters of larger sand effective size cannot produce reasonable water quality (TTC <10 CFU/100ml) in warm climates.
9. The optimum BSF operation residence time should be 23h when raw water has TTC up to 1000 CFU/100ml.

Recommendations

The BSF can be an effective, sustainable solution for water treatment in area c of the West Bank. The filter installation materials are cheap and available from local materials. It requires a minimum periodic maintenance. The present research recommends BSF design and operation as the following:

1. The size of BSF should be related to the family size and number of users. BSF should be ideally operated once per day. If it is still insufficient to meet family needs, the filter can be used twice a day with a residence time of 12 hours. For this reason, a bigger filter which can produce more than 20L per charge is more desirable.
2. Since BSF media efficiency to remove TTC reduces with time, particularly after four years, it is recommended to replace the top 10-20cm of the sand column after this period.
3. The average temperature in West Bank may reach 33°C during summer. It is recommended to install BSF with sand of 0.18 mm effective size to minimize the adverse effects of temperature on BSF efficiency for TTC removal.

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Ambient Air Quality Monitoring: Impetus, Complexities, Challenges and Solutions

By Rao Tatavarti

Dalhousie University

Abstract- The poor state of air quality all over the world in general, and across India in particular, is a cause for extreme concern as it is directly and indirectly linked to the deterioration of human health and economies of nations The many complexities and challenges posed by ambient air quality monitoring, prompted the World Health Organization (WHO) to suggest a road map for all nations for the year 2020 -to arrive at a consensus for effective air quality monitoring by all stakeholders – nations and governments, regulatory and controlling bodies, NGOs, scientists and researchers and private citizens.

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As we approach the end of 2021, the multifaceted and multidimensional problems related to effective ambient air quality monitoring still remain herculean, and extremely expensive for wider deployment to gather a realistic spatio-temporal information related to ambient air quality, in order to draw up effective plans to curb or mitigate the air pollution.

The complexities for effectively monitoring ambient air quality led to confusing practices in selection of sensors and systems for air quality monitoring, the siting of systems, and the empirical approaches followed by different stakeholders in arriving at averaging times related to expensive systems for measurements, resulted in different definitions of air quality.

Today, the confusion is worse confounded with the advent of new entrants into the field advocating low cost sensors with lesser accuracies for niche applications.

Against this backdrop the present two-part paper highlights the impetus, complexities and challenges posed for ambient air quality monitoring in the first part of the paper. The second part of the paper introduces a novel indigenously developed state of art photonic system for ambient air quality monitoring having higher accuracies with overarching capabilities for diverse applications.

A unique calibration facility designed and developed for the indigenous photonic system ensures that after a one-time calibration the system can be deployed for field usage anywhere in the world under any extreme weather conditions.

AUM was compared with the conventional imported ambient air quality monitoring stations and found to be far superior in characteristics.

The indigenously designed and developed system, called as AUM (Air Unique-quality Monitoring) is extremely economical compared to the conventional standard reference stations, thus making it ideal for large scale deployment to effectively monitoring the hitherto eluded spatio temporal variations of ambient air quality.

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Prof. Tatavarti has more than 192 peer reviewed scientific and research publications and 8 international and national patents to his credit and is a distinguished member of SITARA, Fellow of Optical Society of India, Fellow of Andhra Pradesh Academy of Sciences.

I. Impetus

Higher levels of air pollution are a pernicious global problem affecting not only the densely populated countries, but also, countries with sparse populations, as well as regions like Arctic and Antarctica where no population exists. That global pollution is associated with atmospheric and oceanic dynamics and the resulting climate change, with a feedback loop is now accepted and understood. Air quality monitoring therefore involves the systematic collection of physical, chemical, biological, and related data pertaining to ambient air quality, pollution sources, meteorological parameters, and other factors that influence, or are influenced by ambient air quality.

Air pollution may result in huge impacts, causing different effects on human health, on the environment (*e.g.,* ecosystem damage) and on the economy of industrialized and developing countries [1, 2]. For these reasons, air quality monitoring is typically required by national and international regulations to systematically and accurately assess the environmental exposure of the general population to multiple environmental contaminants [3].

Recent research published in April 2020 by researchers of Harvard University USA; made a startling suggestion that even an increase of $1\mu g/m^3$ level of $PM_{2.5}$ could lead to a 15% increase in fatality rates due to COVID -19 infections [4]. The Harvard University study amply demonstrates and underlines the urgent necessity and paramount importance of *effective* ambient air quality monitoring, as air quality *or rather the lack of it,* directly affects the nations' health, economy and security.

It is imperative therefore, to protect the air we breathe by taking actions to ensure its best possible

quality. Measures to ensure good air quality demand accurate and cost effective air quality monitoring.

II. Complexities and Challenges

From a historical perspective, it is imperative to realize that the United States Environmental Protection Agency (US EPA) was one of the first regulatory bodies to worry about air quality and pollution. Starting with the Clean Air Act of 1955 the US EPA has come up with Standards for Measurements (National Ambient Air Quality Measurement Standards – NAAQMS) in 1970 [5, 6], which were followed by the regulatory bodies of other developed and developing countries in Europe (European Union Standards)[7], Australia, Japan [8, 9, 10],World Health Organization, WHO [11, 12] and Asia. India followed suit in 2009 publishing its own standards, by and large culled from the NAAQMS of USEPA and the WHO guidelines [13].

With the advent of new technologies and a better understanding of the Science behind air quality monitoring, US EPA researchers published an important study [14] in the reputed and peer reviewed American Chemical Society Journal in 2013.The study pointed out a number of issues and challenges faced by the existing air quality monitoring methods, the standards practised and concluded that the monitoring methods and practices have seriously jeopardized the quality and sanctity of air quality data.

Subsequently, many scientists and researchers all over the world also concluded that a paradigm shift in air quality monitoring methods and standards is essential by adopting new and emerging technologies. However, neither the regulatory bodies, nor, the industry paid any attention to the growing concerns on the quality of air monitoring systems worldwide.

In 2018, the internationally reputed, peer reviewed Scientific American Journal published startling revelations made by the Centre for Public Integrity in USA, that, for decades the USEPA was complicit in wantonly and systematically under reporting the levels of pollution, taking the general public for a ride. The study pointed out that the hazardous emissions by industries were much larger than reported and documented [15].

This shocked the world's scientific fraternity and all other stakeholders who realized, rather late, that the situations were similar in their respective countries. Consequently, there was a vociferous demand for a paradigm shift in the policies and attitudes of an otherwise complacent and complicit regulatory authorities for air quality / pollution monitoring.

Following the hue and cry, it is now widely accepted worldwide that proper ambient air quality assessment cannot be accomplished, without addressing the following pertinent questions:

1. What are the limitations of current measurements, monitoring techniques and the standards currently being employed across the world?
2. Do the methods of measurements involving synthetic chemicals, themselves result in pollution of air, water and soil?
3. As the objectives determine the degree of accuracy, sensitivity, method of monitoring and the sampling mechanism – in situ or in-vivo sampling, what are the stated assumptions and objectives of the air quality monitoring?
4. What is the area for which measurements are representative and reliable?
5. What is the proper mix and location of fixed stations, moveable stations, airborne stations, and what is the role of modelling in achieving the objectives?
6. What level or degree of errors are acceptable?
7. What is the importance of exposure monitoring as related to the pollutants that are air oriented or to those that occur in other media including the food chain?
8. What related collocated meteorological data must be collected with air quality data?
9. What is the importance of sample averaging times to the design of monitoring stations and the inferences on air pollution?
10. What are the effects of physical and chemical transformations at the sampling locations and network design for example, for monitoring ozone or sulphates?
11. What quality assurance programs are necessary to assure that data are representative and legally and scientifically defensible?
12. What measures need to be taken for including public participation to ensure non-obfuscation and integrity of data?

Based on the knowledge and insights gained over many decades, the world over, air quality monitoring is now expected to involve a rigorous, systematic and complex approach based on the stated objectives and therefore, should necessarily adopt newer knowledge and innovative technologies after due scientific and technical diligence[16].

III. Measurement of Air Quality with Low Cost Sensors

Of late, low-cost air pollution sensors are attracting more and more attention. They offer air pollution monitoring at a lower cost than conventional methods, in theory making air pollution monitoring possible in many more locations. However, at the current stage of development, measurements with low-cost sensors (Electro-Chemical Sensors, Photo Ionization Detectors Optical Particle Counters, Optical Detectors) are often of lower and more questionable data quality than the results from official monitoring stations carried out by pollution monitoring bodies in accordance with international standards and methods [17]. If the quality of the measurements can be improved, low cost solid state sensors could become a

game changer in monitoring air pollution, traffic management, personal exposure and health assessment, citizen science and air pollution assessment in developing countries. But unfortunately there are many intrinsic constraints and limitations associated with the existing low cost solid state sensors. Studies have demonstrated that the signals from sensors not only depend on the air pollutant of interest, but also on a combination of several effects, such as other interfering compounds, temperature, humidity, pressure and signal drift (instability of signal). At high concentrations the signal from the air pollutant can be strong, but at ambient air levels the signal is weaker in comparison to the interfering effects and therefore the utility of the low cost solid state sensors would be severely limited for any real world application unless there is a paradigm improvement in the structure and sensing mechanisms of the sensors *per se*.

IV. Status in India

Interestingly in India, notwithstanding the knowledge regarding the limitations of measurements at fixed locations, and the paradigm shift suggested in the approaches to ambient air quality monitoring methods worldwide, CPCB India and the State Pollution Control Boards, are still refusing to see the woods for the trees by pigheadedly insisting on the questionable measurement methods and standards for the instrumentation -in spite of their two revised guidelines in 2013 and 2018 [18, 19].

Table 1: National Ambient Air Quality Monitoring: *Existing Standards, Guidelines, Methods, and their Drawbacks*

S. No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement	Drawbacks
			Industrial, , Residential, Rural and Other Areas	Ecologically Sensitive Area(*Notified by Central Government*)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Sulphur Dioxide (SO_2), $\mu g/m^3$	Annual* 24 hours**	50 80	20 80	Improved West and Geake Method	Interference of oxides of nitrogen and ozone are well documented — concentrations of interfering oxidants should be less than that of SO_2, i.e., up to about 2 ppm.
					Ultraviolet Fluorescence	This technique is very sensitive but other gaseous components are known to interfere. Quenching (e.g. by O_2 or H_2O) of the excited species can lead to an underestimation of the SO_2 concentration. Positive interference occurs by molecules which absorb radiation and fluoresce in the same region than SO_2 (e.g. NO and HC) [3]. In exhaust gases, nitric oxide (NO) is usually the main positive interferences, while oxygen is the most important quenching species if water vapor is removed by a Nafion dryer. Filters and selective traps are often used to remove interfering gases. Scrubbers for H_2S gases are needed if it is present in high concentrations. Correction for temperature and pressure is made and calibration is made against some primary standard (guidelines).
2	Nitrogen Dioxide (NO_2), $\mu g/m^3$	Annual* 24 hours**	40 80	30 80	Modified Jacob & Hochheiser ($NaAsO_2$) -	This method involves the use of Sodium Arsenite, Nitric oxide (NO), Carbon Dioxide ($C0_2$) and Sulphur Dioxide (SO_2) interfere in the testing.
					Chemiluminescence	Requires elaborate instrumentation and use of various chemicals. Interference from other pollutants like non NO_x reactive nitrogen species like HNO_3 and ambient O_3 can pose interferences. [Ref: EJ Dunlea et al, *Atmos..Chem..Phys.*, 7, 569-604, 2007 and ibid 2691-2704].
3	Particular Matter PM_{10} $\mu g/m^3$	Annual* 24 hours**	60 100	60 100	Gravimetric	Manual intervention is required and may lead to personal errors.
					TOEM	Mechanical noise and dramatic temperature fluctuations can interfere with the operation of a TEOM device [1,2]. In addition, water droplets cannot be distinguished from particle mass, so the device must adjust the incoming air temperature to cause water droplets to evaporate, [3] or contain a dryer or humidity sensor to adjust the readings [4]. Under ideal conditions, TEOM is
						just as accurate as the standard reference method, but its sensitivity presents complications for use for environmental monitoring in urban areas. Ref: [1] (WIKIPEDIA, "Tapered element oscillating microbalance". Queensland Department of Environment and Heritage Protection. 2017-03-27. Retrieved 2017-06-28.

						[2] Gilliam, Joseph H.; Hall, Eric S. (2016-07-13). "Reference and Equivalent Methods Used to Measure National Ambient Air Quality Standards (NAAQS) Criteria Air Pollutants – Volume I". U.S. Environmental Protection Agency. pp. 10, 24, 32. Retrieved 2017-06-28. [3]"Machine-Mounted Continuous Respirable Dust Monitor". NIOSH Technology News. U.S. National Institute for Occupational Safety and Health. July 1997. Retrieved 2017-06-28. [4] Ray, Alison E.; Vaughn, David L. (2009-09-01). "Standard Operating Procedure for the Continuous Measurement of Particulate Matter" (PDF). U.S. Environmental Protection Agency. pp. 1–1, 3-1–3-2, 6-1–6-2. Retrieved 2017-06-28.)
					Beta Attenuation	The measurement of both sizes of particles is not simultaneous (guidelines) To discriminate between particle of different sizes (e. g., between PM_{10} and $PM_{2.5}$), some preliminary separation could be accomplished, for example, by specially designed inertial particle size separators like cyclones or impactors. Drawbacks: (from Thermo- Fischer website, *https://www.thermofisher.com/in/en/home/industrial/environmental/environmental-learning-center/air-quality-analysis-information/beta-attenuation-technology-particulate-matter-measurement.html#:~:text=From%20the%20above%20description%20of,radioactive%20source%20also%20limits%20acceptance*.) The primary drawback is that it is a non-continuous monitoring technology. Typically, only 4 PM readings per hour can be collected. The technology is also fairly expensive limiting its market acceptance. Its radioactive source also limits acceptance.
4	Particulate Matter $PM_{2.5}$ $\mu g/m^3$	Annual* 24 hours**	40 60	40 60	Gravimetric/ TOEM/ Beta- Attenuation	See above
5	Ozone(O_3) $\mu g/m^3$	8 hours** 1 hour**	100 180	100 180	UV Photometric	Require chemical reagents which themselves are pollutants
					Chemiluminescence	Presence of water vapor causes errors.
					Chemical Method	If done manually, there is always a scope for personal errors. Need chemicals as reagents which in turn are pollutants.
6	Lead (Pb) $\mu g/m^3$	Annual* 24 hours**	0.50 1.0	0.50 1.0	AAS / ICP method after sampling on EPM 2000 or equivalent filter paper	Use of argon gas is required to generate plasma. Both maintenance and purchase costs are high. Permissible limits have recently been reduced worldwide, which fall below the detection limits of the ICP AAS. ICP-MS is the preferred instrument now but it is too expensive [Ref: M. Harrington *et al*, Environmental Science: Processes and Impacts 16(2) December 2013, DOI: 10.1039/c3em00486d]
					ED-XRF using Teflon filter	Expensive instrumentation. LEAD standards are used.
7	Carbon Monoxide (CO) mg/ m^3	8 hours** 1 hour**	02 04	02 04	Non Dispersive Infra-Red (NDIR) Spectroscopy	Can be affected by humidity and temperature. Accuracy declines at high concentrations of CO Ref: Trieu-Vuong Dinh *et al*, sensors and actuators B: Chemical, Vol 243, May 2017, 684-689. Standard CO gas needs to be stocked up (Guidelines). Any leak in the gas cylinders can have hazardous consequences.
8	Ammonia (NH_3) $\mu g/m^3$	Annual* 24 hours**	100 400	100 400	Chemiluminescence Indophenol blue method	Requires bubbling of the air through sulphuric acid prior to the analysis. Involves the use of chemical reagents like phenol Need of expensive catalytic molybdenum converters (Guidelines) Operated at high temperatures 950-1000° C, (Guidelines) Filters are used to remove particulate matter. Any gases adsorbed on the particulate matter may be removed during the process Converter efficiency may be gradually lost and correctionsareto be applied during the calculations. The instrument needs to be operated in an environmentally controlled AC room (where temperature and humidity are controlled).

In short, temperature, pressure, humidity, flow and vibration controls are required to be stringently set up at continuous ambient air quality monitoring stations, for effective functioning of the various equipment at a station. The role of interference caused by additives during the tests and the role of scrubbers employed during testing is still ambiguous. In summary, the existing methods of measurements practiced for ambient air quality monitoring are far from sacrosanct and are not problem free, having significant biases, limitations and drawbacks which remain to be addressed.

Against this backdropa group of researchers from academia and industry undertookan elaborate and exhaustive research, during the first half of 2020 to study the status of current ambient air quality monitoring across India. Utilizing data from 233 Continuous Ambient Air Quality Monitoring Stations (CAAQMS) in India, during a period of 180 days from January 1, 2020 to June 30, 2020, highlighted the following issues and limitations which have serious implications to the validity, efficacy and sanctity of air quality/pollution monitoring [20]:

1. The air quality monitoring instrumentation presently being used are characterized by high costs, and a high level of maintenance.
2. The air quality monitoring stations provide representative data only for a very restricted area in space. This is a disadvantage because measurements at adequate spatial scales are essential for monitoring air pollution in heterogeneous environments such as those naturally found in the atmosphere [21].
3. To a large extent the air monitoring stations were sited at locations where sources of pollution were far away.
4. All air quality monitoring stations use a suction mechanism to pump air from a higher elevation and route the air through conduits to different sensors located below in an environmentally controlled container, making the measurements in vivo but not in situ.
5. The problems associated with in-vivo sampling vis-à-vis the preferred in situ sampling are well documented in scientific and technical literature. Most of the standards of in vivo sampling and measurements pertaining to various standalone sensors for pollutant monitoring have significant limitations.
6. The air samples for monitoring are taken from a location well above the height at which the general public live and breathe. The complex natural diffusion processes affecting the fluid flow patterns and the atmospheric stratification effects in the vertical direction raise serious questions regarding the validity of air quality monitoring at elevations well above the domain of human existence and relating the same data to health effects of the population. The role and degree of plausible contamination of the sampled air being routed through conduits before reaching the particular sensors for measurement are well studied and documented in scientific literature, pointing out uncertainties and undocumented errors associated with in vivo sampling techniques of the current air monitoring stations.
7. The non-uniform standards practised by various equipment suppliers across the stations, make Inter comparisons of degrees of pollution very difficult across the different stations.
8. Out of all the CAAQMS, during the study period of six-months, more than 90% of the stations reported missing data (*perhaps*, *due to non-functional sensors*) for periods longer than three to five days continuously.
9. All the stations were not monitoring all the required parameters responsible for computing the air quality index of a location.
10. In bigger cities like New Delhi where more monitoring stations are located, the spatio-temporal variations in air quality are markedly significant.
11. It would therefore be very difficult to determine the spatio-temporal variations in air quality, given the sparse sampling and the fixed nature of the CAAQMS locations across India.
12. Effects of strong and powerful natural events, like Cyclone *Amphan* crossing over land near Kolkata, West Bengal on the East Coast of India (May 21, 2020); and Cyclone *Nisarg* crossing over land near Konkan Coast, Maharashtra on the West Coast of India (June 3, 2020), were not even recorded by the CAAQMS located in the respective regions.
13. Air quality effects of the major industrial accidents (like in Visakhapatnam, Andhra Pradeshon May 7, 2020 when Styrene Gas leaked with its effects spreading to large spatial extent of a 10 km radius) were not even recorded by the Visakhapatnam CAAQMS station.
14. The effects of multiphase chemistry, need to be considered in pollution monitoring using passive sampling techniques [22].
15. Most of the stations indicated that all the monitored parameters were either in the *Good* or in *Satisfactory* category of the CPCB India Standards, while factual ground observations, indicated poor air quality.

The exhaustive study [20] covering the entire geographical region of India over a statistically long period, thus raised disturbing and disconcerting questions on the *validity, efficacy and sanctity* of the current monitoring stations, in spite of their *apparently satisfactory* standards and certifications endorsed by concerned authorities.

The study has also showcased that air quality monitoring resulted in less than appropriate and adequate data, has not been cost effective, and in certain instances has resulted in implementation of costly programs which provided questionable benefits.

With the current air quality measurements getting embroiled in many serious issues and challenges, and threatening to jeopardize the primary objective of the Clean Air Initiatives of the Central Government of India as well as of the many States of India, a strong wakeup call to all the slumbering stakeholders and authorities would therefore be timely and necessary.

Hence it would be apt to summarize that given the limitations in measurements, coupled with the complexities of tropical atmospheric and oceanic dynamics associated with the Indian sub-continent, the current air quality monitoring methods, mechanisms and management needs a thorough overhaul.

V. Accurate, Cost Effective Solutions

It is high time that the concerned stakeholders realize that the solution to the air quality monitoring imbroglio lies in looking at newer and better sensors and technologies. The ability to assess ambient air quality depends heavily on the availability and applicability of appropriate sensors. Until recently, most pollutant sensors capable of providing quantitative information were of the type, where the air to be monitored should be brought to the sensor. Such sensors are restricted to measurement of a parameter at a single point in space, or, when mounted on a mobile platform, at sequential points as a function of time, but cannot be labelled as in-situ sensors.

Moreover, because of the difficulty of relating a point in space remote from the sensor to sensor data, great care must be taken in selecting the site for the sensor, and in drawing meaningful inferences thereafter.

Maximum use of new concepts and methodologies as they become available, therefore is essential. Such concepts as integrated monitoring systems, new optimization techniques and state-of-the-art measurement devices, such as those employing remote sensing techniques, are becoming operational in the sense of being available for testing and application.

Needless to say that ignoring to use them to their fullest capabilities will result in a loss of the opportunity to develop rational environmental assessment tools [21]. As new devices become available, they should be incorporated into operational monitoring systems. There is no doubt of the ever increasing importance of remote sensing for air quality monitoring programs. These techniques can not only replace contact monitors but also will augment and improve monitoring methodology.

As newer techniques and hardware become more available and enhance our ability to monitor our environment, we will be faced with the question of, what is the most cost-effective combination of fixed, mobile contact and remote sensors for a specific monitoring problem? Hence new systems and technologies capable of spatio-temporal monitoring with high sampling frequencies, capable of large spatial areas of coverage would be advantageous and cost effective.

Another area where advances are yet to come is in the development of monitoring methods for assessing exposure-dose relationships. In the past, environmental monitoring has been carried out in response to an already existing hazardous condition. Future monitoring systems must be able to detect potential problems and monitor the appropriate parameters before they reach crisis proportions.

Some possibilities which might be explored are the use of biological exposure indicators as trend monitors to predict changes, and the development of personal exposure meters, such as biochemical measurements which integrate the total exposure of an individual to a pollutant or class of pollutants. When we achieve accurate, valid and broadly applied exposure monitoring, we then shall have made a major step toward achieving the ability to truly and rationally evaluate the management of our air resources.

In summary, air quality management requires an understanding of the type of air pollutants being emitted by various sources from on road vehicles, large industrial facilities, power plants and smaller sources such as residential heating and asphalt paving. The development of emissions inventories is critical for the states to implement accurate and effective air pollution control strategies [23].

These challenges can therefore only be met by portable, light weight sensors and systems which are capable of *accurately* monitoring all pollutants in-situ from remote location, in real time. Sensors with capabilities for simultaneous spatio-temporal monitoring, with high sampling rates would certainly be a boon in our crusade for accurate and cost effective ambient air quality monitoring.

VI. Ambient Air Quality Monitoring– II: Indigenous Photonic System AUM

a) *Indigenous Photonic System for Real Time, Remote Air Quality Monitoring - AUM*

With the current systems and technologies used for air quality monitoring *having serious constraints, in addition to being prohibitively expensive for wider deployment* - the impetus for an indigenous development of a system for real time remote monitoring of all air quality parameters becomes crucial for India not only in achieving self-reliance in high end

technologies, but also in aiding the nation's health and economy.

Against this backdrop Prof. Rao Tatavarti of Gayatri Vidya Parishad, designed and developed a novel innovative photonic system capable of real time remote monitoring of various air parameters simultaneously, to arrive at the in-situ air quality at a particular location or as a spatial profile with high sensitivity and accuracies by adopting COTS (commercially-off-the-shelf) technologies, thus making them significantly cheaper for wider deployment.

An indigenous photonic system, for real time remote monitoring of all air quality parameters was designed and developed, with the sponsorship by DST, Govt. of India under the Clean Air Research Initiative, and M/S CATS Ecosystems Pvt Ltd, Nashik which is the technology transfer partner for commercialization. The indigenous development is christened as AUM (Air Unique-quality Monitoring) system.

b) AUM - System for Real Time, Remote, In-Situ Monitoring of Air Quality

AUM photonic system has a modular design with interchangeable components and modules from any other system. The photonic system AUM comprises of the following subsystems:

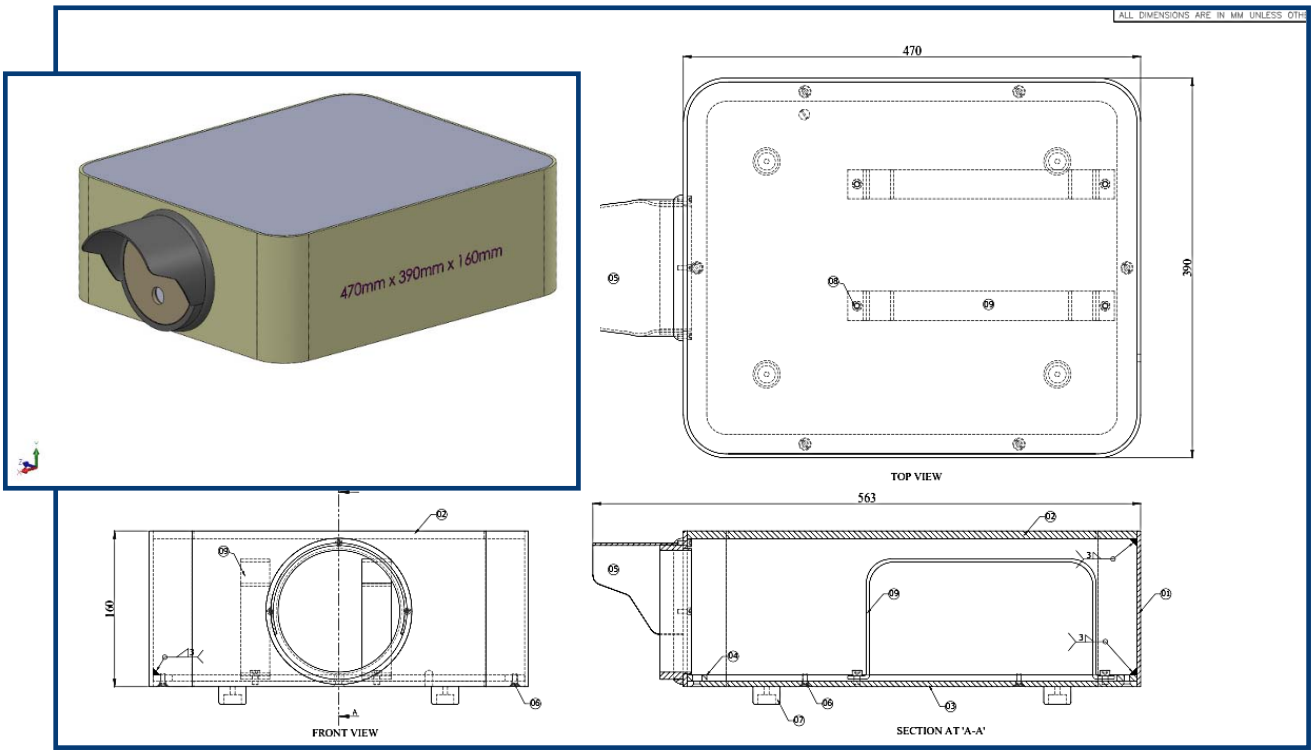
- Photonic System Source – Laser (<10 *milliwat*t, Wavelength 250-850*nm*, <2*mm* circular diameter beam, TEM_{00} Irradiance).
- Photonic System Detector: Position Sensing Photo Detector (low SNR, 20mm × 20mm, Si-Duo Lateral Position Sensing Diode, with submicron (0.01*μm*)/ nanometre (10*nm)* resolution.
- Optical Filter *(transmission at a narrow pass bandwidth ±10nm, centred as per selected source)*
- Optoelectronic Amplifier
- Signal Conditioning Unit
- Signal Processing Unit
- Multilayer PCBs- *(for protection from EMI/EMC, appropriate power electronics, signal conditioning and signal processing)*
- Mechanical Encapsulation Cabinet - *(for housing the photonic system and providing protection from the vagaries of weather, environment and rain).*
- Junction Box *(for housing the integrated electronics, communications interfaces, multilayer PCBs)*.
- Power Source *(rechargeable DC power source, 19V, 7.1 amps)*.
- Wired Communication Unit *(for multichannel lossless transmission of signal data to connected server)*
- Wireless Communication Unit *(for multichannel lossless transmission of signal data to remote server, real time).*

The uniqueness and novelty of AUM (*patent pending*), lies in an innovative application of the principles of laser back scattering, statistical mechanics, optoelectronics, artificial intelligence, machine/deep learning, and Internet of Things - resulting in a unique system capable of identification, classification and quantification of various pollutants *simultaneously* (of accuracies of less than one ppb) and meteorological parameters, with very high precision, sensitivity and accuracy.

AUM is a unique photonic system capable of non-intrusive monitoring in real time of all the air quality parameters of interest at one go, with very high sampling frequencies. AUM has the additional unique capability of enabling spatial profile sampling information in addition to temporal sampling. The system has embedded intelligent algorithms and software operating on a user selectable remote server with data encryption, which ensures data security as well as free flow of desired information to authorized users as per specific requirements.

AUM system comes in two configurations – *standard* and *ruggedized*. Each configuration has again two options for data communication – *wired* or *wireless*. The physical characteristics of each configuration are designed differently enabling them to withstand either normal environmental loads (*standard configuration*), or extreme environmental loads (*ruggedized configuration*).

AUM – Standard System for Field Deployment $(120mm\ X\ 180mm)$



AUM – Integrated Ruggedized System for Field Deployment $(563mm\ X\ 390mm\ X\ 160mm)$

For the ruggedized configuration, additional optical coatings and appendages for AUM photonic system to be supplied to take care of operations during extreme weather conditions (temperatures ranging from $+70^0$C to -25^0C, relative humidity ranging from 0 to 100%, and wind loads up to 250kmph).

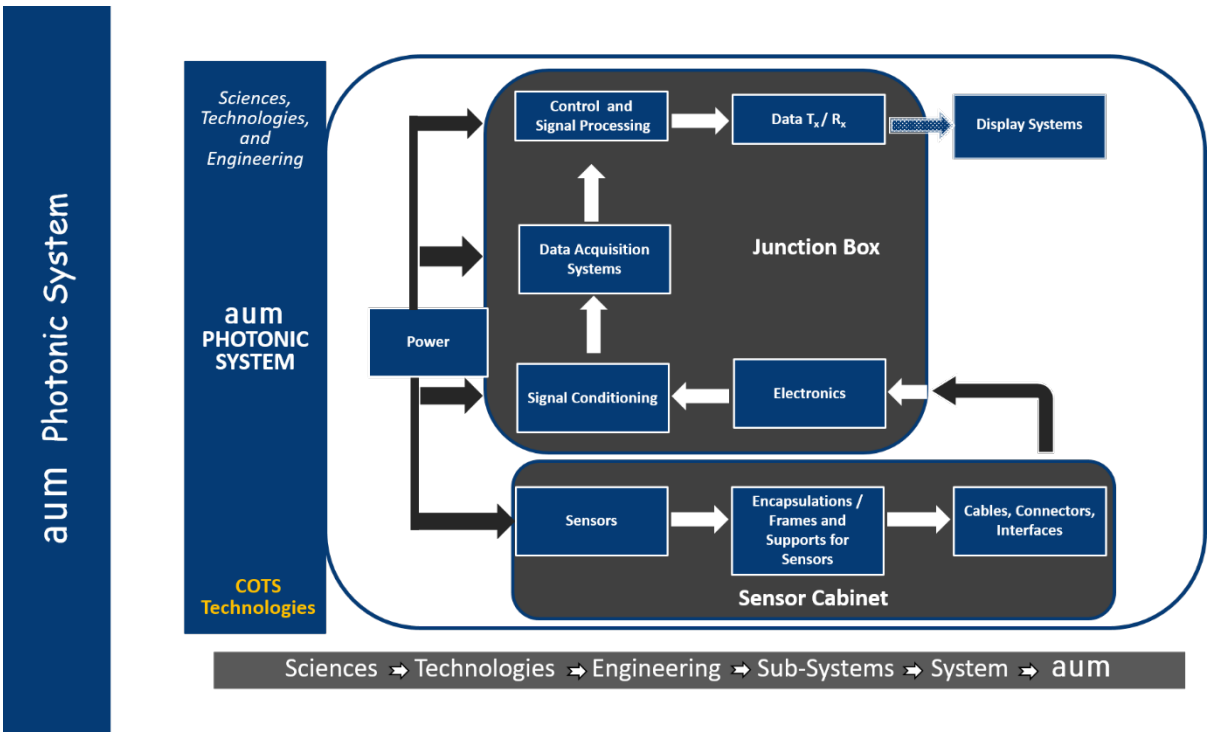
Each of these configurations have two options for data communications – a *wired* option or a *wireless* option enabling different sampling frequencies of data from system as per user requirements. All other technical details of the system are the same in both configurations. The accuracy and resolutions of the outputs are also the same for both the configurations and the data communication options.

AUM is integrated with proprietary software that can be deployed on local or cloud server. The software is developed on Apache Cassandra platform so that it can handle terra bytes of data. AUM equipment is

robust and can functions day and night in harsh environment conditions. AUM is Wi-Fi enabled and can seamlessly connect to any Wi-Fi network protocols. The equipment is also supported with battery backup for 4 hours so as to provide uninterrupted operations even during power failure.

AUM comes packed in an unbreakable, watertight, airtight, dustproof, chemical resistant and corrosion-proof hard case. The external case is made of ultra-high-impact structural copolymer that makes it extremely strong and durable. The external case lid has a neoprene O-ring to ensure water proof and dust proof environment during transportation, and easy to open, double-throw latches that seal perfectly. It has a built-in automatic pressure equalization valve for changes in altitude or temperature. The case uses stainless steel hardware and has padlock protectors to provide added strength and extra security against cutting and theft. It can be carried by three comfortable rubbers over the moulded haul handles, a retractable handle and built-in wheels.

c) *AUM - Photonic System - Sensor Structures, Modules, Mechanisms*



d) *AUM - Sampling Protocol*

AUM System has two configurations, defined by the data communication protocols (Wired and Wireless) from system to the server. AUM has an active sampling, real time remote detection capability. The sampling frequency for the wired version is 1 -10*kHz*, while for the wireless version the sampling frequency is ~150-200*Hz.*

e) *AUM - Calibrations Procedure and Protocol*

Specially designed and developed, portable, light weight Calibration Setup/Facility enables easy calibrations with standard gases, mixtures, at varying ambient environmental conditions of air temperature, air pressure, and relative humidity). The AUM's laser beam would be focussed into the environmentally controllable air chamber and calibrations completed for different standard gases under widely varying ambient air temperatures, pressures, humidity enabling effective calibrations of all pollutants. The standard gases are to obtained from ISO 17025 certified sources. The temperature/humidity/ flow sensors to be used are to meet International Standard specifications with higher accuracies and sensitivities. Once AUM photonic system is calibrated, then routine or periodic calibration is not required.

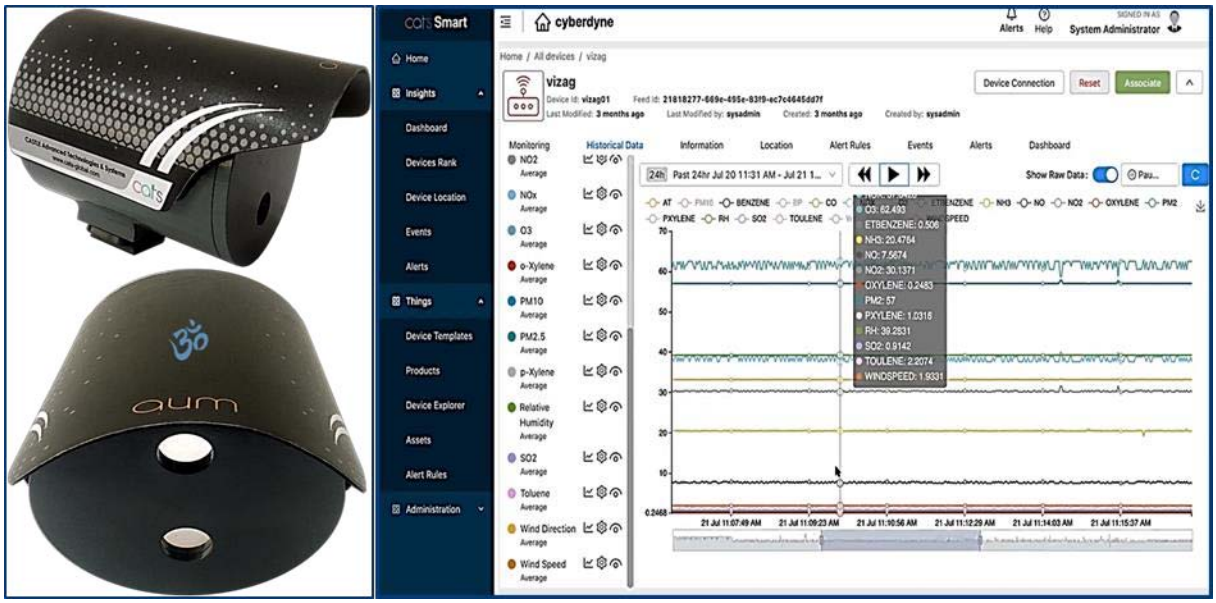
f) *AUM - Laboratory and Field Evaluations*

AUM was successfully evaluated during laboratory trials in a sub-sonic wind tunnel, in the laboratory with gold standards (in collaboration with Effect Tech, UK an ISO 17025 2000 International Standard Accredited Laboratory), and also compared in the field with the imported systems from Environment SA, France and Eco Tech, Australia operated by Karnataka State Pollution Control Board's Central Environmental Laboratory with ISO 17025-2005 & NABL Accreditation; under the aegis of the Central Pollution Control Board of India.

AUM was demonstrated to be very highly sensitive and accurate and capable of simultaneous

detection and quantification of all air quality parameters and offers a number of merits over any of the currently available conventional systems, having the following features and characteristics:

- *Portable, compact, low powered and economical*.
- *Plug and play* system, requires no setting up time and no additional civil infrastructure for housing.
- Provides information on all gases, and meteorological parameters simultaneously.
- *Non-intrusive, remote, in-situ, real time monitoring system with very high sensitivities and accuracies.*
- *Single system capable of monitoring in both spatial and temporal domains, with high sampling rates*.
- Data from sensors seamlessly streamed to a cloud server, from where encrypted real time dash board information is pushed to authorized users.
- System can work continuously, even under extreme weather and climatic conditions
- Embedded intelligent monitoring algorithms to identify and alert impending system failures to enable preventive maintenance.
- Spatial sampling as per user requirements, dictated by unhindered line of sight conditions in the field.



Side and Front Views (top and bottom Left) of AUM System (180 X 220mm), and typical Real Time Dashboard Information (Right)

AUM System has two configurations, defined by the data communication protocols (wired and wireless) from system to the server. AUM has an active sampling, real time remote detection capability. The sampling frequency for the wired version is 1 -10*kHz*, while for the wireless version the sampling frequency is 150-200*Hz.*

AUM photonic system has built in intelligent monitoring system which is capable of performing real time diagnostics. The photonic system has an *optical filter* which is embedded in the system and is part of the hardware.

AUM operates on principle of backscatter of light and there are no moving components inside the system. Faults occur only if one of the components malfunctions. The only component which requires replacement is the laser source, in the AUM Photonic System. The embedded intelligent alert monitoring system would flag a degrading laser source well in advance so that replacement of the same can be planned at least a week in advance. The replacement can be accomplished by a technician/engineer having basic tools within a span of one hour. Replacement of components is easy and simple. The information related to malfunctioning will be alerted and an alarm raised by the intelligent alert monitoring system so that appropriate action can be taken to ensure smooth functioning.

AUM is integrated with proprietary software that can be deployed on local server or laptop. The software is developed on Apache Cassandra platform so that it can handle terra bytes of data. AUM equipment is robust and can functions day and night in harsh environment conditions. AUM is Wi-Fi enabled and can seamlessly connect to any Wi-Fi network protocols. The equipment can also be supported with battery backup for durations specified by user, so as to provide uninterrupted operations even during power failure.

g) AUM - Spatial Profile Monitoring Capabilities

The genesis for AUM technologies lies in the earlier development of photonic system taraNi(Technology for Air-data Reckoning for Aerial Navigational Information) for effectively monitoring

molecular air data products from on-board a fast moving aircraft, supported by Aeronautical Defence Agency (ADA), Ministry of Defence, Government of India. The spatial profiling technology subsystem is an add on feature to the ruggedized version of AUM and facilitates sampling of air quality parameters at varying ranges from system (from less than 10m distance to more than 1 km distance) at sampling intervals of every 1 *minute*. The AUM photonic system version with spatial profiling capabilities is being commercialized under the brand name SAMIRA – Seeing Air in Motion Instrumentation for Remote Sensing Applications - an indigenous system capable of monitoring all air quality parameters and environmental parameters at different ranges (distances) from the system simultaneously. The system was extensively tested in wind tunnels, laboratories and in the field and compared to some of the commercially available systems. Real time, remote monitoring of the spatial profiles of environmental parameters were successfully demonstrated at Kayathar, Tamil Nadu in association with National Institute of Wind Energy (NIWE), Ministry of New and Renewable Energy, Government of India at the Nippon Group (Japan)'s Net Magic Data Centre at Bombay Stock Exchange, Mumbai. Please see Certificates and Testimonials attached from NIWE, Government of India and Net Magic, India.

AUM: Universal Calibration Facility - Indigenous Design and Development

A specially designed and developed AUM universal calibration facility, ensures that after a one-time calibration the AUM photonic system can be deployed anywhere in the world capable of monitoring pertinent gases and environmental parameters.

Aum Photonic System Vis-À-Vis Conventional Ambient Air Quality Monitoring Systems

CHARACTERISTICS	AUM - PHOTONIC SYSTEM	CONVENTIONAL MONITORING SYSTEMS (#EcoTech, Australia; #Environment SA, France; #Thermo-Fischer, USA, etc.)
SYSTEM	1. Single active system focusses a laser beam at the target location and detects the backscattered laser radiation from the target volume of air (location) to qualitatively and quantitatively identify various parameters at the target location which are responsible for back scattered radiation characteristics. 2. Information on specificity and selectivity of pollutants is very high and uniform. 3. Single photonic system capable of monitoring of all air quality (gases, VOCs, PM) parameters and meteorological parameters (temperature, pressure, density, wind speed and wind direction). 4. **Real time**, **remote**, **non-contact**, **in-situ** monitoring as the probing laser beam is focussed at the target location (volume of air) to be monitored. (Eulerian measurement). 5. As the laser beam can be focussed to and fro to different ranges from a single system, spatio – temporal profiling using a single system is possible facilitating spatial profiling over the entire range band (Lagrangian measurement), with a single system at high sampling frequencies of data acquisition at different ranges. 6. Single photonic system can make **Eulerian as well as Lagrangian measurements at high sampling frequencies at locations.** 7. High sampling frequencies of sensing, **150-200 Hz.** 8. **Portable system, light weight**. Even ruggedized version is <10kg in weight. 9. No additional environmentally controlled housing required. 10. No additional infrastructure required. 11. **Occupies only $0.1\ m^3$space.** 12. Low power requirements. 13. **Low capital cost, minimal maintenance, highly economical**. 14. **Low life cycle cost**. 15. **One-time calibration only.System has one calibration protocol**. 16. **Plug and play system, for immediate use, no setting up time required.** 17. No learning curve involved for users. 18. High frequency real time encrypted data, directly streamed to a cloud server. 19. Algorithms and **big data analyticspost relevant digestible information to authorized users in real time, anywhere in the world.** 20. Predictive analytics package in **real time for forecasting of pollution information** for public awareness. 21. **Indigenous system, no constraints in technology transfer**.	1. The AAS, NDIR, Chemiluminescence, UV Photometry, Beta Attenuation, TEOS, Gravimetric, ICP-MS, GC systems are a combination of analytical equipment, electrochemical, electro thermal and optical sensors and analyzers which are connected respectively to data recording device. The suite of sensors, each monitoring a particular parameter employing separate sensing mechanism. Each sensor therefore has varying characteristics, sensitivities, limitations and accuracies. 2. Information on specificity and selectivity of pollutants is sensor specific and variable in a particular station. 3. Multiple sensors and analyzers are sourced from different manufacturers and therefore integration of the same by the third party integrator poses limitations and challenges, in terms of time responses, sampling rates, calibrations, maintenance and error resolution. 4. Volume of air to be monitored is sucked from outside and passed through conduits to different sensors for measurements, hence measurements are not remote, and **not in-situ, butin-vivo**. Flow rate, temperature and humidity variations of sucked air samples routed through conduits affect measurements and introduce errors in measurements. **The in-vivo measurements pose limitations and challenges.** 5. Only one measurement pertaining to the air sample sucked in. 6. **Spatial profiling information not possible**. 7. Low sampling frequencies of data**, <0.0.1Hz.** 8. **Bulky and heavy establishment of infrastructure**. Weighs > 1000kg. 9. **Separate robust housing and environmental control required**. 10. **Additional infrastructure required to house the sensors/analyzers**. 11. **Occupies > 220m^3 of space**. 12. **Higher power requirements**. 13. **Very high capital costs and high maintenance costs.** 14. **Frequent calibrations required. Each sensor needs different calibration procedures and protocols.** 15. **Protocols to be initiated and maintained before usage.** 16. **Setting up time of 2 to 3 weeks required.** 17. Users need apriori training for usage, upkeep and maintenance. 18. Data acquired on a connected system is posted to local server through Wi-Fi, where data cleaning, **post processing are done by intervention, and information posted to users at the end of day.** 19. **No big data analytics, information need to be accessed from server.** 20. **No predictive analytics in real time, no forecasting possible**. Only hindcasting. 21. **Imported systems, no technology transfer**.

CHARACTERISTICS	AUM - PHOTONIC SYSTEM	CONVENTIONAL MONITORING SYSTEMS (#EcoTech, Australia; #Environment SA, France; #Thermo-Fischer, USA, etc.)
ACCURACY AND SENSITIVITY	1. Temporal response of system is $<10ns$. 2. Spatial resolution of detector is $< 100nm$. 3. Higher orders of accuracy and sensitivity, capable of monitoring different gases even at very small concentration levels ($< 1ppb$) and meteorological parameters at <0.1 SI units respectively. 4. Detectability range for all parameters is large (3 to 4 orders of magnitude). 5. Photonic system generally has about three to four orders of magnitude higher sensitivity compared to most conventional systems.	1. Changes in environment such as temperature, pressure, humidity, air turbulence, and airborne particles affect sensors. Temporal responses are therefore slow. 2. Lower temporal responses. Lower sensitivity. 3. Different detectability ranges as per individual sensors (lower detectability ranges). 4. Cross sensitivity is a common problem, especially at low concentrations of gases 5. Species interferences, leaks and contaminations are known problems.
SENSING AREA COVERAGE	1. AUM system can cover from 10mm to 1Km in range, and unit can be rotated 360^0. 2. Data of air can be collected vertically as well as horizontally at distance of every 10mm to 5km as per requirements. The laser beam travels to the targeted area / source of pollutants. 3. With few nos. of installation complete city can be monitored for pollutants and weather conditions. 4. Hence monitoring emission from giant chimney, duct, stack is done with utmost ease. The only limiting factor with respect to area of coverage, is clear line of sight. One single unit from its fixed location can cover a huge area in all 360^0 directions..	1. The polluted air is sucked/pumped in using high energy consuming suction fans. 2. The air has to pass in to the proximity of sensors. Hence area of coverage is the biggest limiting factor. 3. The fixed station (sensor) must be located near the source of gases, which becomes a severe limiting factor. 4. Pollutants, Gasses, Temperature, humidity, Air pressure etc. are measured from fixed location only.
CALIBRATIONS	1. No routine calibration required. 2. Calibrations performed with primary gases / gas mixtures of ISO 17025, ISO 17034 international standards.	1. Routine calibration required, gases and chemical are required to be stored for monthly (periodic) calibration exercise. Refilling for some pollutants monitoring is periodically required. 2. Reagents used for calibrations can themselves be pollutants/contaminants.
TEMPERATURE	1. System can operate in extreme external environments as well as indoors.	1. The system is required to be maintained in controlled environments of temperature and humidity and protected from the vagaries of external weather and dust. Hence environmentally controlled containers are mandatory.
HAZARDS	1. Safe laser having minimal battery power requirements is used. If uninterrupted source of electric power is available, then no battery is required. 2. The system is rugged and can be placed anywhere. 3. The system is designed using CFD (Fluid Simulations and Thermal Analysis) to appropriately dissipate the heat.	1. Minimum of 10kVa of UPS and battery bank is required. 2. Gases like hydrogen, carbon radio isotope (C_{14}) etc. are used by analyzers. Banks of different types of gas cylinders are required to conduct routine calibration. Hence Fire and Safety protocols are mandatory requirements. 3. The complete system has to be installed in a highly protected shelter (container). The area needs to be 100% leak proof, dust proof, environmentally controlled.
EASE OF USE	1. No human intervention. 2. No special training required to operate and maintain.	1. The systems require human intervention. Special training for all different types of analyzer are required. Hence most of the system sold are operated and maintained by respective vendor.
DELIVERY AND INSTALLATION	1. Immediate delivery of system 2. Installation is mere plug and play. 3. No learning curve required.	1. Delivery takes minimum of 90 days 2. Installation is required to be done near the source due to limiting sensing distance. Installation, testing and deploying takes at least 15 days. 3. Users require detailed training on protocols and practices.
USEFUL LIFE	1. With miniscule maintenance, and no moving parts, the useful life shall be more than that of any conventional system.	1. With consistent maintenance, the system has useful life of 10 years.
MOBILE	1. Photonic system can be used as a handheld unit, fitted on any moving vehicle or on a fixed a platform (tripod). The unit is very light in weight. Speed of vehicle is not a constraint. 2. The system can be used to monitor outdoor air as well as indoor air.	1. Pollution station is fixed in one place. Weather monitoring can be integrated with mobile. 2. Mobile unit has to be located on truck as Fixed unit. Individual analyzers are available as handheld, but cumulatively the same have to be integrated and fixed in one place.
SIZE	1. City air quality and weather monitoring system size is compact, of the order of 180mm*220mm.	1. The bulky systems are housed in containers, as big as big 40 feet $\times$ 20 feet$\times$ 20 feet.
MAINTENANCE	1. Only change of laser diode required. A single laser source is designed to operate for 10,000 hours. The unit can also have a self-cleaning mechanism. 2. Inventory required is of laser sources only and based on usage, replacement may be required once in a year.	1. Routine maintenance and cleaning required. Filters need periodic changing. 2. Calibration gases are required to be refilled. Batteries are required to be replaced every 3-5 years based on make and warranty clause.

CHARACTERISTICS	AUM - PHOTONIC SYSTEM	CONVENTIONAL MONITORING SYSTEMS (#EcoTech, Australia; #Environment SA, France; #Thermo-Fischer, USA, etc.)
DATA	1. The photonic system collects data at high sampling frequencies. Hence there is all possibility to provide data per millisecond, if required. 2. Huge data provides very accurate aggregation on per minute basis and makes real time data worthwhile.	1. These systems collect only parametric driven source data per 10 seconds. 2. Old installed systems collect data on hourly basis.
IT ENABLED	1. Big Data ready with Cloud computing. 2. Internet of Things (IoT) and Array of Things (AoT) solutions can be devised based on available data. 3. GPS in built. 4. Predictive, Preventive, Prescriptive and Geo Spatial Analytic is possible. 5. Browser based and personal mobile app available.	1. Most of the available system is based on thin client. 2. Systems are not ready for larger data platforms that can enable solutions using IoT or AoT. 3. No GPS information, fixed bulky station. 4. Absence of Big Data, geo-spatial analytics is very difficult. 5. Mobile apps are generally not provided by system integrator but by respective Govt. Department i.e. pollution control board,
REPORTING	1. The data is centralized for all environmental effects due to weather & pollution. 2. Integrated reporting of all parameters of environment can open new pathways for predicting and preventing the future hazards.	1. Environmental Data is all decentralized. 2. There is no integrated medium till date. Hence reporting is limited.
FINANCIALS		
COST	1. Photonic system Improves on total life cycle costs. In comparison to conferences of sensors with complex integration, the cost of photonic system is less than 30% to its conventional near to equivalent counterpart. 2. The maintenance cost is also very negligible.	1. The conferences of sensors as complete system are highly Capital intensive. 2. Operating and maintain costs per year are more than 30% of CAPEX.
CUSTOMISE TO PAY PER USE ONLY	1. User are open to select the pollutants from a library that they wish to monitor. 2. Some of the selected gases can be deselected and other set of gases can be selected. 3. This works on similar basis of DTH system. One can select TV broadcasting channel and pay for the usage. 4. Photonic system is also available on rental basis.	1. Such mechanism is not possible. 2. Once an analyzer is purchased, the user is fixed with the single or dual type of pollutants for life. 3. Hence huge amount of capital is blocked as multiple systems for independent pollutants are required to be installed. 4. Hence financing options are limited.
OVERALL BENEFITS	1. Low CAPEX and Low OPEX. 2. With number of systems installed across the city, Individual are provided with interactive pattern for the kind of exposure they have with environment. This can lead to break through in early prognosis and diagnosis of health issues related esp. with $PM_{2.5}$. and below.	1. Based on sampling indicators from one or two locations and determining the air quality of a city, is prone with errors. 2. High capital and high operating overheads.
APPLICATIONS		
CONTINUOUS EMISSION MONITORING SYSTEMS (CEMS)	1. CO_2, CO, H/C's, H_2S, NO_X, O_3, SO_X, and other oxidants. 2. Can identify organic particulates. 3. Volatile Organic Compounds (VOC) - such as formaldehyde, benzene, methylene chloride and per chloro ethylene	1. CO_2, CO, H/C's, H_2S, NO_x, O_3, SO_x and other oxidants. 2. Cannot distinguish organic particulates. 3. Volatile Organic Compounds (VOC) - such as formaldehyde, benzene, methylene chloride and per chloro ethylene.
CONTINUOUS OPACITY MONITORING SYSTEMS (COMS)	1. Total Suspended Particles (TSP). Any particles less than 1 μm in diameter 2. Lead Particulates/Particulate Material ($PM_{2.5}$/PM_{10}) and also classifies between lead, metal, gas etc.	1. TSP, Lead Particulates / Particulate Material ($PM_{2.5}$ / PM_{10}). 2. Classification of composition of PM at the level of single equipment is not possible.
CONTINUOUS	1. Can monitor the source from far away distance, only clear line of sight is required.	1. Independent analyzers used for monitoring.
PARAMETRIC MONITORING SYSTEMS (CPMS)	2.Measures a surrogate pollutant like carbon monoxide (CO), Methane, Hydrocarbons etc. or any stationary combustion source. 3.Temperature, humidity, air pressure etc. at different heights can be measured. 4.Smoke, fire etc. Can differentiate between smoke and steam.	2.Respective analyzers / Sensors are required to be located near the source. This is most limiting factor during the course of emergencies like leakage, fire etc. 3.Measures a surrogate pollutant like Carbon Monoxide (CO) Methane, Hydrocarbons or any stationary combustion source. 4.Smoke, fire etc. Does not differentiate smoke and steam.

h) AUM: Technical Data and Specifications[#]

Electrical Power Supply	*230 V, 50 Hz* AC, 15 *amp Electrical Socket*
Current Consumption	135 *watts*
System Detection Range	< 10*m* to >1*km;* Configurable as per user requirements
Accuracy	<1ppb for gases, <0.1 SI units for temperature, wind, pressure
Response Time	<10ns
Sampling Frequency	1-10*kHz* (wired), 150*Hz*-200*Hz* (wireless)
Cable Types	22, 24 AWG
Real Time Data Recording	On Designated Computer Server, Encrypted
Data / Information Display	Real Time Display on PC/Smart Phone Through Internet, Encrypted
Operational Range of Temperature	-25 °*C* to +70 °*C* (Ruggedized), 0°*C* to +55°*C* (Standard)
Operational Range of Humidity	0 to 100%
System Shape / Dimensions	Cuboid/563*mm* × 390*mm* × 160*mm* [(L×W×H) – Ruggedized Version] Cylinder / 180*mm* × 220*mm* [(ø × L) – Standard Version]
Weight	<10.0*Kg*
Protection Class / Deployment	IP65 / IP67 / IP69 / Field Deployable Even in Harsh Environments

i) AUM- Measurement of Pollution Parameters, Accuracies, Detection Ranges, Resolutions

S. No.	Parameter	Accuracy	Detection Range	Accuracy (% Full Scale)	Resolution
1.	NH_3	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
2.	CO	<1 ppm [$\sim mg/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
3.	NO	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
4.	CO_2	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
5.	NO_2	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
6.	O_3	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
7.	SO_2	<1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
8.	NO_x (NO_2+NO)	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
9.	Benzene [C_6H_6]	<1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
10.	Toluene($C_6H_5CH_3$)	<1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.01%	0.5ppb
11.	*o* – Xylene [$C_6H_4(CH_3)_2$]	<1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
12.	*p* – Xylene [$C_6H_4(CH_3)_2$]	<1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
13.	*Et* – Benzene [$C_6H_5CH_2CH_3$]	<1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
14.	$PM_{2.5}$	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
15.	PM_{10}	1 ppb [$\sim\mu g/m^3$]	0 to $10^3 ppm$	0.1%	0.5ppb
16.	Wind Speed	<0.01m/s	0 to 75m/s	0.01%	0.005m/s
17.	Wind Direction	<1°	0° to 360°	0.01%	0.05°
18.	Air Temperature	<0.1°C	-25°C to 70°C	0.01%	0.05°C
19.	Relative Humidity	<0.1%	0 to 100%	0.01%	0.005%
20.	Air Pressure	<1kPa	0 to $10^5 kPa$	0.01%	0.5kPa
21.	Solar Radiation	<1W/m^2	0 to $10^5 W/m^2$	0.01%	0.5W/m^2

** specifications subject to change without notice.*

j) AUM – Certification and Appreciation from Department of Science & Technology, Ministry of Science and Technology, Govt. of India

After critical and detailed reviews by DST, Dr Harsh Vardhan, the Honourable Minister for Science & Technology, Health and Family Welfare, Government of India, tweeted that the indigenously developed photonic system *AUM*, having better qualities, in comparison to any known international systems, is highly economical *and therefore*, rests on the verge of providing a big boost to the nation's efforts towards self- reliance in high-end technologies, and also can additionally be instrumental in supporting the endeavours in improving the nation's health and economy under *#AtmaNirbharBharatAbhiyan*. [24, 25, 26].

k) Diverse Applications of AUM

- Continuous Ambient Air Quality Monitoring System
- Continuous Emission Monitoring System
- Portable Emission Monitoring System
- Continuous Opacity Monitoring System
- Continuous Parametric Monitoring System

l) Way Forward

CATS Eco Systems Pvt. Ltd., Nashik is the technology transfer partner for commercialization of AUM. It is sincerely hoped, that the Ministry of Environment, Forests and Climate Change (CAQM,) and other central and state governmental organizations)in India and other stakeholders around the world would therefore facilitate the due recognition and acceptance of 'AUM' at the earliest, in sync with their established policies of proactively supporting innovative developments for commercialization, as it would certainly be instrumental in supporting the world wide efforts for monitoring and controlling air pollution.

VII. Summary and Conclusions

The indigenously designed and developed photonic system AUM, was successfully tested and evaluated with gold standards and also with some of the continuous ambient air quality monitoring stations of CPCB. The indigenous system was demonstrated to be having many advantages compared to the existing technologies and systems. The system is capable of monitoring all gases (with accuracy of ~*1 ppb*) and the environmental parameters both in spatial and temporal domains simultaneously at high sampling frequencies. The system can be deployed easily as it is light weight and portable. The system is operable in all weather conditions, and being an indigenous development is also highly economical and can certainly boost the nation's efforts towards self-reliance in high end technologies.

In conclusion, AUM is an innovative, unique, and disruptive technology with the following characteristics, unmatched by other known and established systems.

- Highly Sensitive and Accurate
- Portable, Compact, Low powered and Economical.
- Plug and Play System, no setting up time, no additional civil infrastructure for housing.
- Information on all gases, and meteorological parameters.
- Non-intrusive, remote, in-situ, real time monitoring system. accuracies.
- Single System capable of monitoring in both spatial / temporal domains.
- High sampling rates.
- Data from sensors seamlessly streamed to a cloud server
- Encrypted real time dash board information to authorized users.
- Works continuously, even under extreme weather conditions.
- Intelligent monitoring algorithms to identify and alert failures.
- Spatial Sampling as per user requirements.
- Unique calibration facility enabling AUM to be deployed anywhere in the world.

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Effect of Different Application Rates of Lead (Pb) on Urease, Phosphates and Microbial Community Structure in Uyo, Nigeria

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Abstract- Soil contamination with heavy metals occurs as a result of both anthropogenic and natural activities. This research was designed to investigate the effect of different application rates of Lead (Pb) on urease, phosphates and microbial community structure. The study was a screen house experiment, and was carried out in the Department of Soil Science, University of Uyo, between March to October 2018. The experiment was a pot experiment, and Lead nitrate ($Pb(NO_3)_2$) solution was added to wet soil sample at the rates of 0, 150, 300, and 500mg/500g soil and mixed thoroughly and incubated for 12 weeks. Samples were collected at two weeks (2wks), nine weeks (9wks), twelve weeks (12wks) after incubation for analysis of urease, acid and alkaline phosphates, and microbial populations. The results revealed that urease (URE), Acid Phosphatase (ACP), and alkaline phosphatase (ALP) were significantly lower in Pb amended soil samples than those of the control. The urease inhibition rate increased with increasing Pb concentrations. The result was more significant at two weeks of incubation,(28.33%) of the control.

Keywords: *lead, urease, phosphatase, microbial community.*

GJSFR-H Classification: *FOR Code: 050399*

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Effect of Different Application Rates of Lead (Pb) on Urease, Phosphates and Microbial Community Structure in Uyo, Nigeria

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Abstract- Soil contamination with heavy metals occurs as a result of both anthropogenic and natural activities. This research was designed to investigate the effect of different application rates of Lead (Pb) on urease, phosphates and microbial community structure. The study was a screen house experiment, and was carried out in the Department of Soil Science, University of Uyo, between March to October 2018. The experiment was a pot experiment, and Lead nitrate ($Pb(NO_3)_2$) solution was added to wet soil sample at the rates of 0, 150, 300, and 500mg/500g soil and mixed thoroughly and incubated for 12 weeks. Samples were collected at two weeks (2wks), nine weeks (9wks), twelve weeks (12wks) after incubation for analysis of urease, acid and alkaline phosphates, and microbial populations. The results revealed that urease (URE), Acid Phosphatase (ACP), and alkaline phosphatase (ALP) were significantly lower in Pb amended soil samples than those of the control. The urease inhibition rate increased with increasing Pb concentrations. The result was more significant at two weeks of incubation,(28.33%) of the control. The reduction (6.31%) was more at two weeks of incubation in 500mg/500g of treatment. Bacteria, actinomycetes were depressed by 66.25% and 70%, respectively at 12wks in 500mg/g application rate, while fungi decreased in all the amended soil.

Keywords: lead, urease, phosphatase, microbial community.

I. Introduction

Soil contamination with heavy metals occurs as a result of both anthropogenic and natural activities. Heavy metal contamination in the environment is eventually deposited in soil in some forms of low solubility compounds such as pyrite (Huerta-Daiz and Morse, 1992), absorbed on surface-reactive phases, such as Fe and Mn oxides (Copper *et al*., 1970; Hamilton-Taylor *et al*., 2005). Those heavy metals could have long-term hazardous impacts on the health of the soil ecosystem and adverse influence on soil biological processes. Heavy metals can inhibit enzymatic activities by interacting with the enzyme-substrate complexes, denaturing the enzyme protein, and interacting with its active sites (Megharaj *et al*., 2003). Heavy metals can also influence microbial community, which ultimately lead to changes in soil enzymatic activities (Kandeler *et al*., 2000). Aside from long-termed metal-mediated changes in soil enzymatic activities, many reports have shown a large reduction in microbial activity due to short-term exposure to toxic metal (Hamida *et al*., 1992; Doehman and Haanstra, 1984). The bacterial activity was shown to be very sensitive to metal pollution (Diaz-Ravina and Baath, 1996). It was also observed that habitats that have high levels of heavy metal contaminations show a lower number of microbes than uncontaminated habitats (Kandeler *et al*., 2000). Lead (Pb) occurs naturally in soils, but areas impacted by human activities often have significantly elevated Pb levels (Khan *et al.,* 2007), and this affect the soil ecology and microbial depression and changes in enzymatic activities. In their conclusion, Khan *et al*. (2007) opined that heavy metals have inhibiting influences on soil enzymes as well as microbial community structure, soil enzymatic activities are considered to be a good bio-indication reflecting natural and anthropogenic disturbance and be used to evaluate soil pollution (Hinojosea *et al*., 2004; Khan *et al*., 2007). Enzymes accumulated in soils are present as free enzymes such as exo-enzymes released from living cells, endo enzymes released from disintegrated cells, and enzymes bound to cell constituents (Kandeler *et al*., 1976). Kandeler *et al.,* (1996) further stressed that the composition of the microbial community determines the potential of that community for enzyme synthesis and thus any modification of microbial community due to environmental factors.

Lead (Pb) is among the most significant toxic metal, but in normal agricultural soils is in the range of 10 – 100 mg/kg soil (Soon and AD bond, 1993), but in polluted soil, especially near mines or by sewage sludge applications, its contents are even higher than 1000mg/kg soil (Peters and Shem, 1992; Pichtal *et al*., 2000). Higher levels of Pb in soil may adversely affect the activities of soil enzymes, which in turn may result in an adverse effect on various plant parameters influencing crop quality, yield, and possibly human health through the food chain. Base on this background, this research was designed with the following objectives (i) to determine the effect of Pb on soil enzymes, (ii) determine the influence of Pb on microbial community structure.

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II. Materials and Methods

a) Study Area

The study was conducted at the University of Uyo Teaching and Research Farm, Uyo, Akwalbom State, Nigeria. The area is within Latitude 4°32' and 5°44'N and Longitude 7°35' and 8°25'E.

b) Soil Sample Collection

Soil samples were collected using a hand trowel at a depth of 0 – 15cm. There was no fixed interval for sampling, but at random. A total of six (6) location points were taken and pooled together to obtain a composite sample. The samples were taken to the laboratory. The composite samples were split into two, one half was kept for contamination with heavy metal, while the other half was used for enzymes and microbial assays.

c) Experimental Details

The experiment was a pot experiment in a screen house. The wet soil samples were added with Lead (Pb) using Pb $(NO_3)_2$ solution at the rates of 150,300 and 500 mg/kg soil. Four plastic pots were obtained, and each pot was filled with 500g soil. Pot 1 (P1) was the control, Pot 2 (P2) was thoroughly mixed with 150 mg/kg $Pb(NO_3)_2$, Pot 3 (P3) was thoroughly mixed with 300 mg/kg, and Pot 4 (P4) were mixed with 500mg/kg soil.

The contaminated soil samples with $Pb(NO_3)_2$ were incubated in the screen house for 12 weeks. During the incubation period, soil moisture contents were monitored by weighting and adjusting to 60% water holding capacity by deionized water. Samples from each pot was collected at 0,2,9 and 12 weeks for enzymes and microbial community assay.

d) Microbial Analysis

Samples from each treatment of (Pb0, Pb1, Pb2 and Pb3) representing: control (Pb0), (Pb1) 150 mg/500g, (Pb2) 300 mg/500g, (Pb3) 500mg/500g soil.

Samples were enumerated by making ten-fold dilutions of the soil samples from 10^{-1} – 10^{-3},an aliquot of 0.1ml from the 10^{-3} dilution was transferred unto plate in nutrient agar amended with nystatin (0.5-mg/ml) for isolation of bacteria, with potato dextrose agar amended with streptomycin (0.02 – 1mg/ml) was used for the isolation of fungi and Glycerol Agar was used for isolation of actinomycetes. The different cultures were incubated at different temperatures and times required for optimum growth of the microorganisms. Bacteria and actinomycetes were incubated at a temperatures of 37°C for 24 hours in an incubator, while fungi plates were incubated at 28°C for 72 hours. After the respective period of incubation, visible colonies were counted, and the microbial load determined using the formula:- Microbial load = no of colonies x reciprocal of dilution factor, and express as (CFU/g soil).

Isolated colonies were further purified by sub-culturing and identified using the biochemical tests and microscopy.

e) Identification of Isolates

Each isolate was examined for its size, margin, consistency, pigmentation, Gram reaction, and cell morphology. The isolates were characterized as described by Holt *et al*. (1999). Biochemical tests carried out included the production of catalase, indole, and oxidase enzymes. Spore production, and oxidation and formation of sugars were carried out.

f) Determination of Enzymes Activities

i. *Determination of urease*

Urease activity was determined by the method described byGu*et al*., (2009). Briefly, two grams (2g) of the moist soil sample from each pot containing 0mg, 150mg, 300mg, and 500ma of Pb weighed inside four 500ml Erlenmeyer flasks, and 2ml of toluene was measured into each flask and allow to stand for 15 minutes after stirring. The 10ml modified universal buffer (MUB) (pH 6.5) and 10ml of freshly prepared 10% urea solution were added. The flask was covered and incubated in an incubator for 24 hours at 37°C. After incubation, 4ml sodium phenol and 3ml sodium hypochlorite were added to all the Erlenmeyer flasks, and the yellow color developed. The soil solution contents were filtered through Whatman 42 filter paper. The absorbance of the released ammonium was measured using colorimeter at a wavelength of 430nm and the result recorded as NH_4 – N/g soil.

ii. *Determination of Phosphatases*

The method described by Tabatabai and Bremner (1969), Eivazi and Tabatabai (1977) were employed.

One (1) gram of the moist soil sample from the four pots was weighed into 8 Erlenmeyer flasks, (4 for acid phosphatase and 4 for alkaline phosphatase). Two (2) ml of toluene was added, 4ml modified universal buffer (pH 6.5 for assay of acid phosphatase and pH 11 for assay of alkaline phosphatase were added). Then 1ml P-nitro-phenyl phosphate was added. The flasks were covered and incubated at 37°C for 1 hour. After incubation, 1ml 0.5M calcium chloride ($Cacl_2$) and 0.5M Sodium hydroxide (NaOH) were added, and the flask swirled for few seconds to mix. The soil suspension was filtered through Whatman 42 filter paper. The yellow colour was measured using colorimeter at the wavelength of 430nm, and the results were recorded as mg formazan/g soil.

III. Results

Urease (URE), Acid phosphatase (ACP), and Alkaline phosphatase (ALP) were significantly (P=.05) lower in the Lead (Pb) amended soil samples than those of the control (Fig. 1). The enzyme inhibition extent was

clearly seen between different incubation periods and varied as the incubation proceeded, and the highest rate was detected in samples mostly at two (2) weeks of incubation.

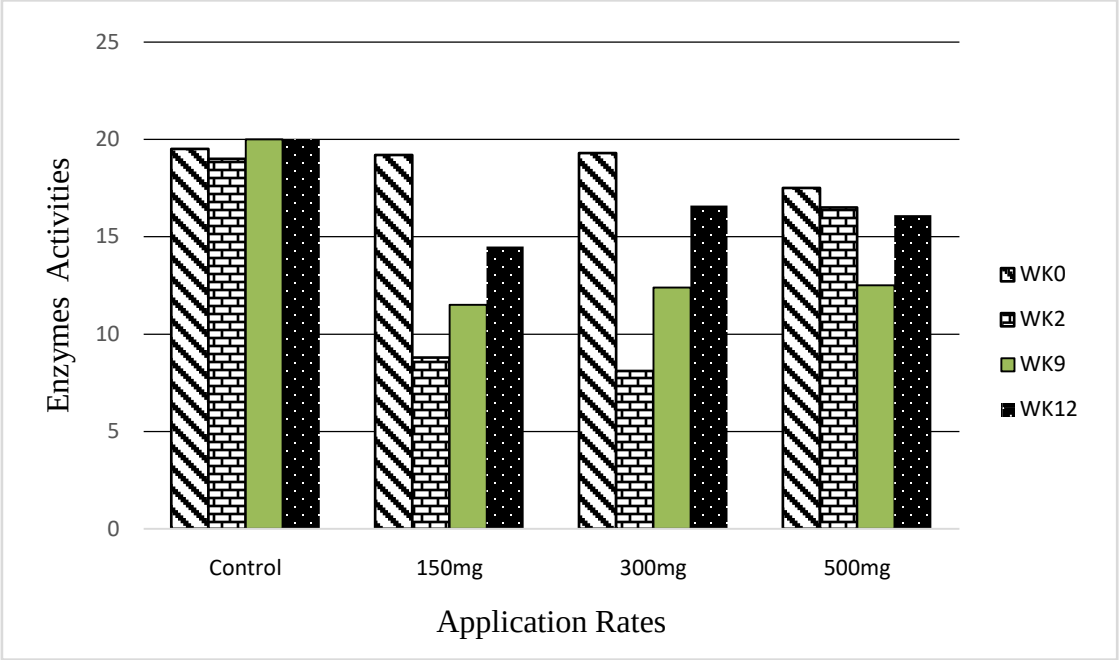

Fig. 1: Effect of Lead (Pb) on urease activity

On day zero, the mean values of urease activity were in all amended soils significantly ($P<0.05$) lower than those in control. The lowest urease activity (90.48%) of the control was found in the treatment 300ml/kg soil at two weeks. Alkaline phosphatase (ALP) activity was also significantly ($P=.05$) affected by the heavy metal (Lead). The values of this enzyme were lower in all the soil amended with lead compared to the control. The reduction was clearlyat two weeks of incubated (28.33%) of the control. Similarly, the activity of Acid phosphatase (ACP) in the lead amended soil decreased with increasing Pb levels (Fig. 2). The reduction was more pronounced at two weeks of incubation and 500ml/kg of soil (6.31%) treatment.

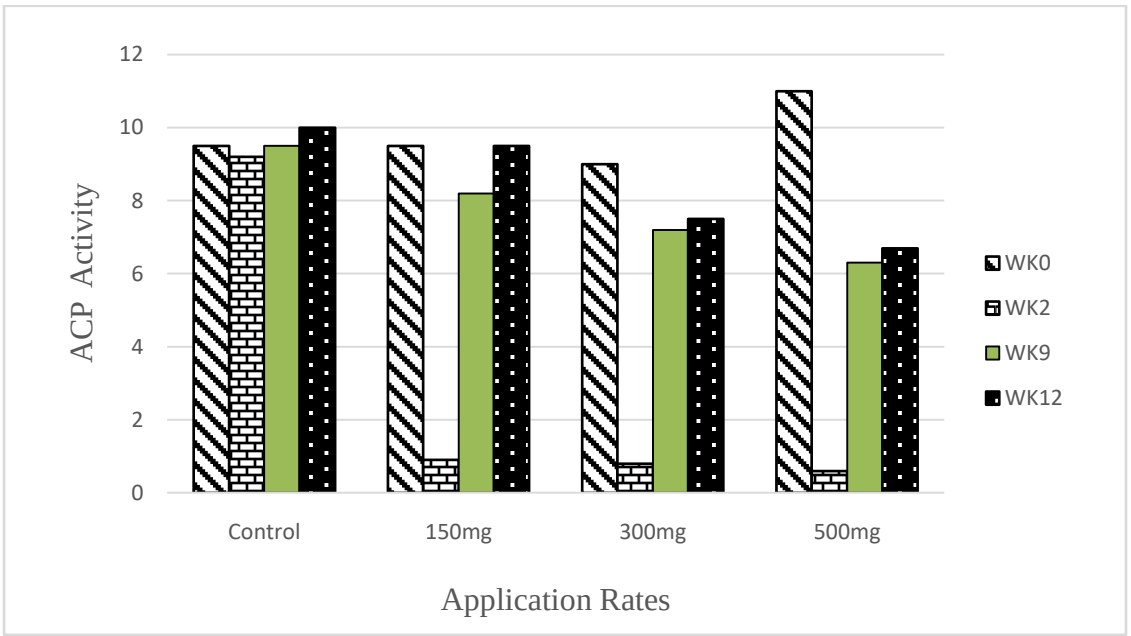

Fig. 2: Effect of Lead (Pb) on Acid Phosphatase activity

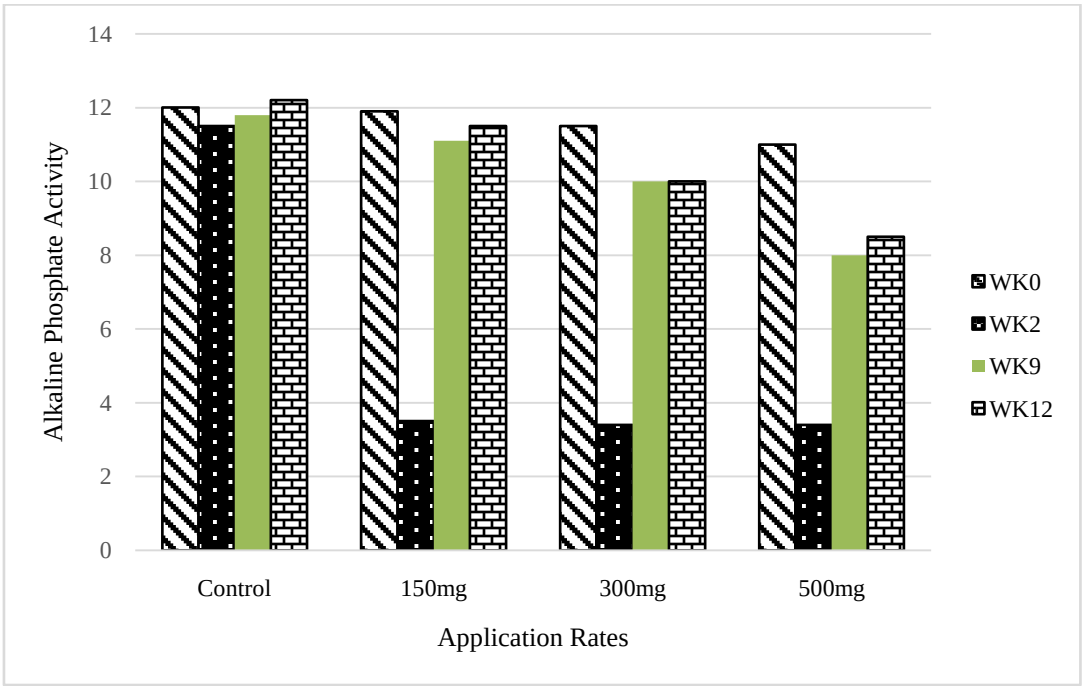

Fig. 3: Effect of Lead (Pb) on Alkaline phosphatase activity

The number of bacteria and Actinomycetes were significantly (P=.05) depressed in the heavy metal amended samples compared to the control (Fig. 4-6). The highest reduction (66.25% and 70.0%) respectively for bacteria and actinomycetes at 12 weeks with 500mg/kg application rate, while fungal cells were not significantly (P<0.05) decreased in all the amended soils compared to the control.

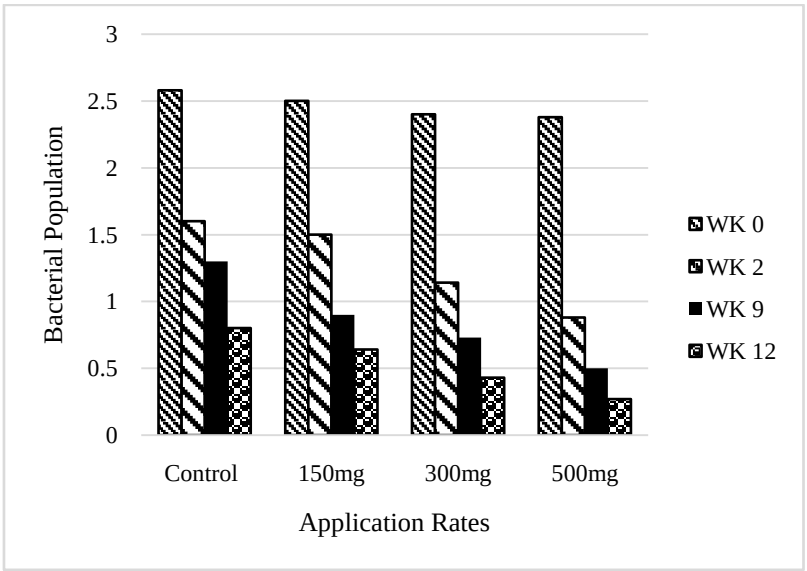

Fig. 4: Effect of Lead (Pb) on bacterial population

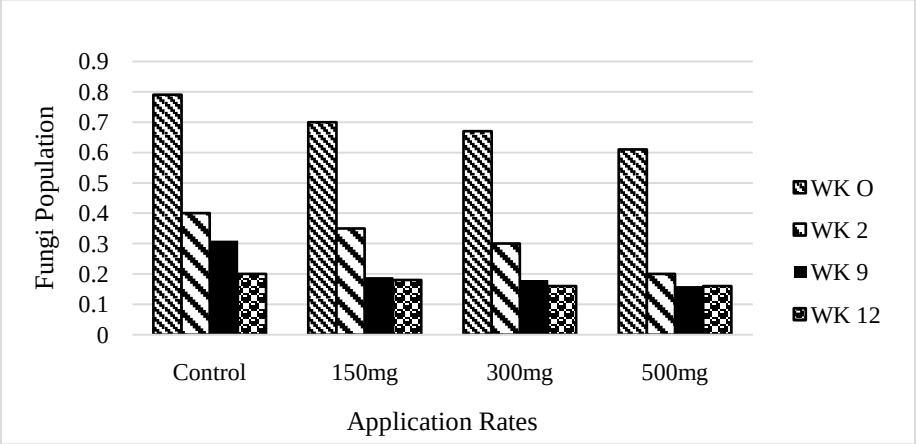

Fig. 5: Effect of Lead (Pb) on fungi population

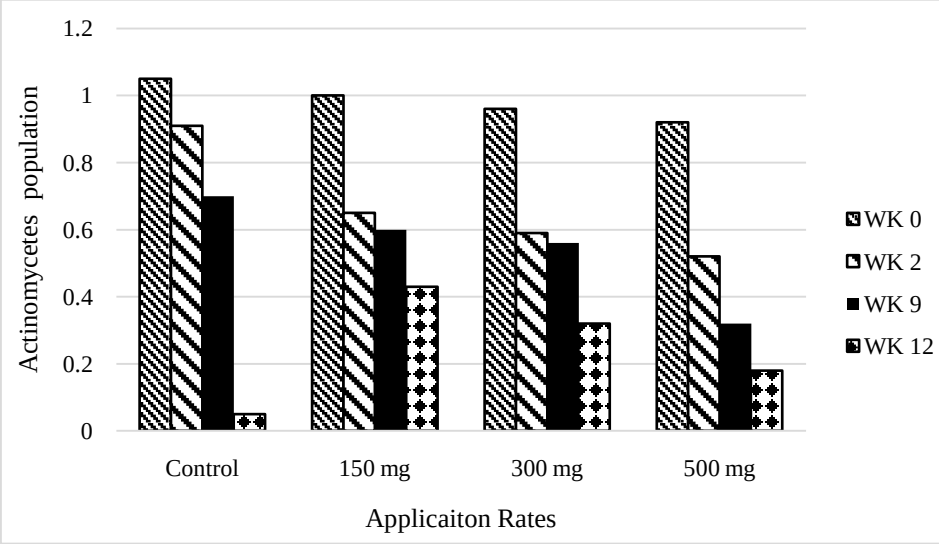

Fig. 6: Effect of Lead (Pb) on Actinomycetes population

IV. Discussion

In the soil environment, almost all reactions are catalyzed by enzymes that are largely of microbial origin and associated with viable cells (Dick *et al*., 1996). Urease enzyme is responsible for the hydrolysis of urea fertilizer applied to the soil into NH_3 and CO_2 with the concomitant rise in soil pH (Andrews *et al*., 1998; Bymes and Amberger, 1989). This in turn results in rapid N loss to the atmosphere through NH_3 volatilization (Fillery*et al*., 1984).

Soil urease originates mainly from plants (Mulvaney and Bremner, 1981). The increased inhibition of soil urease activity is likely to be related to the depression in microbial activity which is known to synthesized urease. These findings corroborated with previous reports by Khan *et al*. (2007) who reported that decrease in enzyme activity could be related to the fact that microorganisms were suddenly exposed to heavy metals. Soil phosphatases are important in soil P-cycling involving in mineralization of organic P and releasing phosphate for plants (Dick and Tabatabai, 1983; Gil-Sotres *et al*., 2005). In this study, both Alp and Acp activities were significantly inhibited with increasing concentration of Pb amendment. This inhibition may probably be due to the denaturing of the enzymes or may be due to the suppression of the microorganisms synthesizing the enzymes. These findings were in line with the studies conducted by Tyler (1974) and Kizikaja *et al*. (2004), independently stressed that enzymatic activities diminished with increasing available concentrations of heavy metals.

The rapid inhibition in enzymatic activities were found in the two weeks of incubation which should be related to the fact that the microorganisms were suddenly exposed to heavy metals. It is well documented that heavy metals react with sulfhydryl groups of enzymes and inhibit and/or inactivate the enzymatic activities. Heavy metals could also indirectly affect soil enzymatic activities by altering the microbial community which synthesizes enzymes altering the microbial community which synthesizes enzymes

(Namnipieri, 1994; Kandeler*et al*., 2000). Acid phosphatase and alkaline phosphatase are synthesized by the root of plants and microorganisms, respectively (Izaguirre-Mayoral *et al*., 2002).

In the soil ecosystem, heavy metals exhibit toxicological effects on soil microbes, which lead to a decrease in their population and activities (Yao *et al*., 2003). The results of this study suggest that the total bioactivity, richness, and diversity of microorganisms decreased with increasing levels of heavy metal concentration, because microorganisms differ in their sensitivity to heavy metal toxicity. The reduction in number of these microbes (Bacteria, Actinomycetes, and fungi) may be because these microbes were suddenly exposed to high levels of heavy metal. Similarly, Akmal *et al*., (2005) also observed changes of microbial community structure in metal amended soils in microbial activity known to synthesize urease. These findings corroborated with previous reports by Khan *et al*., (2007). Soil phosphatases are important in soil P-cycling, involving in mineralization of organic P and releasing phosphate for plants (Dick and Tabatabai, 1983; Gil-sotres*et al*., 2005). In this study, both Alp and Acp activities were significantly inhibited with increasing concentration of lead (Pb) amendment. These findingswere in line with the studies conducted by Tyler (1974) and Kizikaya*et al*. (2004), that soil enzymatic activities diminished with increasing available concentrations of heavy metals. The rapid inhibition in enzymatic activities was found in the twoweeks incubation which should be related to the fact that the microorganisms were suddenly exposed to heavy metal. It is well documented that heavy metals react with sulfhydryl groups of enzymes and inhibit and inactivate the enzymatic activities. Heavy metals could also indirectly affect soil enzymatic activities by altering the microbial community which synthesizes enzymes (Namnipieri, 1994; Kandeler*et al*., 2000). Acid phosphatase and alkaline phosphatase are produced by the root of plants and microorganisms, respectively (Izaguirrer-Magoral*et al*., 2002). In the soil ecosystem, heavy metals exhibit toxicological effects on soil microbes, which lead to a decrease in the population and activities (Yao *et al*., 2003). The results of this study suggest that the total bioactivity, richness, and diversity of microorganisms decreased with increasing levels of heavy metal concentration because microorganisms differ in their sensitivity to heavy metal toxicity. The reduction in the number of these microbes (Bacteria, Actinomycetes, and fungi) may be because these microbes were suddenly exposed to high levels of heavy metal. Similarly, Akmal*et al*. (2005) also observed change in microbial community structure in metal amended soils.

V. Conclusion

The different application rates of 0, 150, 3000, and 500mg/g soil affected soil microbial community structure, and enzyme activities. The highest inhibitory effects on soil microbial and enzyme activities were significantly at two weeks of incubation.

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Fellows may join as a member of the Editorial Board of Global Journals Incorporation (USA) after successful completion of three years as Fellow and as Peer Reviewer. Additionally, Fellows get a chance to nominate other members for Editorial Board.

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ASSOCIATE OF SCIENCE FRONTIER RESEARCH COUNCIL is the membership of Global Journals awarded to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

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To the institution

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Global Journals sends a letter of appreciation of author to the Dean or CEO of the University or Company of which author is a part, signed by editor in chief or chief author.

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Financial

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Associates are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career | Credibility | Financial

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Associate	Fellow	Research Group	Basic
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Certificate, LoR and Momento **2** discounted publishing/year **Gradation** of Research **10** research contacts/day **1 GB** Cloud Storage **GJ** Community Access	**Certificate,** LoR and Momento **Unlimited** discounted publishing/year **Gradation** of Research **Unlimited** research contacts/day **5 GB** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**Certificates,** LoRs and Momentos **Unlimited** free publishing/year **Gradation** of Research **Unlimited** research contacts/day **Unlimited** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**GJ** Community Access

Preferred Author Guidelines

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

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Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

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2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s') names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

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Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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