Pressure based Air Purification Lamp for Multifunctioning Purpose

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Abstract - *Environmental and social issues such as air pollution, flooding and energy crisis have been very prominent in recent years. Studies in the past have attempted to provide solutions distinctively for each problem. Though none of them have approached the issues altogether, to create a 'one stop solution'. There is a need to design a hybrid system which can combine various measures so that the outcome is generated simultaneously in real time. Roads are the epicenter of air pollution, water logging, crimes as well as an ideal point for generation of green energy. The designed module consists of air filter, water level monitor, piezoelectric plates and voice recognition unit. These units are interfaced with computing devices like arduino and raspberry pi. The output is recorded in a centralized system, analyzed and displayed on LCD display. The designed flood level monitor successfully detected the level of water and warned when it was raised beyond safe limit (4 cm in the experimental testing). outcomes obtained on implementation of this system, are satisfactory when tested at urban as well as rural sites. Therefore, based on the proposed work, a regulatory and managing framework can be incorporated in the government for the betterment of people. In future, various dimensions of this study can be specialized to serve different sectors of society.*

Key Words: arduino, hybrid system, piezoelectric plates, raspberry pi, voice recognition

1. INTRODUCTION

Environmental pollution is the contamination of the natural environment which is detrimental to human health and the planet as a whole. Air pollution is the superior form of pollution which is referred as the release of pollutants into the air where annually 2 to 4.1 million deaths occur due to it. Industrial revolution is the main cause of air pollution as they release harmful gases by burning of fossil fuels that emits gases and chemical into the air. Air pollution not only contributes to climate change it shows exacerbation in the surrounding and affect human health by destroying the lungs and damaging the heart and brain with additional respiratory diseases.

Smog and soot are the two prevalent types of air pollution which occurs from emissions of combusting fossil fuels that react with sunlight. Soot (particulate matter) is made up of micro particles in the form of soil, dust, smoke, chemicals, dust or in the form of gas that are carried in the air. Particulate matter is especially dangerous because they penetrate the lungs and worsen bronchitis which lead to heart attacks or even death.

The main motive behind this designed module is to observe the changes occurring in the environment and making an attempt to lessen the pollutants from environment from its roots itself using the existing smart components.

Air pollution can be referred as emission of the harmful contaminants and foreign substances into the atmosphere irrespective of indoors or outdoors. It can be classified as visible or invisible air pollution. The ozone layer is the crucial layer of existence of ecosystem is depleting due to increase in air pollution. Various causes of air pollution are burning of fossil fuels, agricultural activities, exhaust from factories and industries, mining operations, indoor air pollution which affects the ecosystems in terms of respiratory and heart issues. Global warming, acid rain, eutrophication, effect on wildlife, depletion of ozone layer. Pollutants including sulphur dioxide (SO2),nitrogen oxides (NO2) and ozone (O3), particulate matter, carbon monoxide (CO) and volatile organic compounds (VOCs) are the major gases affecting the environment. Carbon dioxide (CO2) and other greenhouse gases like methane, nitrous oxide, etc are separately compared in the world data. The WHO emphasises that air pollution attributes to 9% of deaths globally and eventually shows longer-term threats to the environment viz climate change that may continue in the future. Around 4.3 million outdoor pollution and 2.6 from indoor has been a reason to 7 million premature deaths every year. The EPA, environmental protection agency is cognizant of all the means and techniques the industries use to dump their wastes which lead to introduce use strict protocols and testing methods against these invalid ways to protect the population. They are also measuring the air pollution emitted by vehicles and invented regulatory measures which the help of centres for disease control (CDC) they monitor pollen issues and use solutions to reduce pollen in the atmosphere.

In India, especially in the urban areas, we witness overflowing roads hampering the flow of traffic during every monsoon. No matter how efficient the drainage system is present in the city, due to flash-floods, a considerable depth of water is observed on roads, which is not suitable for the movement of traffic. Lack of judgment of the depth of water by the pedestrians and the drivers has led to many accidents.

Only if we could come to know the depth of water at various cross sections of the road with certain intervals, the traffic can be managed safely over that part of the road. For that a manually operating instrument (such as Measurement Rod) will not be viable considering no. of

points to be operated and the safety in the operation. Even a real time data feed is practically impossible in any manual method.

Considering the need of the hour, we have designed a system which provides an effective solution to the discussed issue by fulfilling all the requirements. It consists of a sensor which measures the depth of water on roads and it is fitted in a module. The module is to be installed on a street lamp pole.

Dependency on non-renewable sources decreasing these sources day by day and in near future it may get exhausted completely. Hence it is required to explore for alternative sources and shift our dependency on renewable sources. This will conserve non-renewable sources and produce clean energy. These renewable sources include solar cells (Solar energy), wind mills (Wind energy), geothermal power plants (Geothermal energy), tidal turbine (Tidal energy) etc. Solar power provides a considerable amount of energy per area and volume, but unfortunately is limited to applications that are actually sunlit. We utilize a large part of our muscular energy for moving from one place to other and also the infrastructure like roads, railways, runway bears a large amount of mechanical strain energy. This energy i.e. muscular or mechanical strain on various infrastructures gets wasted. But it is possible to convert this mechanical energy in to electrical pulse form with the help of piezoelectric transducers. These electrical pulses, which are alternating in nature, can be directly utilized or may be captured by a storage device for further utilization. Efforts have been put in this work to harvest energy from mechanical stress using the principle of piezoelectric energy conversion. For a harvesting system of constant thickness, the generated power increases with increase in applied force. The output power of harvester depends on increase in the thickness. various models of piezoelectric generators are given in, The output power obtained from piezoelectric generators depends on various factors like which piezoelectric sensor has been used, it's packing density, type of strain applied to it, electronic circuitry to process the pulse generated, storage device, and load connected to it. When a simple rectifier is used the output power generated greatly depends upon the load connected. The important criteria for maximizing the output power are to match the optimal load of the harvester to that of converter circuit. Several techniques are available for converting mechanical vibration energy to electrical energy. The most prevalent methods among them are electrostatic, electromagnetic and piezoelectric conversion [11]. A majority of current research has been done on piezoelectric conversion due to low complexity of its analysis and fabrication. Most of research however has targeted a specific device scale.

2. LITERATURE REVIEW

Prabjit barn et al. (2018), the research done in Ulaanbaatar, Mongolia stated that the air in the residentials isn't good for the health of pregnant women as the majority air pollution is found indoors. **Songsukthawan P. & Jettanasen C. (2017)-** The electrical energy generation and storage from piezoelectric materials are focused and discussed in this paper. This kind of materials is able to directly convert mechanical energy into electrical one, which can be later stored by utilizing energy harvesting technique/circuit This paper focuses how to extract energy from piezoelectric materials to be stored in the energy storage device such as battery, in order to later supply electronic/electrical device/equipment. **Huang Kang et al. (2014)** invention relates to an air purifier installed on an ordinary street lamp pole. The filtering mechanism is arranged on the support in a sleeving mode. When the air purifier works, external air required to be purified enters the air purifier through the air inlet hood under the action of ionic wind generated by a generation electrode pole and is filtered by the filtering mesh. **Majid Kajbafzadeh et al. (2015)** comparing with other sources, it shows that the development of adverse cardiovascular health outcomes is caused due to combustion-derived air pollution. The exposure to traffic-related air pollution (TRAP) comes out with coronary heart disease mortality hypertension and stroke, and myocardial issues. Wood combustion in residentials is also the major source of particulate matter which is detrimental to health. **Ken smigielski et al. (2018)-** The effects of PM loading on pressure drop and the capture efficiency of customised-fabricated high-efficiency particulate air (HEPA) filters are determined and are compared with the same filters after being wet cleaned and reused multiple times.

In their research, **Konstantinos Loizou et al. (2015)** have addressed the importance of a water lever monitor sensor in the fields of water storage tanks. This sensor is reliable as it reduces the impact of metallic corrosion through direct contact of the capacitor electrodes with the water.
John D. Boon et al. (2008) have studied a microwave water level sensor obtained in U.S. coastal areas by the National Oceanic and Atmospheric Administration (NOAA). The advantages of this sensor over an ultrasonic sensor are high reflectivity of microwave radiation from water surface, low sensitivity to variations in air temperature and humidity. R. **M. Shrenika et al. (2017)-** They have demonstrated the implementation of LabVIEW and Arduino into an ultrasonic water level sensor. The research concluded that Ultrasonic sensor provides non-contact water level measurement hence can be used reduce wastage of water, power consumption and monitor the water level automatically.

Dadasaheb K. Mane, (2013) has used a GSM module and Ultrasonic sensor to develop an alert system for the rivers during monsoon season. To alert the river-sided people by sending warning SMS when the river crosses its dangerous limit. The ultrasonic sensor measures the level of river water and categorizes into 4 conditions, vig. high, medium low, medium and low. **Elhalwagy, A. M., Ghoneem, M. Y. M., & Elhadidi, M. (2017)**- This Paper seeks to spread piezoelectric energy harvesting floor applications, through

Facilitate how to conciliate and harmonize between the challenging requirement of usage factors and the application possibilities using a proposed tool. Feasibility study guide supported by various case studies that has been described as a benchmark for the future applications. **Najini, H., & Muthukumaraswamy, S. A. (2017)**- This paper presents a technical simulation-based system to support the concept of generating energy from road traffic using piezo-electric materials. It investigates practicality and feasibility using a real-time simulation platform known as MATLAB-Simulink. **Kumar, D., Chaturvedi P. & Jejurikar, N. (2014)**- An efficient way has been presented to capture the generated energy via dedicated IC and boost it by a converter to get regulated output for charging the batteries of smart phones. It can be implemented to generate large power more efficiently by suitably considering the several factors mentioned above and implementing it on the large scale. **Arya Vijayan et al. (2019)** applied IoT architecture for various multipurpose requirement hence can be used in this hybrid concept., **Biradar Shilpa et al. (2019)** applied the concept of applying E-waste concrete which can be environmentally friendly [3], **Chowdary Mohanlal et al. (2019)** has used GIS 4-Dimentional application which can be applied in placing this streetlamp according to geographic locations [5]. **Chhaya Zende et al. (2019)** researched in the area of reusable materials which can be applied in making hybrid projects in case of smart cities [4]. **Mahesh S. Singh et al. (2019)** invented R II method for labour productivity whereas **Sanika Kandalekar et al. (2019)** has constructed pervious concrete pavements which in this project can be applied for reducing floods etc. **Pradnya Patil et al. (2019)** worked on how PVA fibres can be used by NDT tests. **Pallavi Patil et al. (2019)** has incorporated RMMM techniques for huge projects in infrastructures [15], **Shobhana Jadhav et al. (2019)** simulated the route through application of GIS which will be useful in placement of streetlamps. **Pravin Shahi et al. (2018)** research in the field of repairing and rehabilitation [17], **Prathamesh Brid et al. (2017)** has applied fuzzy AHP which can be used for sound detection in this project [15]. **R Hazarika et al. (2019)** has constructed a sustainable and smart techniques for water generation through atmosphere. **A. Chavan et al. (2019)** has constructed a water harvesting techniques which can be added in this hybrid project as a future scope.

3. PROBLEM STATEMENT

Although there have been numerous studies on these environmental and social issues, none of the researchers have provided an all in one solution. It is the need of the hour to tackle these issues with efficient, economical and sustainable solutions.

The current air pollution methods use ionization techniques to filter air which is costly and need high maintenance. Present flood monitoring systems in cities are not much sophisticated in terms of accuracy, real time data analysis and data sharing with public. There has been less focus on the management of traffic on the roads. For that a system is required to designed which will monitor the water level on roads so that traffic accidents can be minimised drastically. Also, the system needs to be merged with the traffic lights too. The full potential of green energy production using piezo-electric effect is also need to be achieved on existing road and streets. It is required to provide an advanced solution with satisfactory performance with minimum cost.

4. OBJECTIVES

Keeping the comprehensive idea of the problem statement, following objectives are framed in our research:

1. To design a system which will help in management of traffic on roads by providing real time data to the traffic management body regarding depth and location of floodwater, thus reducing the impact on the people and preventing probable accidents.
2. The main objective of this project is to make an attempt to provide a solution to reduce the particulate matter level in the environment which is dangerous for the ecosystem. Roads are epicenter for pollution and the existing street lamps is the stem to the roots of air pollution where the designed module will be planted on the street lamps to detect the air quality using IOT components and an attempt is made to lower the particulate matter using the HEPA filter. It has the efficiency in highest terms of filtration process and is sustainable for a longer period of time completely depending on the usage and can be replaced after 3-4 months. An IOT sensor named BMP 280 is used to monitor the clogging and working efficiency. Another sensor MQ135 is used to sense the AQI (air quality index) on daily basis. The module will be helping to control the effects of air pollution on the environment and to make the air safer for all to breath.
3. To Design a free-green energy production System from wasting kinetic power of vehicle on road-ways, while cost efficiently saving it and using the energy for innovative smart street lamp and remaining for electricity house storage.

5. METHODOLOGY

We have designed a module which consists various components working in coordination as shown in fig. 1. We found an electric pole is a very dynamic place where we can implement our research methodology [4]. The main reasons being its vicinity to the pollution epicenter i.e. road. Also, it serves as a structure to protect the module and sufficient height to mount on, to serve its 3-fold purpose.

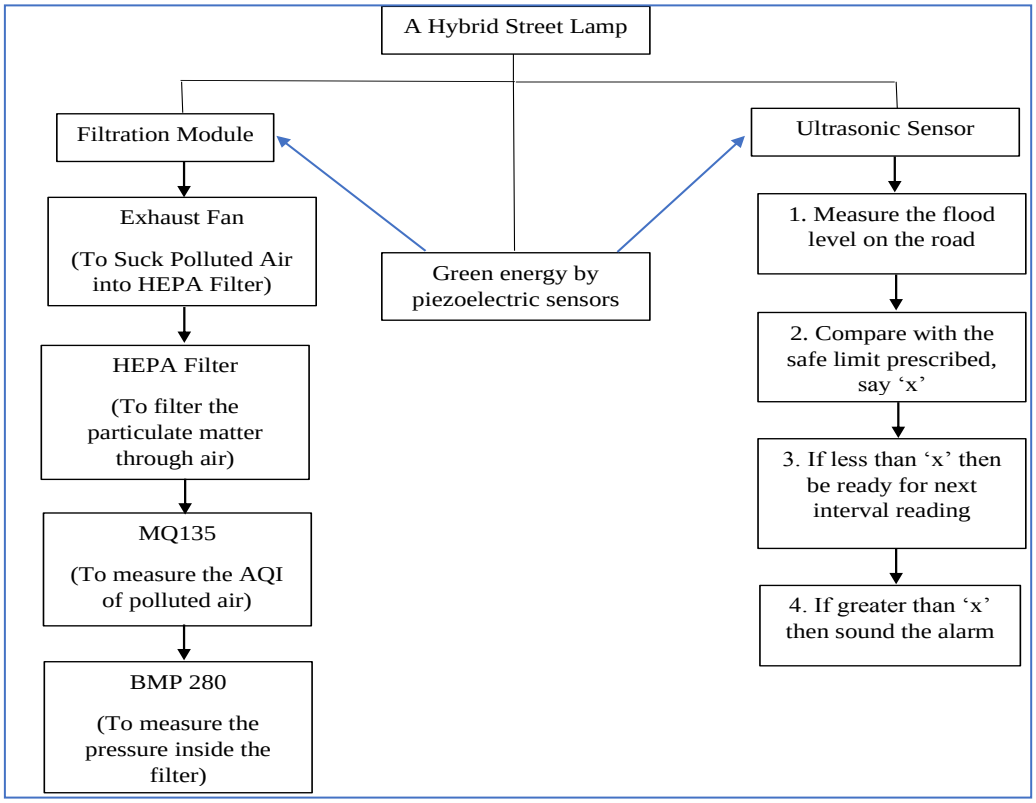

Fig. 1: Functioning of Hybrid Lamp Module

5.1. Air purification system:

The first being an air filter. a cylindrical structure with pores on it which allows the air to pass through it and the HEPA filter inside the cylinder absorbs the polluted air with particulate matter in it. There's a suction fan on the top of the filter used to give direction to the air flow and absorption purpose. The HEPA filter is an aerodynamic 360° cylindrical unit with 3 layered filters primary, HEPA and activated carbon layers.

The primary layer is made with PET (polyethylene terephthalate) and filters out large particles and floating matter like dust, hair and floccules. The HEPA traps the PM 2.5, PM 0.3 pollen and other respirable particles allowing only clean air to pass through. The activated carbon filters out the formaldehyde, odour and absorbs the harmful gases across a large surface area. It is combined with an anti- formaldehyde formula that effectively absorbs chemicals and smoke. This 360° triple layer filter cleans out around 310 m^3/h CADR (clean air delivery rate) [11]. The efficiency of this filter is of 3-6 months depending on its usage. An IOT [2] component BMP280 [10] known as barometric pressure sensor is fixed inside the HEPA measures temperature, pressure and altitude of a place. It monitors the filter's lifespan and reminders are received when the filter needs replacement [5].

The sensor measures the absorbing efficiency as the pressure intensity fluctuates from a higher value to lower when the filter gets clogged by the floating materials. AQI (air quality index) measured with another IOT component

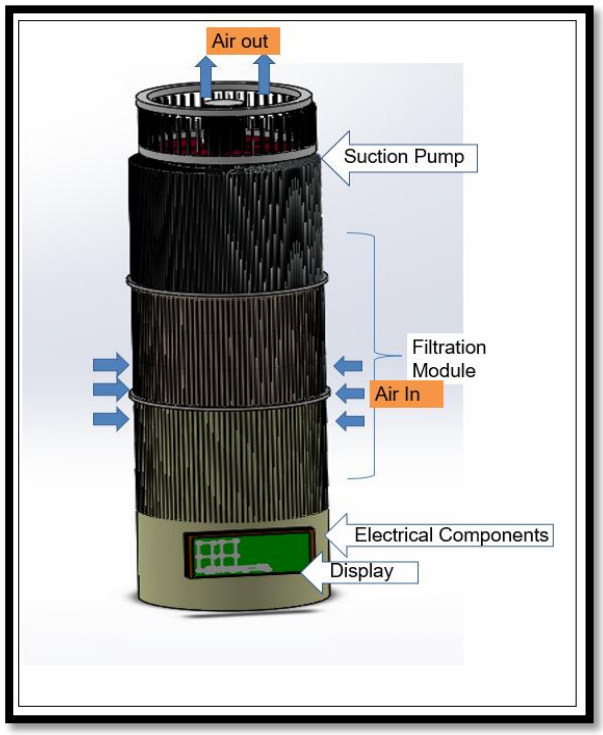

Fig. 2: Prototype 3D model of Hybrid Lamp Module

MQ135 [12] which detects a wide range of gases like MQ135 [12] which detects a wide range of gases like ammonia, sulphide and benzene steam. These sensors are integrated with Arduino UNO to determine the air quality and pressure intensity where the on-time values of the

same is to be displayed on an LCD screen on the outer side of the module as shown in the fig. 2.

5.2. Water Level Monitoring System:

The module is equipped with an ultrasonic sensor as a flood level monitor on the road. Ultrasonic sensor is a reliable [13], effective [14] and economic [20] device for such purpose. HC-SR04 (shown in fig. 3) provides 2 cm to 400 cm non-contact measurement of the distance. For effectual angle of 15 degree, the ranging accuracy can reach to 3mm. 5V power supply can be used to power it. It will be used to detect the rising water level (as per the proposed idea). The HC-SR04 is a proximity sensor that tells whether an object is in front of it and provides the distance between the object and the sensor.

Fig. 3 : HC-SR04 Ultrasonic Sensor
(source: google images)

It works on the following principle (as shown in fig. 4):

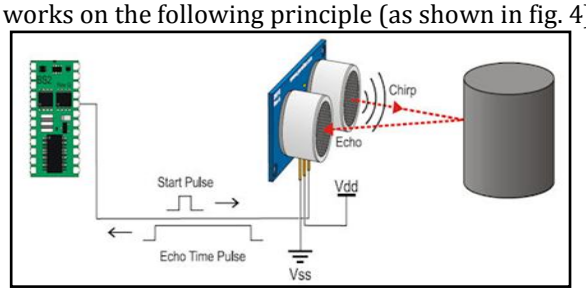

Fig. 4: Principle of ultrasonic sensor
(source: google images)

$$\text{Distance} = \frac{\text{Time interval between transmitted wave and received wave}}{2}$$

Filling in the constants and known values-

$$\text{Distance (in cm)} = \frac{[(\text{Duration of pulse}) * 0.0134]}{2}$$

The sensor is integrated into an arduino UNO along with a red-light indicator. A program is embedded in the system which shows the level of water on road in real time. The reading is displayed on the LCD screen. We can set a safe limit and when the water level rises beyond that the beeper goes on [9]. The information can also be fed directly to a traffic monitoring system.

5.3. Green energy production:

The third aspect of this project is generation of green energy using piezoelectric sensor. There are 10 piezoelectric sensors used in the prototype, all kept in series order and are covered by silica gel on either side to prevent the breaking of plates under vehicle loads. These panels are encased protected and to be put under the roads on which vehicles will be passing. On passage, the vehicle exerts a pressure on the plates under the road and the piezoelectric sensors converts vibrational energy into electric energy [10].

In fig. 5, the prototype of the street lighting system is shown along with its circuit diagram in fig. 6, where the piezo sensors are placed beneath the slabs of the road. The vehicles are not always in same phase with each other, the piezoelectric sensors will not be pressed on in the same phase either. This requires us to make use of some provision to rectify the current being produced. Therefore, we have introduced Villard Cascade Circuits into the system. It is kept one in series with every piezoelectric material. It ensures the current to flow in only one direction. By the piezoelectric materials, the loss in every vibration, seems not much remarkable.

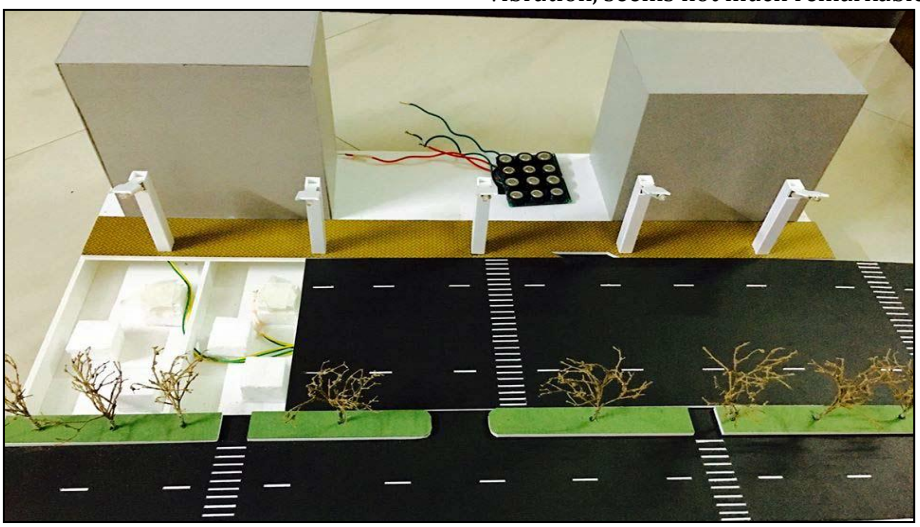

Fig. 5. The prototype smart street lighting system

Also, now the rectified current found to be capable of charging the supercapacitor in lesser amount of time. On full charge, the supercapacitors in series/parallel can allow a voltage of 9V. It is what we need to light up the bulbs for 25 Farads. 12 V of voltage is already obtained to operate the lights. Voltage & current multipliers and Inverters are used along with Villard Cascade circuit where there is need of AC supply in street lamp & requirements of strong power.

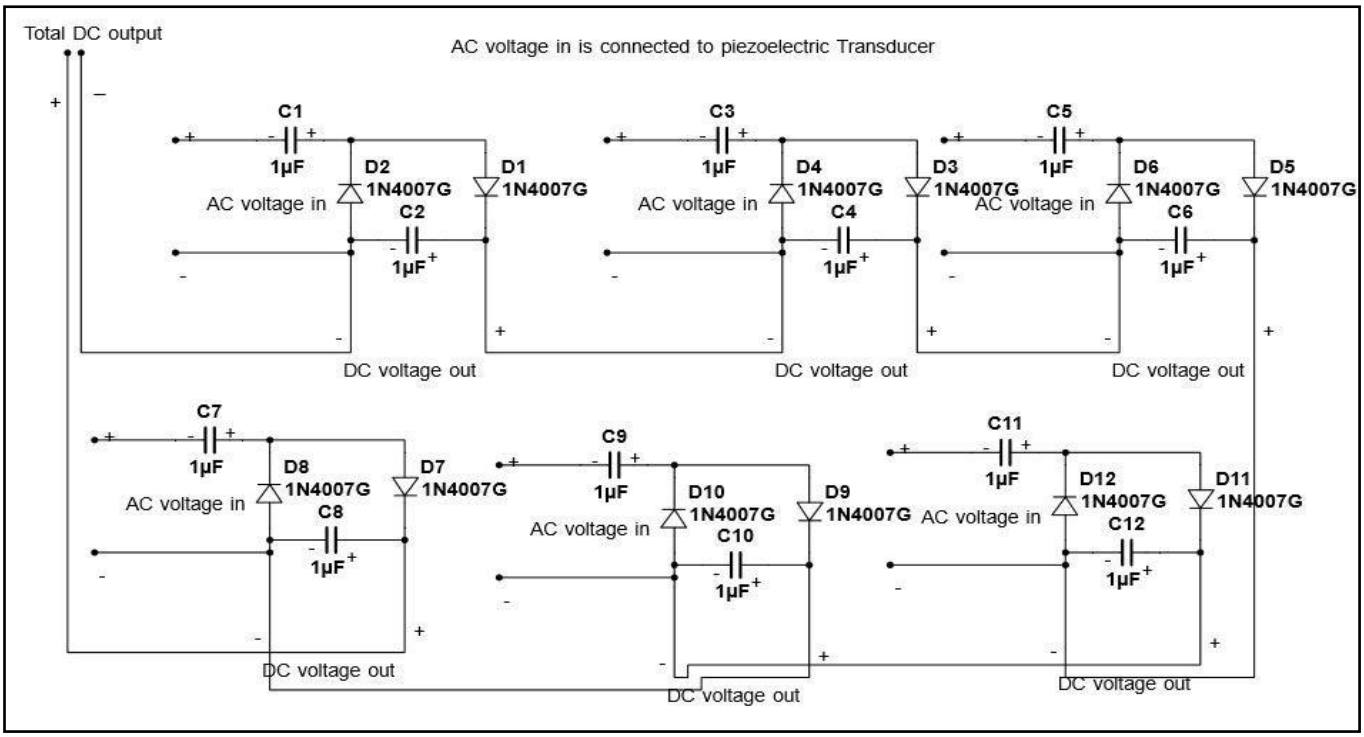

Fig. 6: Circuit Diagram

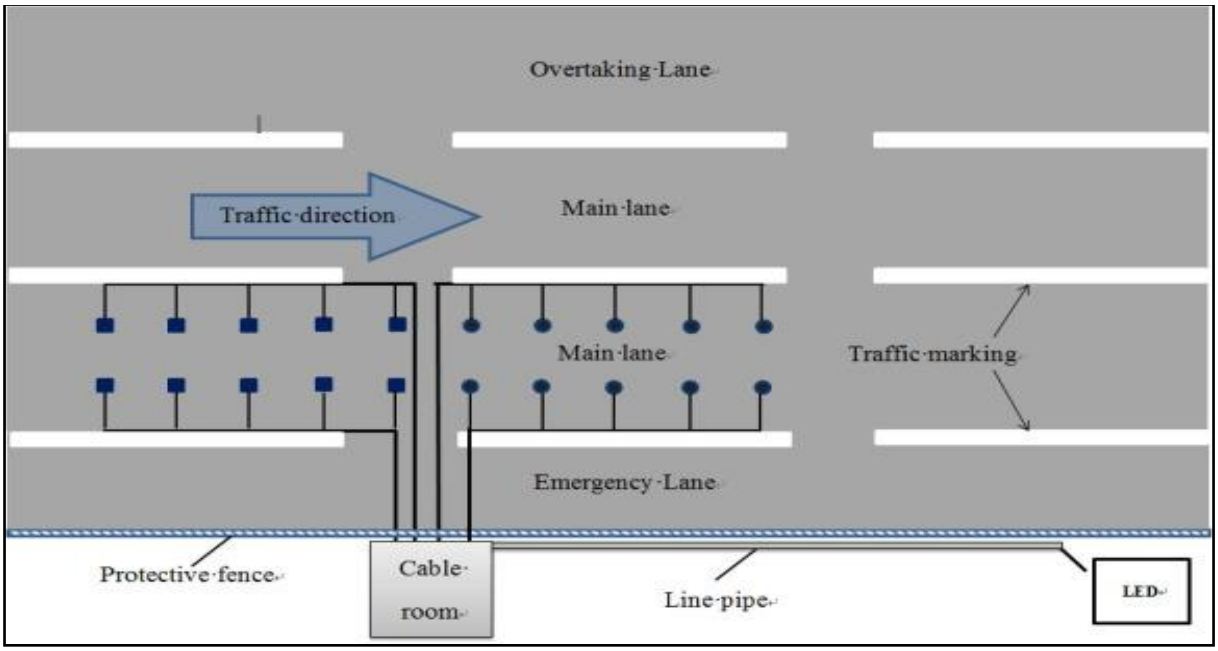

Fig. 7: Details of Road

(Source: Google Images)

Instead of conventional light sources like sodium bulbs, the system will be lighting up LED lights. With power rating of 10 watts, each light is more efficient than any other light sources being used for these purposes. To retain its integrity and keep working if one light is damaged by any external cause, the lights will be placed across each other in parallel. We are even opting for 3-Stage approach that is piezeo system below the road, Battery settings on road and

other circuits for lamp above the road as shown in fig 7. Even we are trying have a road of type as suggested by Prof. Rajagopalan Vasudevan for a great elasticity and long-life road for piezeo-cushning effect.

6. EXPERIMENTAL RESULTS

The air quality index measured by the MQ135 is then displayed on the LCD screen. There needs to be considerable difference between the filtered air and the outside air in terms of AQI, if not, then the filter can be turned off to achieve economy. The pressure inside the HEPA filter is measured by the BMP 280 sensor and the same is displayed too. When this pressure drops significantly after few months, it will serve as indicator to change the filter media. These two sensors help to monitor the performance of the filter.

While holding the Ultrasonic sensor near an experimental water body, we observed the results over an LCD display as shown in fig. 8. As soon as the water level increased beyond the limit (4 cm in this experiment), a beeper went on imitating a danger signal. In our prototype we have planned to implement a GSM module to send the alert to public and traffic authorities [6].

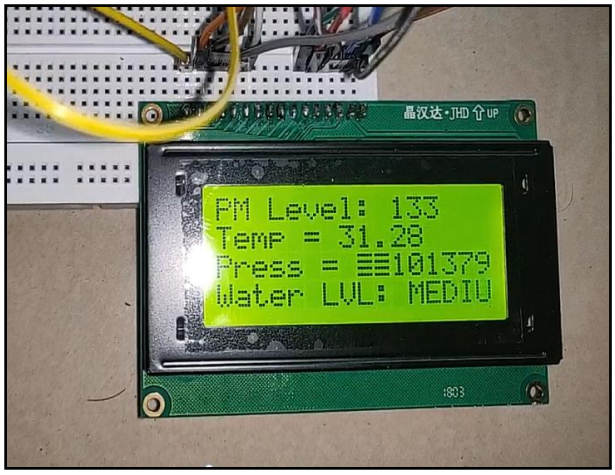

Fig. 8: Results displayed on LCD

- **Calculations for green Energy:**

Contents	Amount
KW (kilowatt) needed daily power for device	0.23KW
KWH price by Government (official)	Rs.5 from minimum to 500kwh
Needed electricity for 170 days	0.23*170 = 40KW
Needed cost of electricity for 170 days: KWs (kilowatt) needed daily power for device* KWH price by Government (official)	0.23KW*Rs.5*170=196Rs.approximately 200Rs.
Vehicle passing, per day: Given parameter is according to survey, observation and simulation	500 to 1000
Lifespan of complete system	6 months (approximately 170 days)
Initial piezo set cost: (unit & its equipment price * number of piezo cell)	Rs.50*100=Rs.5000
Initial one component cost (including all accessories)	6400Rs.
Total initial cost for per 5meter square area: (5*Initial piezo set cost) + (Initial one component cost)	Rs.31400
Total initial cost for 100 square meter area: (100*Initial piezo set cost) + (20*Initial one component cost)	6,28,000 Rs.
Daily generation: (Number of pass, per day, per square meter * power generated watt for each square meter * number of square meters)	(400*24000W*100) = 960,000,000 W

Generation of power for 170 days	960,000,000 W*170 =1,63,200 MW
Power loss in Watt: Any natural Disaster or unforeseen condition (assume 100 days as like in pandemic situation)	100*960,000,000 = $960*10^8$
Actual power generated: Generation of power for 170 days- Power loss in Watt	67,200 MW
KW Generated price in Rs for 170 days: (Daily generation capacity by KWh * KWH price by Government (official)	960,000KW*5*170 = $816*10^9$ Rs.
Losses in power generation in Rs: Any natural Disaster or unforeseen condition	Actual power generated*5 = $336*10^9$ Rs.
Total cost for 6 months: (Total initial cost for 100 square meter area for Lifespan of 170days) + (Maintenance & Services)	6,28,000 + 5000 = 6,33,000 Rs.
Profit gained in terms of monetary value: (KW Generated price in Rs for 170 days)- (Total cost for 6months)	480 Crore -approximate 10 Lacs = approximately 450 Crore
KW power gained from 100 m^2 area for 170 days: (Actual power generated) - (Needed electricity for 170 days)	67,200 MW – 40 KW = approximately 60 GW

7. CONCLUSIONS

The designed hybrid street lamp helps in monitoring the time to time air quality in the surrounding environment. The HEPA filter traps the particulate matter up to 0.3 and the pollen grains too which causes respiratory diseases may reduce. The proposed system is a reliable solution for the escalating concern of air pollution in the city. When implemented on real ground basis a centralized view will be provided to the official authorities to monitor the changes in the air quality. The bottom-up method helps the air flow equally in the environment and will restrict the air from getting polluted by the car emissions.

The pressure sensor in the hollow space of the filter notifies via the display for the servicing or changing the clogged filter. Ultrasonic sensor used for detecting the flood level has been proved effective as it beeps on the given height parameter which is chosen to notify during the heavy rainfalls. The sensor gives a clear indication of the rising water level without any errors yet and can effectively turn on the led bulb once it reaches the estimated height. Still it will require weekly maintenance as precautionary methods. This research can be adopted and be used to avoid traffic and the damages to the cars and even accidents because it can be integrated with the online road apps to notify the public about a road being blocked due to floods.

Green energy generated with the help of Piezoelectric sensors is going to serve the proposed system with electricity with no additional charges.

It can bring a big toll and benefit the country with better revenue if implemented on large scale. The amount of carbon emission and carbon footprint will also decrease and can promote sustainable development in the cities.

REFERENCES

1. Akshay Chavan, Manav Dodiya, Sagar Davate, Sameer Prajapati, Karthik Nagarajan (2019) "Sustainable Water Harvesting Technique by Condensation of Water through Atmosphere in an Optimized Approach for Future Cities in India" - Conference On Technologies For Future Cities (CTFC) 2019,(April 2019), SSRN(Elsevier), (March 5, 2019) ISSN: 2278-3075, ISBN: 978-93-82626-27-5, July 2019 ,pp.1- https://futurecities.mes.ac.in/wp-content/uploads/2019/04/CTFC-2019-Final-Proceedings.pdf(203-207) http://dx.doi.org/10.2139/ssrn.3346936
2. Arya Vijayan, Raju Narwade and Karthik Nagarjan (2019): "Real Time Water Leakage Monitoring System Using IoT Based Architecture "International Journal for Research in Engineering Application & Management (IJREAM), (Nov-2019), ISSN: 2454-9150, Vol-05, Issue-08, pp.24-30, DOI : 10.35291/2454-9150.2019.0480

3. Biradar Shilpa, Karthik Nagarajan, Raju Narwade, Prof. Gayatri Deshpande, (2019): "E-Waste: An Alternative to Partial Replacement of Coarse Aggregate in Concrete", International Journal of Engineering Research & Technology (IJERT), (July-2019) ISSN: 2278-0181, Volume 08, Issue 07 (July 2019), pp.993-999
4. Chhaya Zende, Karthik Nagarajan, Raju Narwade (2019) : "Manufacturing Techniques of Sustainable Recyclable Formwork By A Smart Material Waste Composite Material (WCM) for Infrastructural Projects of Future Cities - A Swachh Bharat Abhiyan Initiative " , International Journal of Management, Technology And Engineering (IJMTE) , (June-2019), ISSN NO : 2249-7455 ,Vol:9, Issue:6, pp.666-671
5. Chowdary Mohanlal, Karthik Nagarajan and Raju Narwade (2019): "Applications of 4D GIS Model in Construction Management " International Journal of Innovative Technology and Exploring Engineering (IJITEE), (July-2019) ISSN: 2278-3075, Volume-8 Issue-9, July 2019 , pp.2597-2608
6. Dadasaheb K. Mane, on "Disaster Flood Alert System Using Ultrasonic Sensor", International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 1, January- 2013.
7. doi: 10.14445/23488352/IJCE-V6I3P105
8. https://www.sciencedirect.com/science/article/pii/S0160412018311413
9. https://store.arduino.cc/usa/arduino-uno-rev3
10. https://www.bosch-sensortec.com/products/environmental-sensors/pressure-sensors/pressure-sensors-bmp280-1.htm
11. https://www.mi.com/in/air-purifier
12. https://www.rhydolabz.com/sensors-gas-sensors-c-137_140/air-quality-sensor-mq135-p-1115.html
13. https://www.sciencedirect.com/science/article/pii/S0160412018311413
14. John D. Boon and John M. Brubaker, on "Acoustic-Microwave Water Level Sensor Comparisons in an Estuarine Environment', 978-1-4244-2620-1/08/$25.00 ©2008 IEEE.
15. Konstantinos Loizou, Eftichios Koutroulis, Dimitrios Zalikas and Georgios Liontas, on "A low-cost capacitive sensor for water level monitoring in large-scale storage tanks", 978-1-4799-7800-7/15/$31.00 ©2015 IEEE.
16. Pallavi Patil, Karthik Nagarajan and Raju Narwade (2019) : " Resource Management of Infrastructural Project for Future Cities: A Re Modified Minimum Moment method " International Journal of Management, Technology And Engineering (IJMTE) , (Feb-2019), ISSN NO : 2249-7455, Vol:9, Issue:2, pp.1094-1099
17. Prathamesh Brid, Karthik Nagarajan and Raju Narwade (2017) "Fuzzy AHP-Vikor Method for Decision Making for Residential Project" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 8, August 2017, pp17136-17140
18. Pravin Shahi and Raju Narwade (2018) "Optimization Measures and Techniques of Structural Assessment– A Non-Destructive Test Approach'' International Journal of Civil Engineering and Technology (IJCIET) Volume 9, Issue 3, March 2018, pp. 906–913
19. Rahul Hazarika, Raunak Upadhyay, Sayali Joshi, Tarandeep Singh, Karthik Nagarajan (2019) "A Sustainable Smart Technique for Generating Water from Atmosphere for Future Cities - A Thermal Electric Cooling Approach," Conference On Technologies For Future Cities (CTFC) (March 5, 2019), SSRN(Elsevier), (Apr 2019) ISSN: 2278-3075 July 2019 ,ISBN: 978-93-82626-27-5,pp.1-6 https://futurecities.mes.ac.in/wp-content/uploads/2019/04/CTFC-2019-Final-Proceedings.pdf
20. Sanika Kandalekar, Raju Narwade and Karthik Nagarajan (2019) : "Feasibility of Pervious Concrete Pavement: A Case Study of Karanjade Node, Panvel " SSRG International Journal of Civil Engineering (SSRG-IJCE)" ,(March-2019) , ISSN: 2348-8352 , Volume 6, Issue 3 - March 2019 , pp.35-40.
21. Shrenika R. M., Swati S. Chikmath, Dr. Ravi Kumar A. V., Mrs. Divyashree Y. V. and Mrs. Roopa K Swamy, on "Non-contact Water Level Monitoring System Implemented Using LabVIEW and Arduino", 978-1-5090-6701-5/17 $31.00 © 2017 IEEE.