Final Report on

Designing of Integrated Environmental Management Information System (IEMIS)

Formulation of Air Quality Index (AQI) and Pollutant Emission Inventory (PEI) for Nepal

Submitted To:
Department of Environment (DoENV)
Ministry of Population and Environment,
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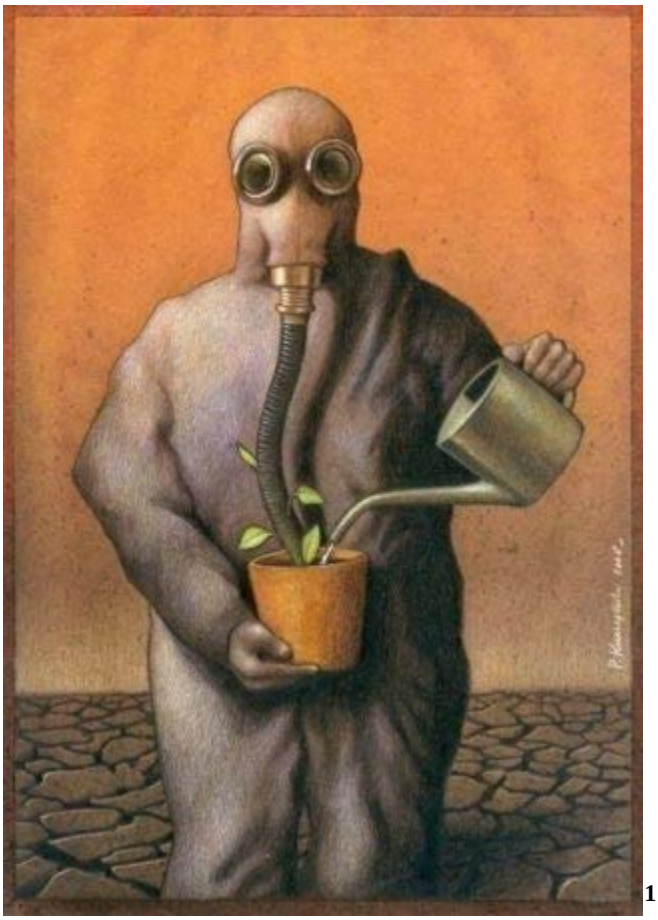
Management Training Environmental Engineering Consultancy

When the last tree is cut and the air to breathe is sickening, when the last fish is caught, and the last river is polluted, you will realize, too late, that wealth is not in bank accounts and that you can't eat money.



1

[1] Picture courtesy https://www.pinterest.com/pin/537476536760830771/

Table of Content:

List of Tables

List of Figures

Abbreviations:

APEI	Air Pollutant Emission Inventory
AQHI	Air Quality Health Index Canada
AQI	Air Quality Index
CO	Carbon monoxide
DoEnv	Department of Environmental
EPA	Environment Protection Act
EPR	Environment Protection Regulation
EIMDB	Environmental Information Metadata Base
EPM	Environmental Planning and Management
GON	Government of Nepal
GHGs	Greenhouse gases
IEMIS	Integrated Environmental Management Information System
Pb	Lead
MIS	Management Information Systems
MTEEC	Management Training Environmental and Engineering Consultancy
NAAQS	National Ambient Air Quality Standard
NGOs and INGOs	National and international non-governmental organizations
NEPM	National Environment Protection Measure Australia
NO_2	Nitrogen dioxide
O_3	Ozone
PM_{10} and $PM_{2.5}$	Particulate matters
SO_2	Sulfur dioxide
TSP	Total suspended particles
EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Chemicals
WHO	World Health Organization

1. Introduction

Management Training Environmental and Engineering Consultancy (MTEEC) was assigned as a consultant to "**Designing of Integrated Environmental Management Information System (IEMIS)**" (here in after study or project) by Department of Environmental (DoEnv) on 2072.12.26.

1.1 Background

IEMIS is defined as "organizational-technical systems for systematically obtaining, processing, and making available relevant environmental information available in various sectors in an integrated manner"[1]. IEMIS is sound practical basis for environmental management within organizations. Environmental Management Information System (EMIS) consists of formalized steps to capture information, as well as fixed procedures to retrieve this information. Accordingly, the development of Environmental Management Information Systems (EMIS) attempts to simplify and automate environmental management tasks and encapsulate such techniques as environmental cost accounting, lifecycle assessment, as well as auditing and compliance[2]. IEMIS empowers staffs of an organization and all the stakeholders of environment to effectively manage environmental, health and safety programs by providing real time data and situation about environment in an organized form. In addition, EMIS covers the gathering of all relevant information for the Environmental Planning and Management (EPM) Process. It also validates subjective as well as objective studies related to environment, data related to environment and other information carried out by various organizations through mainstreaming it in single system. It also saves time and money by checking repeated study to generate same data base for similar work by different organization at the same time.

[1] El-Gayor, O and Fritz, B.D. 2006. Environmental management information systems (EMIS) for sustainable development: a conceptual overview. *Communications of the Association for Information Systems*, 17(34): 756-784.

[2] Rikhardsson, P.M. 2001. Corporate Environmental management and information technology. *Ecosystem management and auditing*, 8: 90-99.

1.2 Need and importance of IEMIS and its uses for Nepal

- **To manage records in an integrated manner**: Large quantity of records in Nepal are still produced in paper storage media. Integrated environmental management information system helps to store the multitude of data in one place, making it assessable whenever it is wanted or needed in digital format in an integrated form. In doing so it also reduces the administrative costs as filing equipment, staffing among others.
- **To improve efficiency and productivity:** It is often found that different organizations produce similar kinds of data. An integrated information system helps to enhance information retrieval within and outside of the organization through the sharing of knowledge and effort across the same lines. Thus making sure that there is no repetition of data across organizations.
- **Problem identification and assessment**: Identification of priority issues and establishment of targets for environmental policy. It also helps in search and evaluation of policy alternatives, including environmental management instruments and measures.
- **To support better management decision making**: Availability of good information lies at the heart of effective and equitable decision making. Hence, cohesive and effective information management system is a necessary part of the quest to make more forward looking, comprehensive decisions impacting environment stewardship.
- **Implementation and evaluation of policy performance:** An integrated environmental management provides an effective methods of communication that allows broad, interactive participation in the planning, assessment, decision making and evaluation.

1.3 Understanding of the project

We understand that Department of Environment (DoE) was established in 2012 under the Ministry of Science, Technology and Environment, Government of Nepal. The primary responsibility of the department is to implement and monitor the activities that are directly or indirectly related to environmental pollutions. At the same time it is responsible for maintaining the standards in compliance of the Environment Protection Act (EPA), 2053, and Environment Protection Regulation (EPR), 2054 set out by the Government of Nepal. For the purpose, department of environment works in coordination with diverse line agencies from different ministries and

stakeholders such as non-governmental organizations, private entities, industries, local committees, media and the people at the end.

In Nepal, Management Information Systems (MIS) by Government of Nepal (GON) are in practice in various other sectors (health and education) but MIS in environment sector by GON is not practiced yet. As consequence, government as well as national and international non-governmental organizations (NGOs and INGOs) working in environmental sector made various studies repeating same sector for same kind of data and situation. On the other hand, the data and information generated by these organizations in environment sector make only use for their own purpose and is not valid for other organizations and or study. Therefore a MIS in environment sector is immediate need to overcome these situations. Not only is the creation of such MIS but also the timely update mechanism an important prerequisite for achieving environmental goals. In this regard, Department of Environment (DoEnv) carried out a feasibility study for the establishment of Integrated Environment Management Information System (IEMIS) that collects, manages, analyses data and publishes reports on regular basis. Now, it is planning to go ahead with the creation and deployment of such system. MTEEC was chosen as the consultant organization and this is the inception report for the project.

1.4 Scope of the project

Department of Environment (DoEnv) carried out a feasibility study for the establishment of Integrated Environment Management Information System (IEMIS). For this our organization, Management Training Environmental and Engineering Consultancy (MTEEC), was assigned as a consultant for "Feasibility Study for Establishment of Integrated Environmental Management Information System in Nepal by Department of Environmental (DoEnv) and submitted the report on July, 2015. The study suggested a core set of 89 environmental indicators under 12 thematic areas/module and based on these it was suggested that an Environmental Information Metadata Base (EIMDB) be created for cataloguing, searching, retrieving and sharing environmental indicators information, maps, and graphs via the software. Also, the study proposed a software model including users' requirement, their role and responsibilities, hardware, software and human resource requirement, the outlook of the system and also recommended a data validation mechanism. The current study, as we believe, is the first stage for the designing the Integrated Environment Management Information System (IEMIS) for one of the modules among the 12 as

suggested by the feasibility study. It is foreseeable that the system will be designed for all the indicators in the coming years and this current study will prove beneficial in such an endeavor.

1.5 Objectives

Broad Objective: The major objective of this project is to create and deploy an Integrated Environment Management Information System (IEMIS) based on the feasibility study for the establishment of Integrated Environment Management Information System (IEMIS) in Nepal.

Specific Objectives:

- Preliminary design of the Integrated Environmental Management Information Systems (IEMIS) for Air which is one of the 12 modules suggested during the feasibility study
- Provide a format for data entry into the system and define the output for that particular module/theme.

1.6 Deliverables

The final deliverable of the phase 1 will be the general structure of the initial system which includes the following:

- Data input formats on any one of the modules/themes and its respective indicators
- Flow of information through the initial system
- Output of the system in the form of a report
- User groups and roles with access levels (who has what access)

2. Literature Review

2.1 Criteria Air Pollutants

The six pollutants carbon monoxide (CO), particulate matters (PM_{10} and $PM_{2.5}$), ozone, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb) are often referred to as criteria pollutants. These have been known to harm human health and the environment and also cause damage to properties. However, in light of the fact that lead (Pb) are not known in real time and cannot contribute to the real time AQI, it has been excluded from this study.

- **Carbon monoxide**: CO is an odorless, colorless gas and is an important criteria pollutant that is ubiquitous in urban environment. CO production mostly occurs from sources having incomplete combustion and are highest during cold weather. Vehicle exhaust contribute to the majority of CO emission. Other important sources include fuel combustion in industrial processes and natural sources as wildfire.
- **Particulate matters**: particulate matters consists of mixture of solid and liquid droplets that are either emitted directly to when pollutants emitted by various sources react in atmosphere. Particles comes in wide range of sizes and are often classified as PM_{10} (particles between 2.5-10 micrometers) and $PM_{2.5}$ (particles that are 2.5 micrometers or less in diameter). Major sources include dusts stirred up by moving vehicles, crushing and grinding operations, wood and agriculture burning and other industrial or combustion processes.
- **Ozone**: Ozone is a secondary pollutant formed in the atmosphere when pollutants (emitted by cars, power plants, industrial boilers, refineries and chemical plants) reach chemically in sunlight. Although ozone layers in the stratosphere protects from harmful UV radiation, it can have negative impact on the health of the people when its concentration is high near the ground level.
- **Sulfur dioxide**: Sulfur dioxide is a colorless, reactive gas and is produced when sulfur containing fuels as coal and oil are burned. Major sources include power plants, refineries and industrial boilers.

- **Nitrogen dioxide**: the major source of NO_2 is combustion processes. It forms quickly from emissions from cars, trucks, buses, power plants and off-road equipment.

2.2 Health Implications of Criteria Pollutants

Some of the most frequent health impacts of the pollutants are listed below in table 1.

Table 1 Most Frequent Health Impacts of the Criteria Pollutants

Pollutant	Health Impacts
Carbon monoxide	• Reduce the oxygen-carrying capacity of the blood • Cause headache, dizziness, vomiting, and nausea and in extreme cases death
Particulate matter	• Effects on breathing, respiratory symptoms, decrease in pulmonary function • Damage to lung tissue, cancer, and premature death
Ozone	• Irritate the respiratory system • Reduce lung function and cause lung damage • Aggravate asthma and other chronic lung diseases
Sulfur dioxide	• Reduced lung function • Bronchoconstriction (narrowing of airways) • Aggravate asthma
Nitrogen dioxide	• Decrement in lung function • Chronic respiratory illness

2.3 Air Quality Monitoring and Air Quality Index (AQI)

Air is indisputably one of the most important natural resource. Clean air is vital for human health and wellbeing. However, most cities around the world, particularly in developing countries, are experiencing worsening air pollution due to a number of factors as uncontrolled urbanization, increasing number of fossils fuel burning vehicles and highly concentrated industries around these areas. The World Health Organization (WHO) and other international agencies have long identified urban air pollution as a critical public health problem. Furthermore, the air pollution can have a number of a profound negative impact on regional and global scale like in the form of global warming and climate change. An effective monitoring of air pollution is the need of the hour so that the citizens are better informed of the kind and level of pollution they are exposed to. Also, it will help decision makers to formulate and implement realistic and effective strategies and action plans to improve air quality. To address these, the concept of Air Quality Index (AQI) has been

developed and used effectively in many developed countries over the last three decades. An AQI is defined as an overall scheme that transform weighted values of individual air pollution (CO, $PM_{2.5}$ etc.) related parameters in a single number or a set of numbers.

2.4 Applications of Air Quality Monitoring and Index:

An AQI can be used by general public, decision makers, government official and scientists and serves different purposes. Some of these are listed below:

- **Location classification**: The air quality of different locations can be quantified and locations/cities can be compared and classified based on potential hazards.
- **Resource allocation**: AQI can help in determining priority pollutants and location and resources can be channeled accordingly.
- **Conformance to standards**: The extent to which the current standards have been adhered to can be determined and causes behind the non-conformance to these standards can be identified.
- **Trend analysis**: The status of air quality over a period of time can monitored and the subsequent degradation/improvement can be analyzed. This in turn helps in planning control measures if the pollution has be found to be constantly deteriorating.
- **Public information**: Provides a simplified platform for dissemination of data in a format that can be understood easily by the general public.

Despite these obvious applications, there has not been significant effort to develop and use AQI in Nepal, primarily due to the following three reasons:

- Modest air quality monitoring programs
- Lack of continuation of such programs
- Absence of comprehensive air quality standards

2.5 Air Quality Monitoring In Nepal

Recently, Numbeo which is a crowd-sourced global database has ranked Kathmandu the third most polluted city in the world after Tetovo (Macedonia) and Cairo (Egypt). Although the methodology for the ranking is highly debatable, it shows the grim air pollution status in Kathmandu and other urban areas of the country. Dust pollution from the massive demolition and reconstruction activities under road expansion and earthquake recovery in Kathmandu Valley has seriously

affected the environment and public health. The levels of particulate matters (PM) in the ambient has risen to hazardous levels. A 2014 report of the Ministry of Science, Technology and Environment showed that the PM_{10} levels in the air of Kathmandu was 400 $\mu g/m^3$ which is more than three folds of permissible limit of 120 $\mu g/m^3$ set by the National Ambient Air Quality Standards 2012[3]. Other major sources of particulate matters in Kathmandu are brick kilns, domestic fuel burning, vehicles and other mobile sources. The National Ambient Air Quality Standards, 2012 sets the limits on some of the most important pollutants but the government has neither conducted the monitoring of the adherence to these limits nor taken any effective actions to abate the levels of pollution. Six monitoring stations were set up to monitor ambient air quality of the Kathmandu Valley in 2002, but they went defunct in 2007 and since then the agency has been relying on international agencies for measuring air quality.

2.6 Air Quality Policies and Standards in Nepal

The government has introduced several policies, legislation and standards related to air pollution in Nepal. Some of the most important standards are given below:

2.6.1 National Ambient Air Quality Standard (NAAQS, 2012)

Table 2 National Ambient Air Quality Standard (NAAQS, 2012)

Parameters	Units	Averaging time	Con. Max.
TSP[4]	$\mu g/m^3$	24-hours	230
PM_{10}	$\mu g/m^3$	24-hours	120
$PM_{2.5}$	$\mu g/m^3$	24-hours	40
Sulfur Dioxide	$\mu g/m^3$	Annual	50
		24-hours	70
Nitrogen Dioxide	$\mu g/m^3$	Annual	40
		24-hours	80
Carbon Monoxide	$\mu g/m^3$	8-hours	10,000
Ozone	$\mu g/m^3$	8-hours	157
Lead	$\mu g/m^3$	Annual	0.5
Benzene	$\mu g/m^3$	Annual	5

[3] http://kathmandupost.ekantipur.com/news/2016-03-20/kathmandu-3rd-most-polluted-city-in-the-world.html
[4] Total Suspended particle (TSP)

2.6.2 Indoor Air Quality Standard and Implementation Guidelines (2009)

Table 3 Indoor Air Quality Standard and Implementation Guidelines (2009)

Pollutant	Maximum Concentration	
	Averaging time	Level
PM_{10}	24-hours	120 µg/m^3
	1-hours	200 µg/m^3
$PM_{2.5}$	24-hours	60 µg/m^3
	1-hours	100 µg/m^3
CO	8-hours	9 ppm (10 mg/m^3)
	1-hours	35 ppm (40 mg/m^3)
CO_2	8-hours	1000 ppm (1800 mg/$m^{3)}$

2.6.3 Other Relevant Policies and Standards

- Environment Protection Act (1997) and Environment Protection Rules (1999)
- Nepal Vehicle Mass Emission Standard, 2069
- Brick Kiln Stack Emission Standard, 2008
- Standard for Emission from Industrial Boilers, Cement and Crusher Industries and Diesel Generators
- Climate Change Policy, 2011

2.6.4 Health Related Description in NAAQS, 2003

A color coded descriptor to describe the effect on human health defined by using PM_{10} concentrations as the determining factor was given by GON in NAAQS, 2003[5].

Table 4 Color Coded Description of the Effect on Human Health based on PM_{10} Concentration Range

Descriptor	**Colour**	**PM_{10} (µg /m^3)**
Good	Green	< 60
Moderate	Yellow	60-119
Unhealthy	Orange	120-349
Very unhealthy	Red	350-425
Hazardous	Purple	> 425

[5] Ambient Air Quality of Kathmandu Valley. Ministry of Environment, Science and Technology, 2007.

2.7 Indoor Air Quality Status and Sources

Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures that have an impact on its occupants. Indoor air pollution is one of the biggest environmental problems especially in developing and least developed countries. Around 3 billion people cook and heat their homes using solid fuels which produces high levels of damaging pollutant and this combined with poorly ventilated homes severely impacts the health of the people living there. The World Health Organization estimates that 4.3 million people a year die prematurely from illness attributable to the household air pollution[6]. Predominantly children and women are the most affected by indoor air pollution. Some of the most common health impacts include:

- Chronic obstructive pulmonary disease (COPD)
- Acute lower respiratory infections (ALRI)
- Cardiovascular diseases
- Lung cancer
- Cataract
- Burns and poisoning
- Others as tuberculosis, asthma etc.

The major indoor air pollutants are NO_2, SO_2, CO_2, particulate matter, CO, ozone, volatile organic chemicals (VOCs), formaldehyde and asbestos while the major sources are fuel-burning combustion appliances, tobacco products, building materials and furnishings, products for household cleaning and maintenance, personal care, or hobbies, central heating and cooling systems and humidification devices, excess moisture and outdoor sources such as: radon, pesticides and outdoor air pollution.

2.8 Outdoor Air Quality Monitoring around the world

For this project, we studied a number of air quality monitoring and data dissemination mechanism that are employed by governments around the world. Some of them are discussed as below:

[6] World Health Organization (2014). Retrieved on 22.06.2016 http://www.who.int/indoorair/en/

2.8.1 Australia: Air Quality Index (AQI) and Live Air Data

The air quality index is calculated as the proportion of concentration of pollution and the National Environment Protection Measure (NEPM) standard of that particular pollutant.

$$\text{Air Quality Index Value} = \frac{\text{Pollutant concentration}}{\text{Pollution standard concetration}} \times 100$$

The air quality index comprises five color-coded categories with the index values over 100 indicating that the pollutant concentration exceeds the air quality standard based on health studies.

Not available	Very good 0–33	Good 34–66	Fair 67–99	Poor 100–149	Very poor >150

http://www.ehp.qld.gov.au/air/data/search.php?day=29&month=04&year=2016&hour=17&category_id=1&mode=measurement&goto=Latest+hour

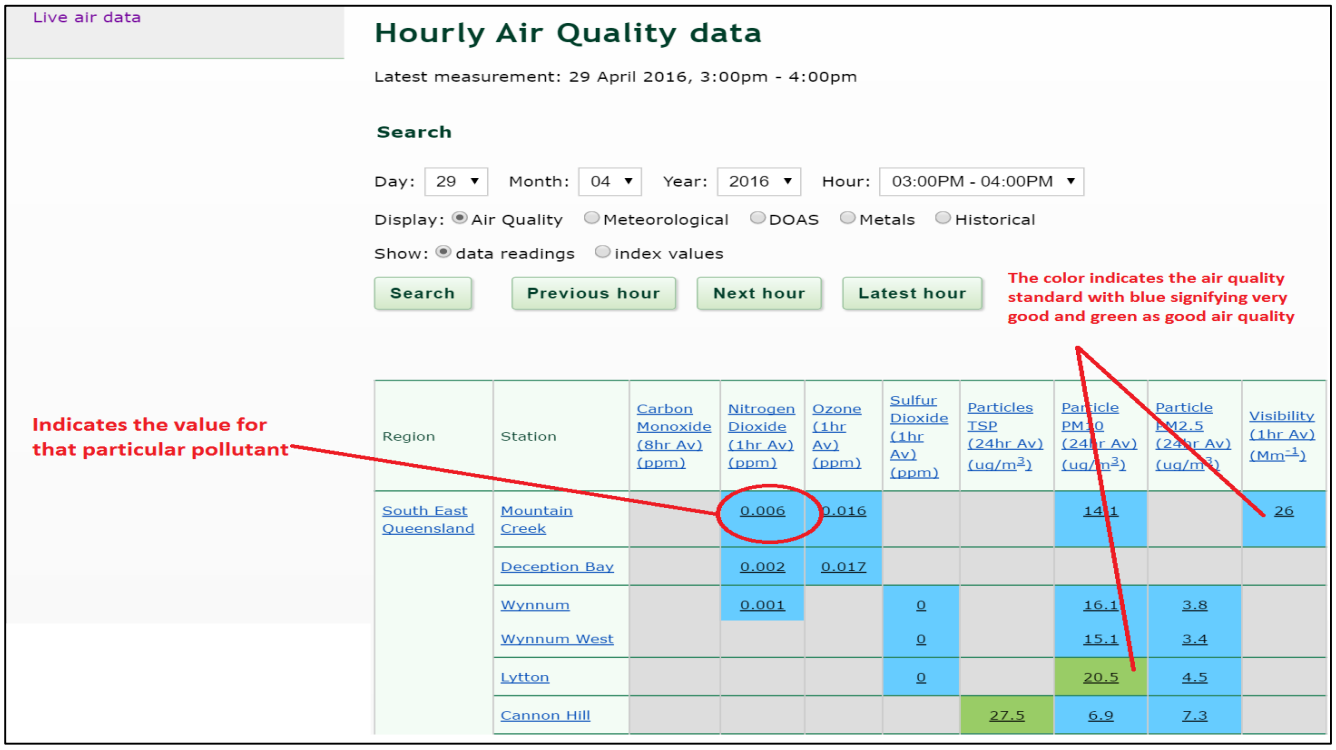


Figure 1 Hourly Air Quality Data Dissemination in Australia

2.8.2 Canada: Air Pollutant Emission Inventory and Air Quality Health Index

The Air Pollutant Emission Inventory (APEI) is an annual report of air pollutant emissions across Canada published by Environment and Climate Change, Government of Canada. It provides current and historic data on the release of air pollutants from different sources. The emission data are reported by individual facilities and Environment and Climate Change Canada also run their own estimates. It can be accessed using the online query tool, a screenshot of which is provided below.

http://ec.gc.ca/inrp-npri/donnees-data/ap/index.cfm?lang=En

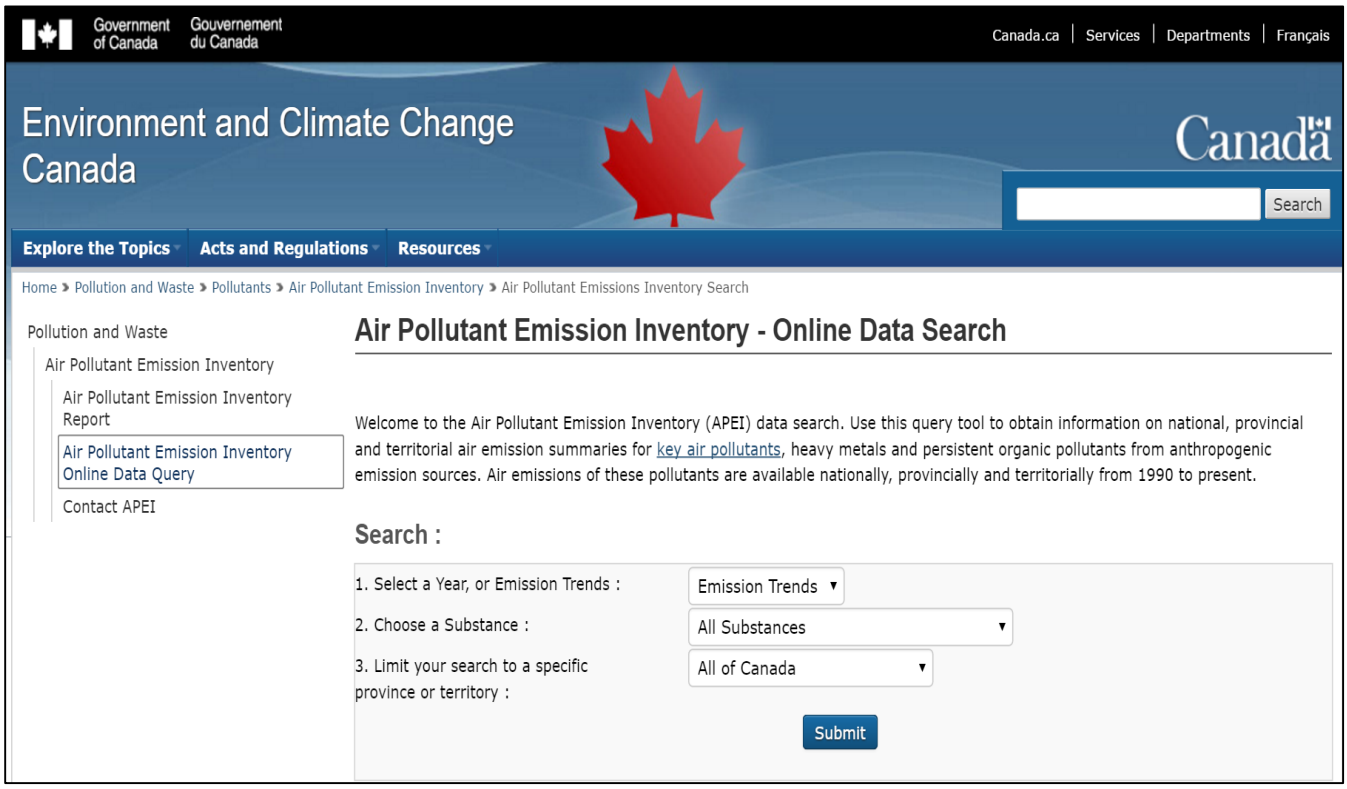


Figure 2 Air Pollution Emission Inventory for Canada

The AQHI is a tool designed to inform the public about the status of air quality around them. The AQHI is calculated based on the relative risks of a combination of common air pollutants that is known to harm human health. These pollutants are:

- Ozone (O3) at ground level,
- Particulate Matter ($PM_{2.5}$/PM_{10}) and
- Nitrogen Dioxide (NO2)

Concentrations of these three pollutants are measured continuously in urban areas across Canada by the National Air Pollution Surveillance (NAPS) Network. AQHI is measured on a scale ranging from 1-10+ and higher the level the more there is a risk to health.

2.8.3 India: Air Quality Index (AQI)

The Air Quality Index of India was launched in 2015 and basically considers the health implications of 5 categories of pollutants: particulate matter ($PM_{2.5}$ and PM_{10}), SO_2, NO_2, CO and O_3. The following formula is used to calculated sub index (I_p) for individual pollutant

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}$$

Where,
I_p= the index for pollutant p
C_p=the rounded concentration of pollutant p
BP_{Hi}= the breakpoint that is greater than or equal to C_p
BP_{Lo}= the breakpoint that is less than or equal to C_p
I_{Hi}=the AQI value corresponding to BP_{Hi}
I_{Lo}= the AQI value corresponding to BP_{Lo}

Finally, AQI is calculated as: AQI = Max (I_p)[7].

[7] The maximum value of I_p among all the individual pollutants is the AQI

The information is then disseminated online in the following form.

http://aqicn.org/city/delhi/anand-vihar/

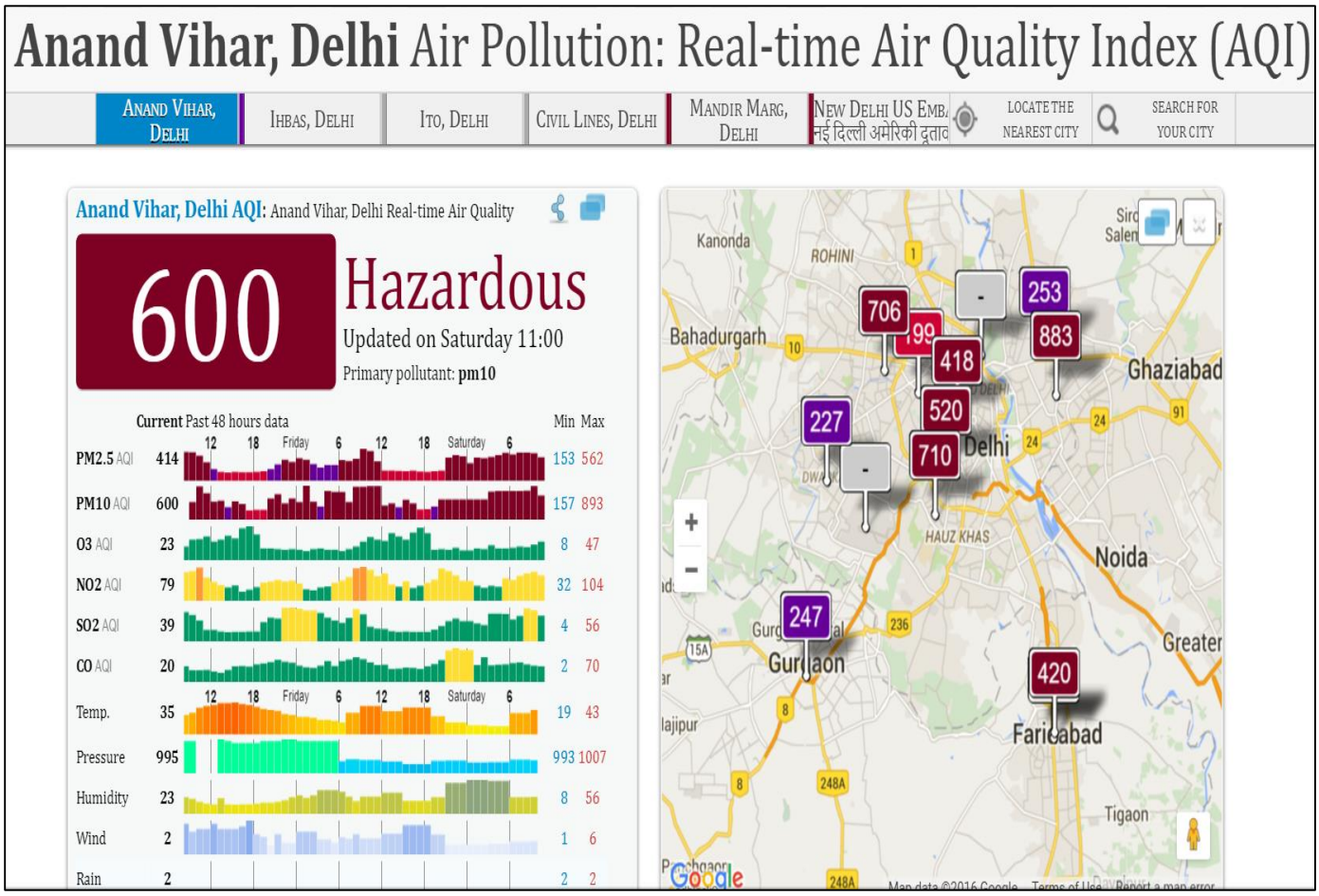


Figure 3 Real Time Air Quality Index (AQI) in Nepal

2.8.4 United States of America: Air Quality Index (AQI)

The Air Quality Index (AQI) used in India and the USA are the same. It was developed by United States Environmental Protection Agency (EPA) and India uses the same AQI calculation and health implication color code scheme as USA. The Real time monitoring data and forecasts of air quality that are color-coded in terms of the air quality index are available from EPA's Air Now web site while historical air monitoring data including AQI charts and maps are available at EPA's Air Data website.

https://www.airnow.gov/index.cfm?action=airnow.main

https://www3.epa.gov/airdata/ad_viz_tile.html

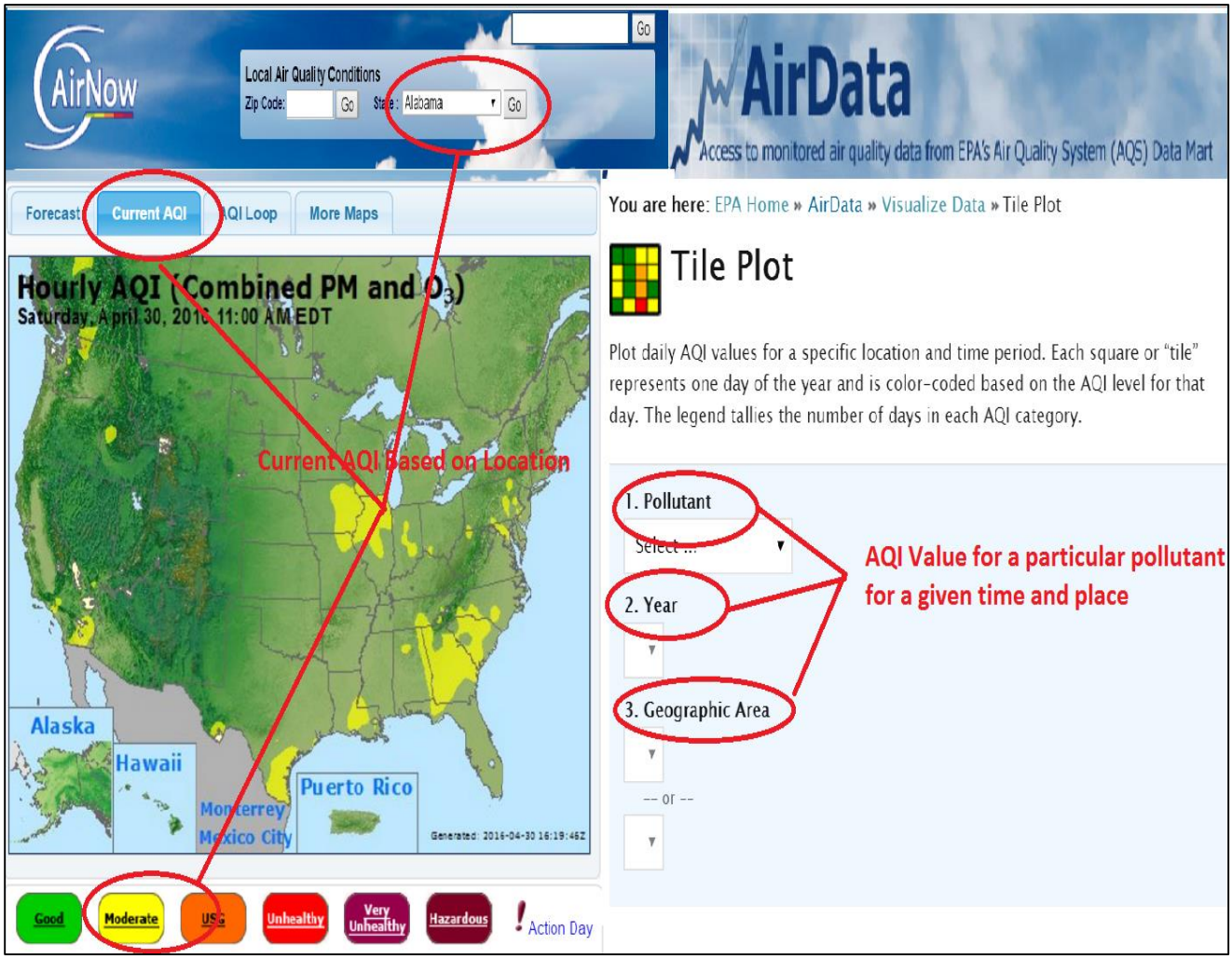


Figure 4 AQI Dissemination Portal Used in US

2.8.5 United Kingdom: National Atmospheric Emissions Inventory

The National Atmospheric Emissions Inventory (NAEI) is used by UK to keep historic and current data on a majority of pollutants. The data base has record for greenhouse gases (GHGs), air pollutants, heavy metals and base cations and particulate matter for different sectors as energy, industrial, agriculture among others.

http://naei.defra.gov.uk/data/data-selector?view=greenhouse-gases

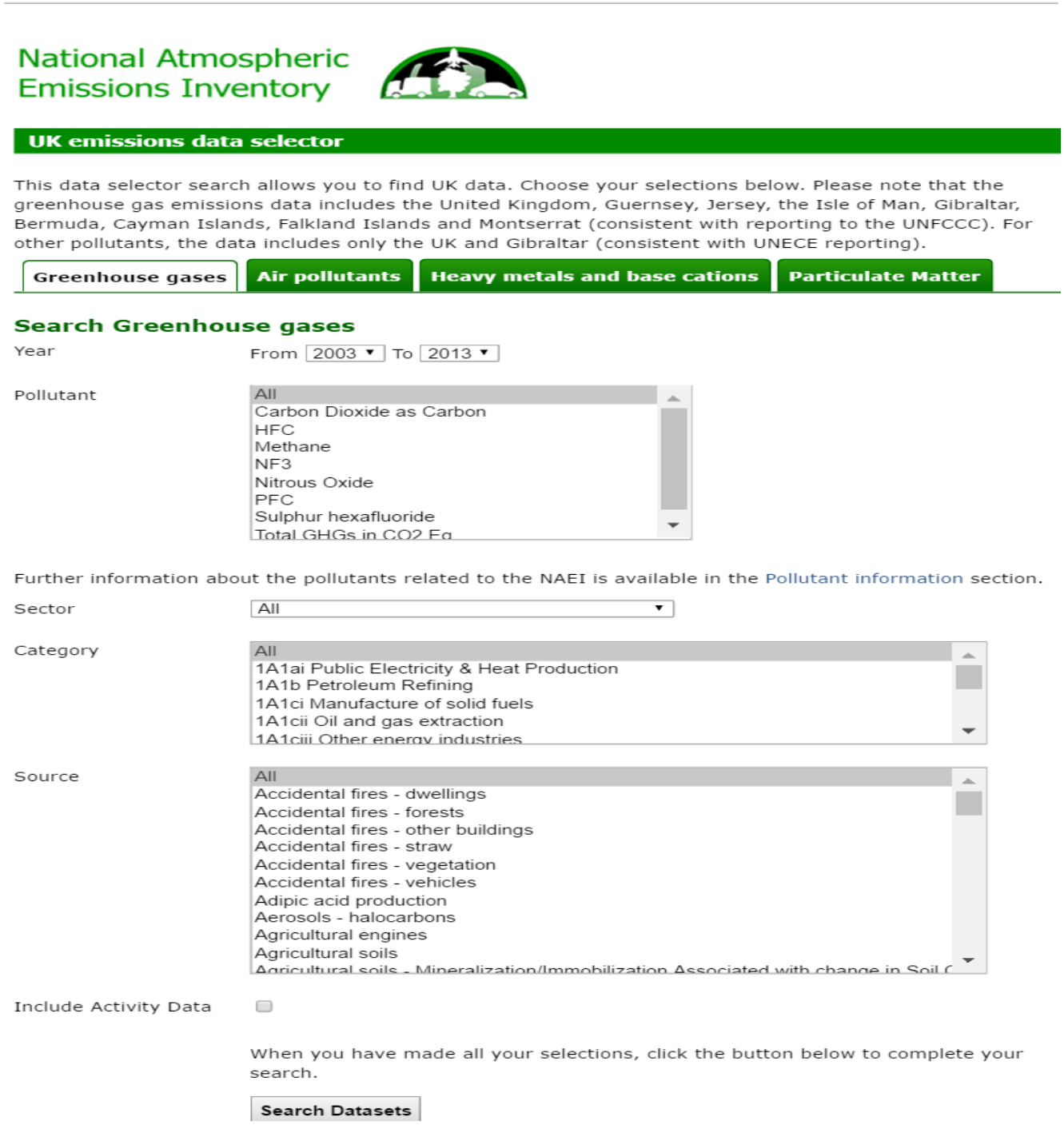


Figure 5 : National Atmospheric Emissions Inventory UK

3. Methodology

3.1 Air Quality Index (AQI) Calculation

An air quality index is defined as an overall scheme that transforms the weighed values of individual air pollution related parameters (for example, pollutant concentrations) into a single number or set of numbers (Ott, 1978). Primarily two steps are involved in formulating an AQI:

(i) Formation of sub-indices (for each pollutant) and

(ii) Aggregation of sub-indices to get an overall AQI.

The general equation for the sub-index (I_i) for a given pollutant concentration (Cp) is calculated using the formula developed by U.S. Environmental Protection Agency (EPA)[8] and given as:

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}$$

Where,
I_p= the index for pollutant p
C_p=the rounded concentration of pollutant p
BP_{Hi}= the breakpoint that is greater than or equal to C_p
BP_{Lo}= the breakpoint that is less than or equal to C_p
I_{Hi}=the AQI value corresponding to BP_{Hi}
I_{Lo}= the AQI value corresponding to BP_{Lo}

Here I_p is calculated for all individual pollutant and the maximum value of I_p among all the individual pollutants is the final AQI value.

AQI = Max (I_p)

Overall AQI is calculated only if data are available for minimum three pollutants out of which one should necessarily be either PM2.5 or PM10. Else, data are considered insufficient for calculating AQI.

[8] Guidelines for the Reporting of Daily Air Quality- the Air Quality Index (AQI), U.S. Environmental Protection Agency (EPA), 2006

There are other methods that can be used to get the final AQI value like Weighted Additive Form, Root-Sum-Power Form (non-linear aggregation form) and Root-Mean-Square Form. But for the purpose of this study the maximum operator system is selected. There are two main reason for this:

- Free from eclipsing (over-estimation of pollution level) and ambiguity (underestimation of the pollution)[9]
- Health effects of combination of pollutants (synergistic effects) are not known and thus a health based index cannot be combined or weighted

3.2 Breakpoints for the AQI

The following breakpoints will be used for the calculation of AQI. Also, to present status of the air quality and its effects on human health, the following description and color coding is proposed to be adopted for the AQI of Nepal.

Table 5 Breakpoints for the Calculation of AQI

This Breakpoint……						…..equals this AQI	And this category
PM_{10} 24-hr (µg /m^3)	$PM_{2.5}$ 24-hr (µg /m^3)	NO_2 24-hr (µg /m^3)	O_3 8-hr (µg /m^3)	CO 8-hr (mg /m^3)	SO_2 24-hr (µg /m^3)		
0-50	0-30	0-40	0-50	0-1.0	0-40	0-50	Good
51-100	31-60	41-80	51-100	1.1-2.0	41-80	51-100	Satisfactory
101-250	61-90	81-180	101-168	2.1-10	81-380	101-200	Moderately Polluted
251-350	91-120	181-280	169-208	10-17	381-800	201-300	Poor
351-430	121-250	281-400	209-748[10]	17-34	801-1600	301-400	Very Poor
430+	250+	400+	748+	34+	1600+	401-500	Severe

[9] Refer to National Air Quality Index, Central Pollution Control Board Government of India (2014)
[10] One hourly monitoring (for mathematical calculation only)

3.3 Health Implications of different AQI Categories[11]

Table below shows health statements for every AQI category for people to understand health effects and protect themselves from these effects.

Table 6 Health Implications for the Corresponding AQI Value

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people
Moderately polluted (101–200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

3.4 Outdoor Air Quality Monitoring Mechanisms

3.4.1 Online Monitoring and Calculation:

Although there are no current automated and functional air quality monitoring stations in Nepal, the real time monitoring data of pollution parameters like PM_{10}, $PM_{2.5}$, Co and others will be available when such stations will be operated in Nepal in the coming future. Keeping this in mind, the software will be developed in such a way that the AQI can be calculated in real time and displayed as the color coding proposed in table 5. But for the current AQI to be useful and effective there is the need to setup online monitoring stations and repair the existing ones so that a continuous data will be available easily for computation of AQI not only for Kathmandu valley but also for other cities in Nepal.

[11] National Air Quality Index, Central Pollution Control Board Government of India (2014)

3.4.2 Manual:

Ideally, manual calculation of AQI from historic air quality data is not suitable as it cannot be quickly disseminated. However, it is important to use these in some productive manner. Hence, these types of past data from different government or related organizations can be used to calculate historical AQIs on a weekly or monthly basis. The data interpretation can then be used in two different manners:

- Identify the months of the year having the highest levels of pollution and caution people in the risk groups[12] accordingly.
- Rank places with in cities or cities themselves for further prioritization of actions on air pollution control.

3.5 Emission Inventory

An emission inventory is an accounting method used to estimate and keep record of the total emission of individual pollutants in a year[13]. An emission inventory gives the average amount of the emitted pollutants for the whole area over which it is collected: it is a macro-scale method which does not pinpoint the location of the polluting sources or give any indication of seasonal variations. But it provides the different sectors and the respective sources of emission. This particular study focuses on the six criteria pollutants used in the calculation of AQI together with total suspended particles (TSP). The emission inventory developed here follows both top down and bottom up method for keeping emission record.

- The top-down method uses data from a greater emission area and disaggregated it into sub-units. For example: the total emissions of CO, SO_2, NO_2, and particulate matter from the transport sector is disintegrated to get the data on the total fuel used, total number of vehicles, total length of roads, and so on.

[12] Especially young children, older adults and people with respiratory diseases

[13] Pradhan, BB; Dangol, PM; Bhaunju, RM; Pradhan, S (2012) Rapid urban assessment of air quality for Kathmandu, Nepal: Summary. Kathmandu: ICIMOD.

- The bottom-up approach uses the data from different field surveys or field visits and compile it to estimate the emission from a particular sector. For example: the data from iron/steel production, different industries as pulp/paper and so on are aggregated to estimate the total emission from a particular sector: in this case industrial processes.

3.6 Indoor Air Quality Status

Unlike outdoor air quality, indoor air quality is hard to generalize for a particular area as it is mainly calculated on a household level. So the online database on indoor air pollution will only deal with individual units of households. For this the pollutants are classified into 4 categories.

- Primary: PM_{10}, $PM_{2.5}$, VOCs
- Secondary: CO, SO_x, NO_x
- Special: O3, formaldehyde, microbial agents
- Ventilatory: CO2

3.7 Data verification

Data validation or verification is often a topic of great importance when it comes to databases. It is extremely important for generation of reliable results as it can provide checks to ensure that inappropriate data is prevented from entering the system. Also, having a valid data is a must as it provides a consistent, functional and value oriented service to its user. The data verification should be done before the data processing and the reports generated should be reviewed before its dissemination to the public. The dataset that goes into the system can be categorized as official and unofficial dataset and both of these require verification before being entered into the system.

- **Official dataset**: Government ministries and departments, other governmental entities
- **Unofficial dataset**: NGOs, INGOs, Industries and different literature sources that are non-governmental

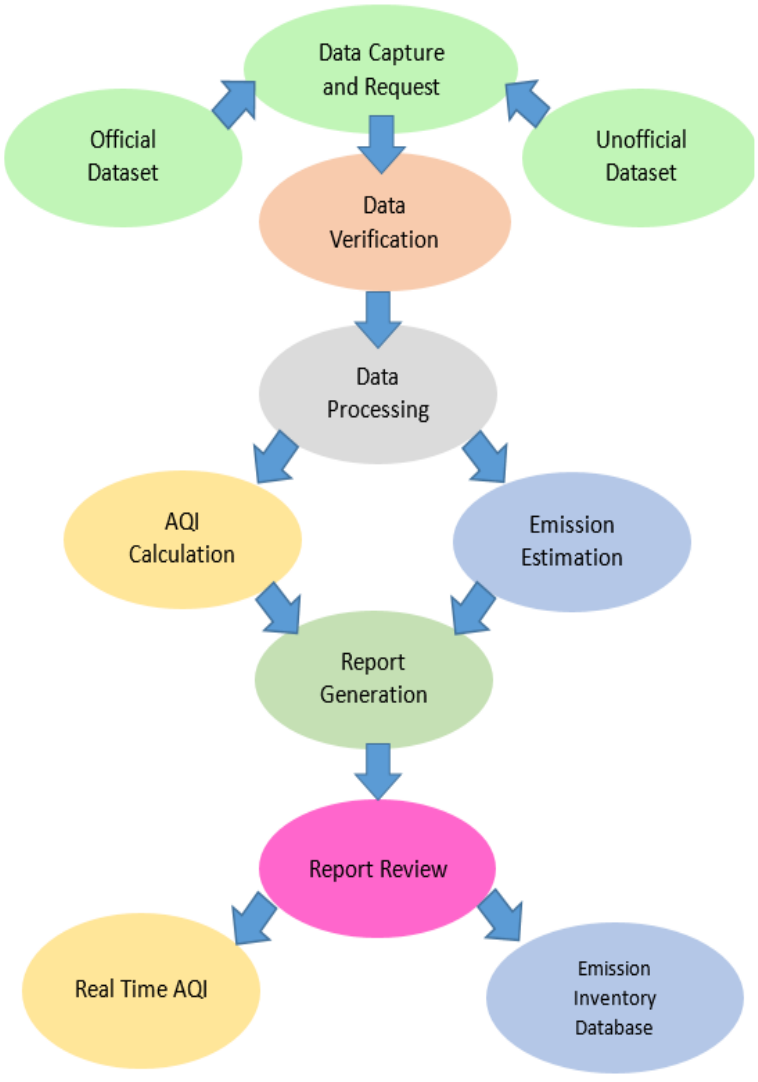


Figure 6 Data Verification Mechanism Together With Input and Output Processes

3.8 Limitations of the study:

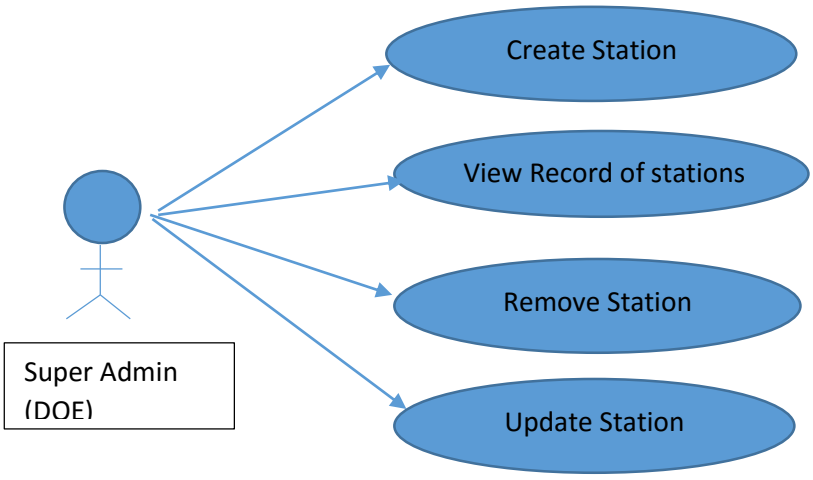
- A legal framework to define the AQI and the cut off points for pollutants based on its health implications doesn't exist in Nepal (except PM_{10}). But this study aims to recommend a viable system that is suitable in Nepalese context with an optimism that a legal groundwork for such system will be laid in the coming days.
- The system we have developed is mostly based on manual calculation because of the fact that real time pollutant data are not available in Nepal. Having said that, we have developed the system in such a way that it can easily migrate to a new system should real time data generating stations come in existence in the near future. The support needed for this and other support will be provided by the consultancy at some charge to be negotiated between the department and MTEEC.
- At this moment of time, it is not possible to get a comprehensive data for individual pollutants or specific emission source for designing the emission inventory. But we have developed an improvised framework for keeping such inventory and with the advent of more data sources, it is hoped that it can provide a clear picture on the emission trends differentiated on the basis of pollutant and sources.

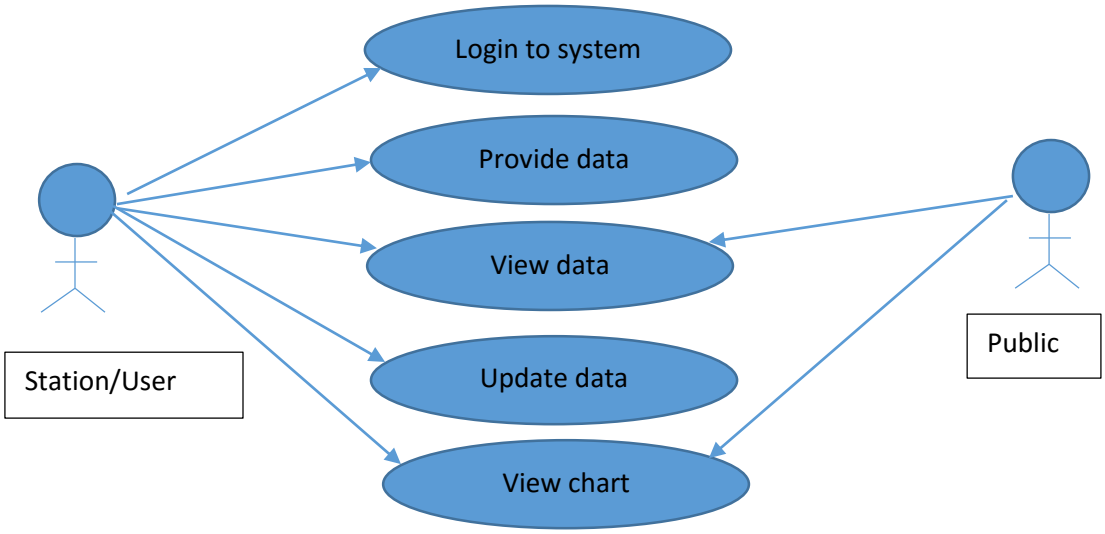
4. Results and Discussion

4.1 About the Online Portal

The website enables local air monitoring stations to submit data about pollutants like NO, SO2, Ozone etc. found in air to the centralized database system maintained by the Department of the environment. The main object of collecting data from the local air monitoring stations is to show the quality of air and related health hazards due to the quality of air. Public can view the status of air in their surrounding and the major pollutant because of which quality of air is affected the most and related health hazards. Also quality of air of past fifteen days can also be viewed.

Stations will provide data about air collected at their station on the daily basis. The main pollutants about which the stations will provide data are: NO, SO2, CO, PM10, PM15 and ozone. The data provided by the station will be checked against the standard values of these pollutants and Air Quality Index (AQI) will be calculated. The pollutant which have the maximum AQI in a day is considered as the major pollutant of that particular day. Stations can view provided data and make modifications to provided data if some mistake occurred during data entry. To provide data or to manipulate data by the stations, first they have to login into the system with provided credential by DOE to them. DOE will be acting as the super admin of the system. It can create any number of stations, modify data about the existing stations, and remove station. DOE will provide credentials to the stations for providing data from their stations.



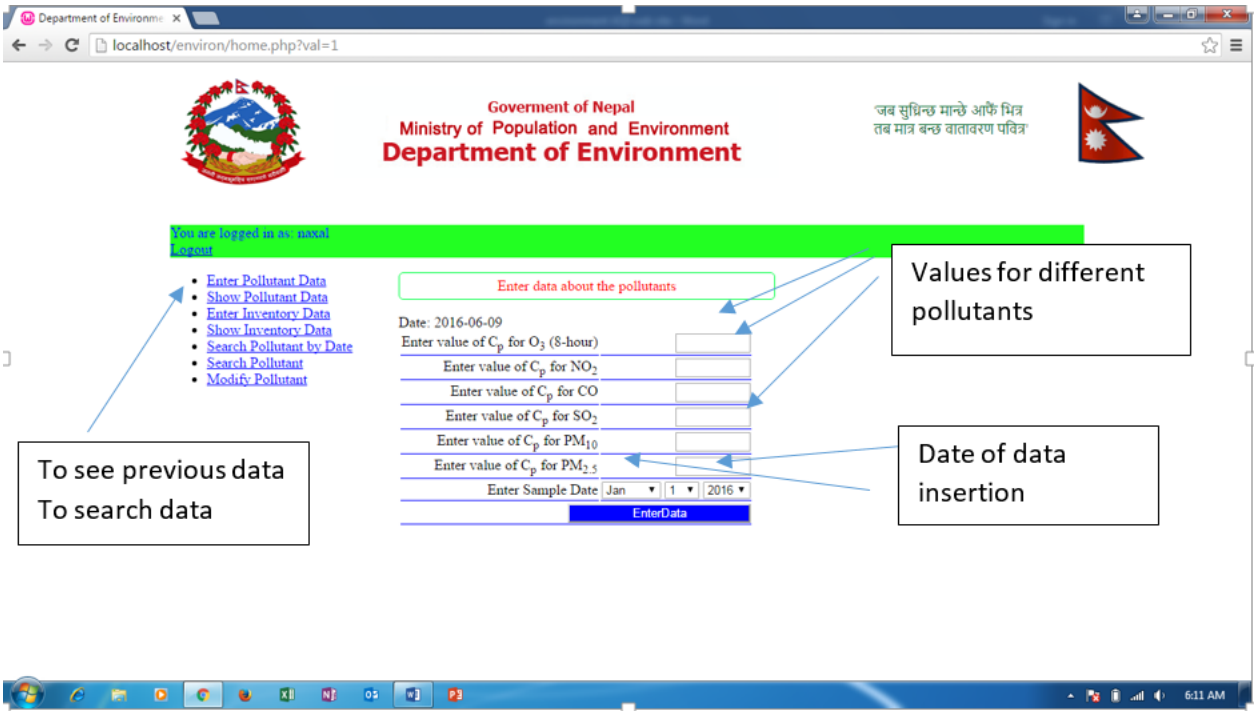


4.2 Logging Into The System

- First user (station) will login into the system using given login page. Users have to use Login id and password provided to them by the DOE to enter into the system.

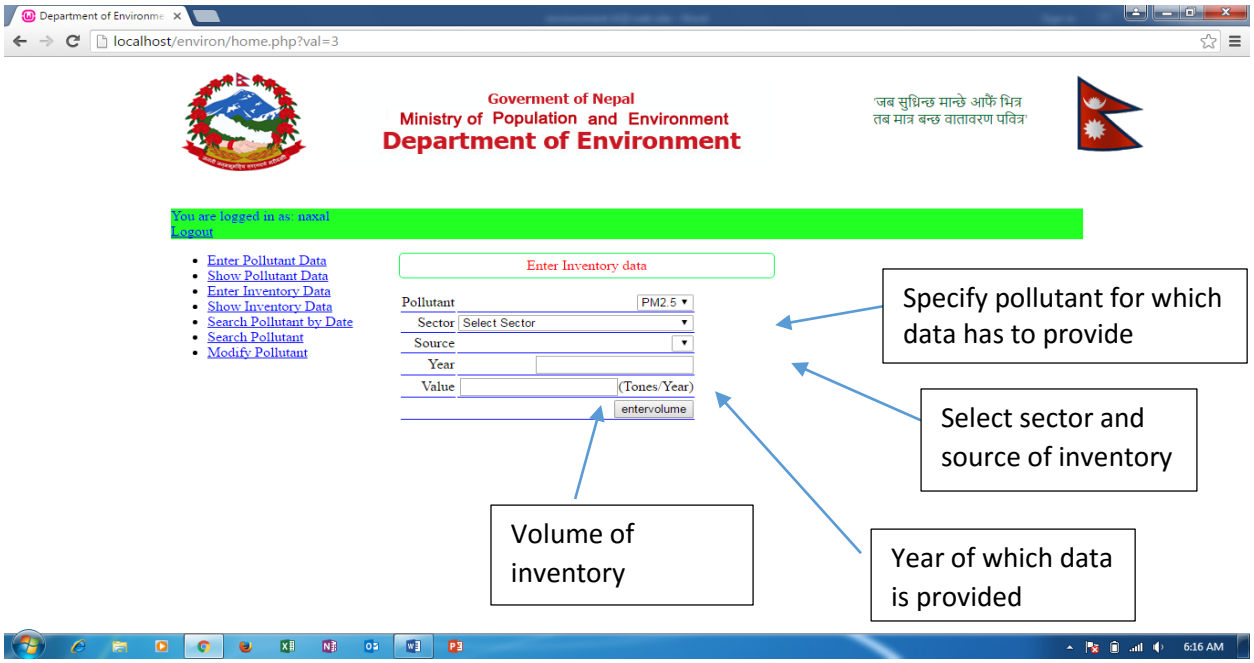
4.2.1 AQI Data Entry

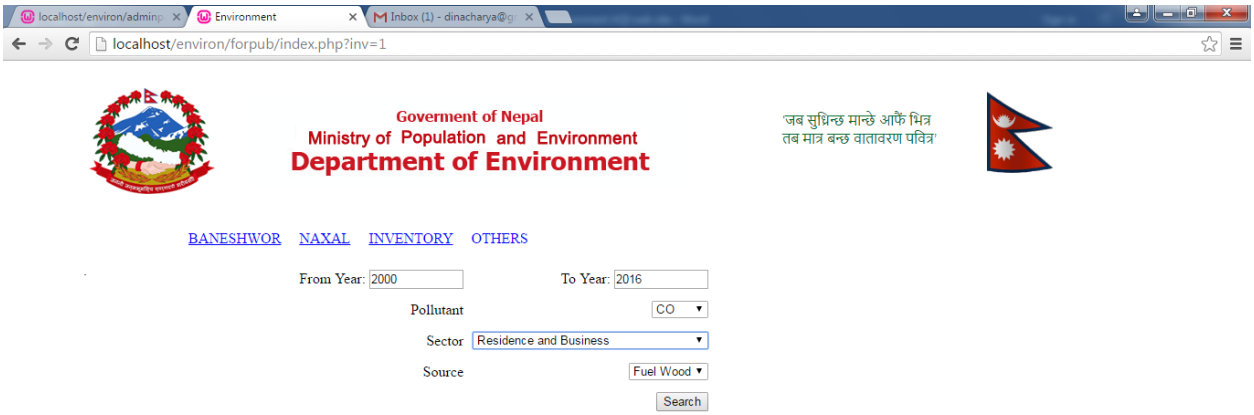
After successful login following screen will appear where user can provide data about the pollutants, see the provided data, and search previous data about the pollutants.



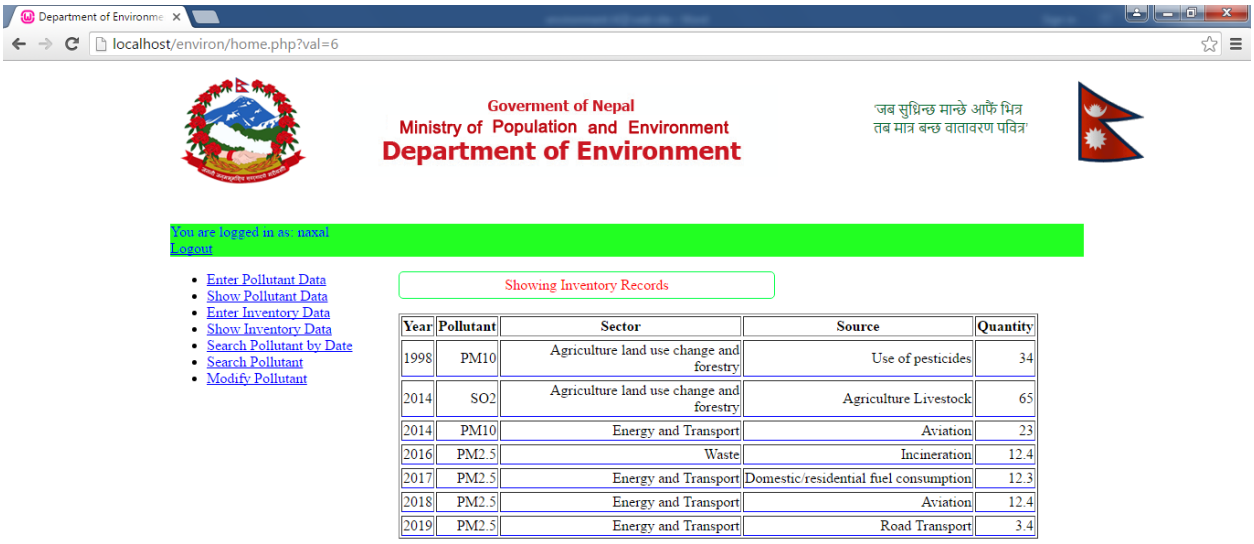
4.2.2 Pollution Inventory Data Entry

Station can see only its data. User have to click Enter inventory data to provide data about inventory data:





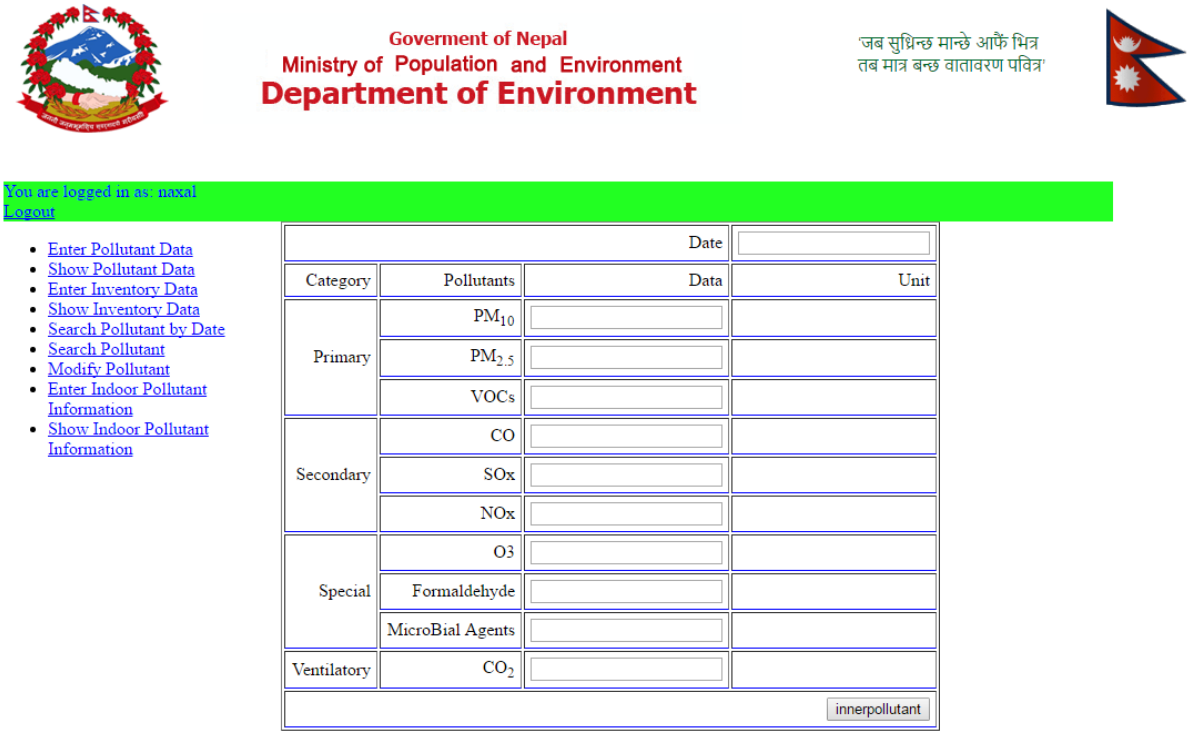
- To see inventory data user has to click show inventory data



- To search pollutant data, user has to specify of which **date** or has to select pollutant of which he/she has to see data:

4.2.3 Indoor Air Pollution Data Entry

The data for the 4 categories of indoor air pollutants needs to be done for individual households providing the date of data capture and unit.



4.3 Public Interface Page

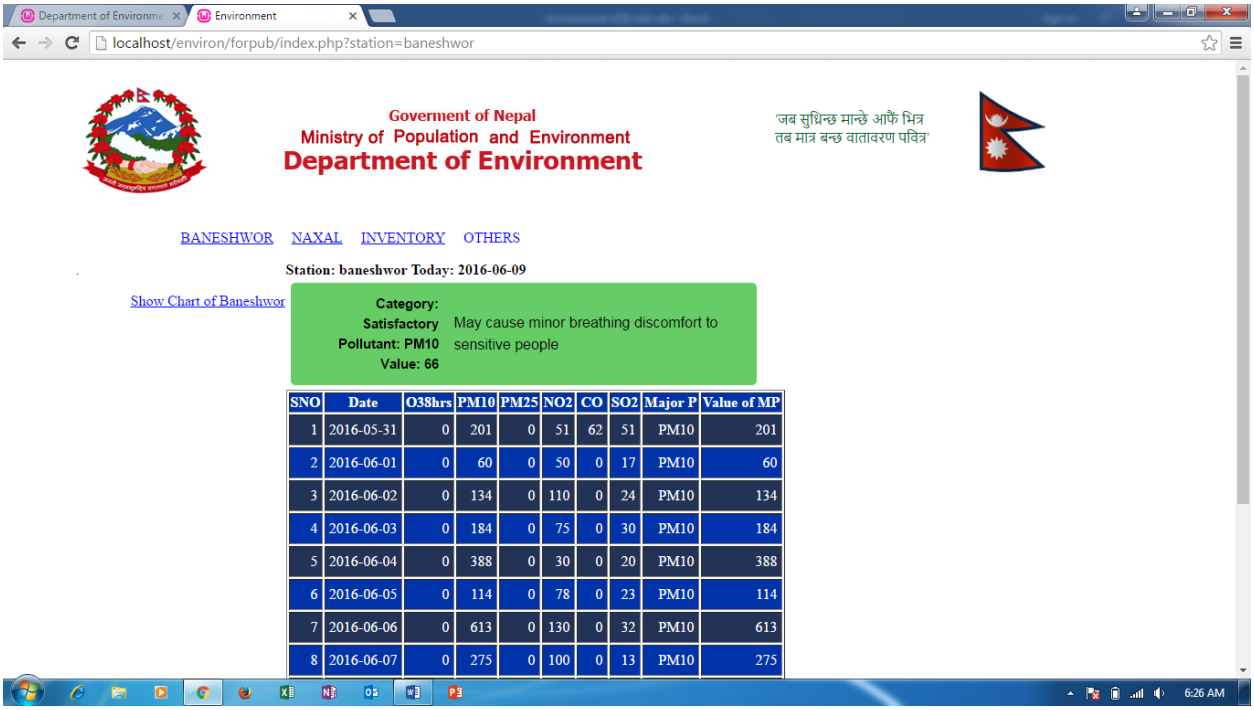
- Public can see data about the pollutants at different station and know the health hazard in that region. To view data by public they have to use following page:

From that page, they have to choose station of which they want to see date, they can see data in chart also.

4.4 Web Based Dissemination

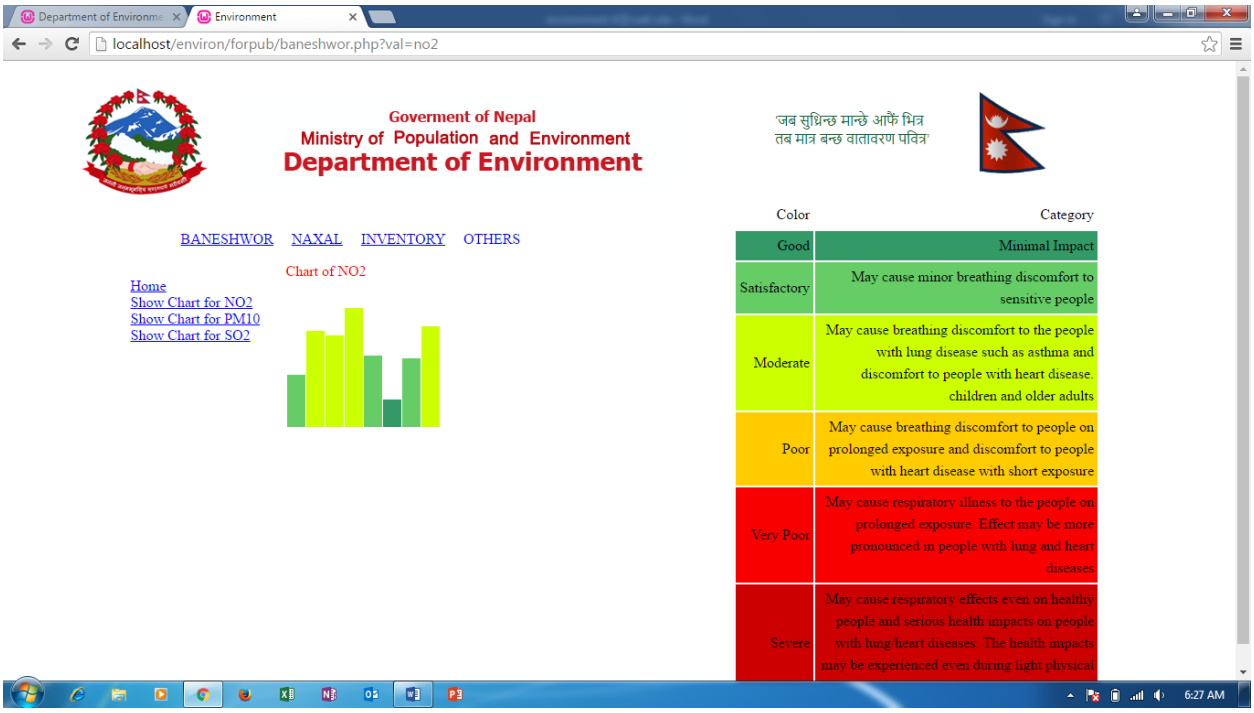
4.4.1 AQI

The AQI data is displayed on the screen and the color coding signifies the corresponding health implications.



SNO	Date	O38hrs	PM10	PM25	NO2	CO	SO2	Major P	Value of MP
1	2016-05-31	0	201	0	51	62	51	PM10	201
2	2016-06-01	0	60	0	50	0	17	PM10	60
3	2016-06-02	0	134	0	110	0	24	PM10	134
4	2016-06-03	0	184	0	75	0	30	PM10	184
5	2016-06-04	0	388	0	30	0	20	PM10	388
6	2016-06-05	0	114	0	78	0	23	PM10	114
7	2016-06-06	0	613	0	130	0	32	PM10	613
8	2016-06-07	0	275	0	100	0	13	PM10	275

- To view data in chart, link Chart of (station name) has to be clicked and has to click the link related to pollutant of which chart has to be displayed.



4.4.2 Emission Inventory

Public can also see data of inventory. User has to specify beginning year and end year, select pollutant, sector and source to view data about inventory of specific pollutant for specified time period. For this given page is used:

4.4.3 Indoor Air Pollution Status

The indoor air pollution data can be seen for individual households. This is because it is very hard to generalize the indoor air pollution data based on a broader area.

Goverment of Nepal
Ministry of Population and Environment
Department of Environment

'जब सुध्रिन्छ मान्छे आफैं भित्र
तब मात्र बन्छ वातावरण पवित्र'

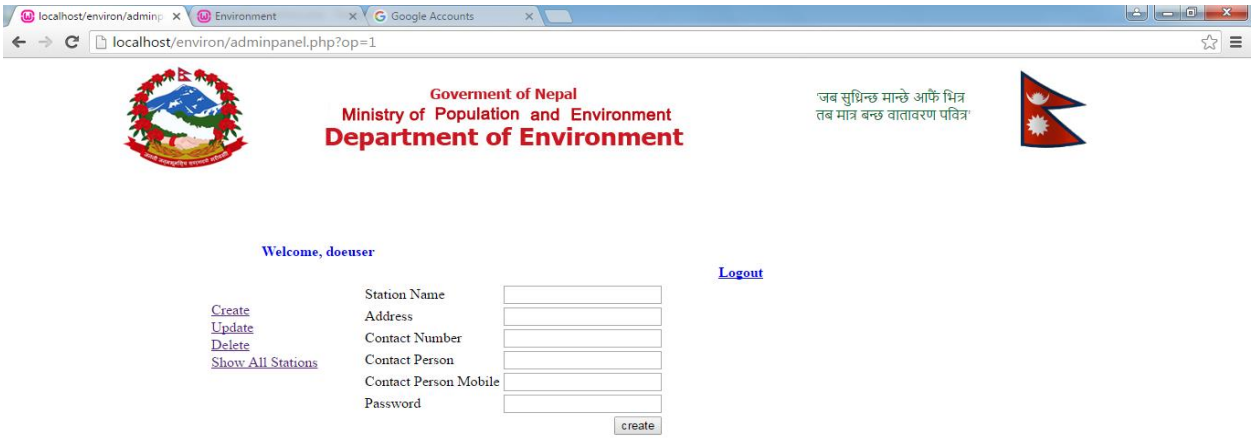
You are logged in as: naxal
Logout

- Enter Pollutant Data
- Show Pollutant Data
- Enter Inventory Data
- Show Inventory Data
- Search Pollutant by Date
- Search Pollutant
- Modify Pollutant
- Enter Indoor Pollutant Information
- Show Indoor Pollutant Information

Year	Primary			Secondary			Special			Ventilatory
	PM10	PM2.5	VOCs	CO	SOx	NOx	O3	Formaldehyde	Microbialagents	CO2
2011	3		3	3	3	0	3	0	0	3
2012	3.44		22.3	22.3	9	0	8.99	0	0	3.56
2013	44.55	33.56	3.45	3.45	5.66	0	5.77	0	0	8.99
2014	44.55	55.66	66.77	77.88	88.99	0	22.33	0	0	33.44
2015	44	55	66	77	88	99	100	200	200	200

4.5 Login Credentials

The main Administrator, Department of Environment, can create new users (stations), update values of existing users, remove users, and view information about users.



- Viewing stations information

Station Name	Address	Contact Number	Contact Person	Contact Person Mobile
baneshwor	New Baneshwor	4479939	Sabina	9841458749
naxal	naxal	44323232	Rama	9851023345

- To modify data of station, name of station of which data is to be changed has to be provided.

5. Conclusion and Recommendation

An online portal for air quality monitoring through AQI and pollution inventory mechanism through API was developed. Literature from different countries were studied and the formula developed by EPA for AQI calculation was used. Also, the breakoff points and corresponding health implications practiced by Government of India was used as the cultural and environmental setting closes matches between India and Nepal. The data entry, user's credentials and verification mechanism was defined. Apart from that, an online portal for AQI and API was constructed that includes admin and users credential differential, data entry and editing mechanism and public interface. The public interface includes AQI and API visualization in the form of graphs and tables.

Some of the recommendation of the study are:

- A through research into the AQI and breakoff points and corresponding health implication for different pollutants needs to be done. Hence, we recommend a comprehensive study on this in the coming year.
- The budgeting ceiling for the projects similar to this one should be increased in the future so that IEMIS for more one indicator can be developed concurrently.
- A great deal of difficulty was faced in getting data on air pollution, so we recommend that the air pollution monitoring stations be brought into function as soon as possible so that there is no more a data gap.
- The Air Quality Index (AQI) and Air Pollution Inventory (API) are early in its development cycle and hence are not foolproof. So we recommend that support from other governmental organization and concerned authorities be taken to enhance its functionality and usability.