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Air Pollution Control Devices: A Comparative Study

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To check the growing menace of air pollution, a general awareness among the masses about the pollution aspects of the society has become utmost essential in modern times. We, therefore, have ventured to correlate all the aspects of sources of air pollution, structure and composition of atmosphere, sources of pollutants, their transformation, transport and effects on all animates and inanimates and air pollution control devices commonly used in modern industries. The industries chosen are Smith-Kline, Beecham (H.M.M.) Nabha, Milk Food India Ltd., Bahadurgarh, Patiala, Rasan Detergents, Bahadurgarh, Patiala, Punjab, India.

INTRODUCTION

Human beings have long affected their environment but it is only in the last half century or so that the scope of this influence has become global, so much so that even seemingly innocuous actions such as driving a car or cutting down a tree can influence the physical and chemical systems that govern the earth.

Due to modernization and with rapid industrialisation, industrial wastes have also been growing in volume. It has become necessary that industries should solve the issue in an economically and technically viable manner. There are, however, certain economic and demographic compulsions for developing countries like India. In the developed world, the industrial revolution preceded environmental consciousness. For countries like India, domestic and export compulsions present a different picture. So, we cannot ignore minimum needs of our population. According to NDC (National Development Council) report India's present population would double by the year 2035 and India would become the most populous country in the world.

An enormous increase in population results in the contamination of environment. Human action produces four kinds of stresses on the environment. These are eutrophic, exploitative, disruptive and the stress caused by the release of toxic substances and hazardous material like lead, mercury, chromium and ozone depleting CFCs. As in the case of all dynamic systems, industrial activity leads to an invariable discharge of wastes and byproducts resulting from the processes. These substances, toxins or free state chemical complexes which may form hazardous compounds, become a part of the ecosystem and are likely to distort their functioning. When concentrated on living organisms, these substances may harm or threaten their existence. But only the industries are not to blame for environmental destruc-

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tion, certain useful materials may also contaminate the environment. Fertilizers, for example, increase the fertility of the soil but pollute water if carried there by rain.

The present work concerned with the study of pollution of air, air pollutants, structure and composition of atmosphere, sources of pollutants, their transformation, transport and effects.

1. Pollution and Pollutants[1–13]

It may be defined as a change in the physical, chemical or biological aspects of environment which makes it harmful for the living organisms. It can be defined as an addition or excessive addition of certain materials to the physical environment (water, air and soil) making it less fit or unfit for life. The type of pollution depends on the area affected by it. Accordingly it is called as air pollution, water pollution, soil pollution and noise pollution.

Pollutants: Pollutants are the materials which disturb the balance of ecosystem. They may be defined as the substances present in the environment in harmful concentrations. They are often the residues of the materials we make, use or throw away. However, all pollutants are not waste materials. Nitrogen and phosphorus are used to enrich the soil for increased crop yields but pollute the water if present in excess.

The pollutants are classified from different points of view. According to their existence in nature they may be quantitative or qualitative.

Quantitative Pollutants: These are the substances which normally occur in nature but are also added in large quantities by man. For instance, CO_2 is always present in the air and is also released by industries and automobiles.

Qualitative Pollutants: These are the substances which do not occur in nature but are added by man. The insecticides for example are qualitative pollutants.

According to their natural disposal, the pollutants may be biodegradable and non-biodegradable.

Biodegradable Pollutants: These are quickly degraded by natural means. Sewage and Heat are pollutants of this category.

Non-biodegradable Pollutants: These are not degraded or are degraded very slowly in nature. D.D.T., arsenic and plastics are the pollutants of this category. These pollutants accumulate and may get biologically magnified as they pass through the food chains.

2. Atmosphere

It is the thick gaseous envelope, called air, which surrounds the earth and permeates its crust and waters. Composition of the atmosphere is quite uniform up to a height of 80 km. Higher levels have lighter gases. The atmosphere is denser near the earth and rarer away from the earth. The atmospheric pressure is more near the earth than away from it. The atmosphere has a layer of ozone which acts as a screen that prevents the sun's ultraviolet rays from reaching the earth. These rays could be lethal for living organisms.

Composition of Atmosphere: The dry air at sea-level contains an average about 78% nitrogen, 21% oxygen, 0.93% argon and 0.03% carbon dioxide by volume. In addition to the above, the atmosphere contains water in the form of vapour, droplets as well as ice particles. The presence of water is extremely important for creating our weather and climate. Besides these the atmosphere also contains additional compounds which show spatial and temporal variations and if exceeding a certain threshold value are considered air pollutants. These might be gases such as SO_2 (sulphur dioxide), CO (carbon monoxide), NO_x (oxides of nitrogen), other organic/inorganic gases, fine droplets of liquids (aerosols) or particulates (dust, soot particles etc.). Gaseous composition of natural dry air is given below.

TABLE-1
CONCENTRATION OF ATMOSPHERIC GASES IN CLEAN, DRY AIR AT GROUND LEVEL

Gas	Concentration (PPM by volume)	Concentration (% by volume)
Nitrogen (N_2)	280,000	78.09
Oxygen (O_2)	209,000	20.95
Argon (Ar)	9,300	0.93
Carbon dioxide (CO_2)	320	0.032
Neon (Ne)	18	0.0018
Helium (He)	5.2000	0.00052
Methane (CH_4)	1.5000	0.00015
Krypton (Kr)	1.0000	0.00010
Hydrogen (H_2)	0.5000	0.00005
Dinitrogen oxide (N_2O)	0.2000	0.00002
Carbon monoxide (CO)	0.1000	0.00001
Xenon (Xe)	0.0800	0.000008
Ozone (O_3)	0.0200	0.000002
Ammonia (NH_3)	0.0060	0.0000006
Nitrogen dioxide (NO_2)	0.0010	0.0000001
Nitric oxide (NO)	0.0006	0.00000006
Sulphur dioxide (SO_2)	0.0002	0.00000002
Hydrogen sulphide (H_2S)	0.0002	0.00000002

3. Meaning of Air Pollution

Air pollution refers to the release into the atmosphere of materials that are harmful to living beings and affect the system as a whole.

Classification of Air Pollutants

All air pollutants are classified according to origin, chemical composition and state of matter.

(i) *Origin:* According to their origin, pollutants which are directly emitted are primary pollutants, *e.g.*, SO_2, NO_x, HC etc., while pollutants which are produced due to the photochemical action in the atmosphere are secondary pollutants, *e.g.*, ozone (O_3), peroxyacyl nitrate (PAN).

(ii) *Chemical composition:* Pollutants, whether primary or secondary, may be further classified according to their chemical composition, as either organic or inorganic.

Organic compounds contain carbon and hydrogen mainly and may also contain elements such as oxygen, nitrogen, phosphorus and sulfur, while inorganic materials found in contaminated atmosphere include carbon monoxide, carbon dioxide, carbonates, sulfur oxides, nitrogen oxides, ozone, hydrogen fluoride and hydrogen chloride.

(iii) *State of Matter:* Pollutants can be further classified as particulate pollutants are finely divided solids and liquids including dust, fumes, smoke, flyash, mist and spray. Under proper conditions, particulate pollutants will settle out of the atmosphere. Gaseous pollutants are those which form less fluids that completely occupy the space into which they are released. These behave much as air and do not settle out of the atmosphere. Among common gaseous pollutants are carbon oxides, sulfur oxides, nitrogen oxides, hydrocarbons and oxidants.

4. Air Pollution Sources

Air pollution is natural as well as man-made.

Natural Air Pollution: Natural air pollution includes forest fires, wind erosion, volcanic activities, etc. Volcanic eruptions release gases which pollute the air. Pollution of air by volcanic eruptions in certain geological periods seems to have changed the earth's climate. In March 1993, Mayon volcano in the Philippines erupted again, spewing a thick cloud of ash 3,000 metres into the sky convering the neighbouring villages and rice fields. It had first erupted in Feb. 1993. Dust storms are another factor in the pollution of air. In the semi-arid zone of Northern India, natural dust might lead to high concentration of suspended particulate matter (SPM), in certain areas, at times even exceeding the national standards. Pollen, spores, cysts, bacteria, marsh gas are also natural pollutants. Forest fires release harmful gases.

Paddy fields, animals and termites produce a good deal of methane gas (an air pollutant). Thus methane produced by these natural processes becomes one of the major contributors to the global warming. Acidic soils produce little methane, but alkaline soils emit methane profusely. The total injection of methane from paddy fields of India is $3\text{–}9 \times 10^{12}$ g/yr, against the global injection of around 110×10^{12} g/yr, *i.e.*, about 2% of global paddy field emissions.

India has a very large animal population (500 million) as against the world cattle head of 1,200 million (in 1980) and animals are a major source of methane. Thus this source must be alarmingly large. The contribution of Indian animals is around 7×10^{12} g/yr against the world average of 80×10^{12} g/yr, *i.e.*, 2% of global methane emission from animals. Wetlands also make significant contribution.

Anthropoganic Air Pollution: Man has been polluting the air ever since he started using fire. Industrialization and invention of automobiles have speeded up the pollution of air. Over- population, deforestation, nuclear explosion and explosives used in wars are also contributing to air pollution. It has been estimated that human activities contribute only a fraction (0.05%) of the total annual emissions into the air.

The major sources of air pollution are fossil fuel (coal and petroleum), biomass burning and industries. Coal is largely carbon but contains some incombustible minerals, sulphur and nitrogen. Petroleum consists mainly of hydrocarbons, sulphur and nitrogen but also contains lead. Burning of fossil fuel produces oxides of carbon, nitrogen and sulphur. Industries besides releasing the above oxides, formed in the combustion of coal and petroleum in them, also add many harmful chemicals to the air.

Anthropogonic air pollution sources are normally subdivided into the following cateogries: point sources and non-point sources.

Point Sources

They add pollutants to the air at particular points from their tall chimneys. These pollutants affect restricted areas only but to a large extent.

Non-point sources

(a) *Line source:* They add pollutants along narrow belts over long distances. Automobiles are the largest source of air pollution in cities.

(b) *Area source:* Towns and cities are the area sources of air pollution. They add smoke and gases from fire over wide areas.

The following list shows some relevant pollutants emitted by different sources:

TABLE-2

Source	Major emission
Thermal Power Plant Bodies	SPM, SO_2, NO_x
Petrochemical Plants	Hydrocarbons
Fertilizer Plant	H_2S, SO_2, NO_x, Urea dust, SPM
Chemical Plant	Depending on chemical
Vehicles	CO, NO_x, HC
Agricultural	SPM
Domestic	SPM, Benzo(a) pyrene

Stationary Combustion Sources

Since the industrial revolution, the major fuels in the developed areas of the world have been coal and petroleum, coal is largely carbon, which on burning produces CO_2. Petroleum consists of compounds of hydrogen and carbon; on burning it forms CO_2 and H_2O. Sulphur is an essential element of life. Since coal and oil are derived from living organisms, these fuels always contain some sulphur. When the fuel burns, so does sulphur, producing a mixture of oxides, mainly SO_2 and SO_3. High SO_2 concentrations have been associated with major air pollution.

Nitrogen, like sulphur, is common to living tissue and therefore is found in all fossil fuels. It produces oxides on burning like NO and NO_2.

Finally, even if no other elements are present, carbon and hydrocarbons produce pollutants because they burn incompletely. Some of these pollutants are gaseous, while others are particles. One such gas is carbon monoxide, which is colourless, odourless and non-irritating, yet very toxic. Particles that consis mostly of carbons are called soot, which is known to be carcinogenic.

There is broad scientific agreement that the phenomenon of global warming as a result of greenhouse effect will raise the temperature between 0.7°C and 3.6°C by 2050. There is general concurrence that carbon dioxide and chlorofluorocarbons (CFC) like freon are responsible for the greenhouse effect.

No precise estimate is available on the quantum of industrial waste generated in our country. However, according to an OECD study on waste generation as a function of economic activity, the estimated annual hazardous waste generation in India was about 0.3 million tonnes per annum in 1984. Now, it may be one million tonnes.

However, the city of Ludhiana occupies a place of pride on the industrial map of the country and can be rightly called the home of small scale and household industries. There has been a rapid growth of industries in Ludhiana which makes it the most polluted city of the country.

Transportation System

In India, there are tentatively 12 lacs 4 wheeled petrol driven vehicles (cars, jeeps, etc.) which may increase to 1.6 million by 1991–92. As regards distribution of vehicle pollution, the metropolitan cities like Mumbai, Calcutta, Delhi, Chennai and Bangalore together approximately account for use of 50% of cars, 20% of two and three wheelers and 15% of diesel vehicles in the country as a whole.

The ambient air quality in Delhi gives it the dubious distinction of being the fourth most polluted city in the world. A major reason for the increase in air pollution is the rising number of motor vehicles and the two coal-based thermal power plants that operate within city limits. Of the total emission load of around 2090 tpd, over 1319.96 tpd, are due to automobile exhaust: 60% of the total emissions.

Domestic Air Pollution

In India, a very high percentage of population lives below poverty line. In news published in the *Economic Times*, the percentage of people below the poverty line (1983–84) was 49.5% in Bihar, 46.2% in Madhya Pradesh, 45.3% in Uttar Pradesh, 42.8% in Orissa, 39.6% in Tamil Nadu and 39.2% in West Bengal. This obviously has resulted in very poor and inadequate housing conditions and inadequate sanitation in the average residential areas. Further, the poor people canno use the right type of cooking fuel too in their kitchens. LPG is the best cooking fuel, provided due care is taken on the upkeep of stove nozzles and leakage avoided, failing which pollution hazards and even death can be caused.

Smoke produced due to burning of conventional fuels like biomass, animal dung cakes, hard-coke in 'Angithis' and 'Chulhas' is the principal pollutant in the kitchens of such homes. It has been established that the smoke level in the kitchens, using biomass or animal dung cakes as fuel and having poor ventilation provision with doors kept closed during winter, is so high that the women folk working in such ktichens inhale smoke which is equivalent to smoking 24 packets of cigarettes per day. The burning of animal dung cakes is the most disastrous. It emits the hydrocarbon, benzo(a) pyrene, which causes cancer.

The recent studies have shown that the concentration of pollutants in the kitchens of rural folk and the underprivileged is quite high.

Air Pollution due to Nuclear Accidents

Many nuclear accidents occur these days. These produce radioactive particles that are thrown high up into the air as huge clouds. These particles are carried over long distances by wind and gradually settle over the earth as fallout or are brought down by rain.

Agricultural Pollution

Due to modern agricultrure, new sources of air pollution have come to light. Indiscriminate use of pesticides leads to pesticide residues in the food chain in vegetables, eggs, fish, meat, milk and its products, edible oils, etc. By burning of crop residues, forests, hydrocarbons, methane (CH_4), sulphur oxides (SO_x), carbon monoxide (CO), carbon dioxide (CO_2) etc., are released in the atmosphere. All these factors lead to ozone depletion, acid-rain and global warming.

The transmission and transport of air pollutants depends upon weather and climatic conditions. The air pollutants coming from different sources form a cycle.

5. Effects of Air Pollution

Effect on Humans: Industries and automobiles release very fine solid and liquid particles into the air. Flyash and soot from burning of coal, metal dust containing lead, chromium, nickel, arsenic, cadmium, zinc and mercury from metallurgical processes, cotton dust from textile mills and pesticides sprayed on drops are examples of particulate pollutants in the air. They cause respiratory trouble. Combustion of petroleum in automobiles emits particulate lead compounds and affects haemoglobin formation.

Of the vehicular emissions, carbon monoxide (CO) is certainly the most undesirable. Carbon monoxide combines with haemoglobin and reduces the oxygen carrying capacity of haemoglobin.

Nitric oxide (NO) is a relatively inert gas and only moderately toxic. Like CO, NO can also combine with haemoglobin to reduce the oxygen-carrying capacity of the blood. NO_2 causes respiratory problems.

Sulphur oxides including H_2SO_4, SO_2 and sulfate salts tends to irritate the mucous membranes of the respiratory tract and foster the development of chronic respiratory diseases, particularly bronchitis and pulmonary emphysema. Hydrocarbons are a variety of compounds emitted as a result of evaporation and incomplete combustion of fuel and these are known to be carcinogenic. Further hydrocarbons react with oxides of nitrogen in the presence of sunlight and cause photochemical smog which can be seen as a brown haze over the skyline.

Effect on Plants and Animals: Dry cement kiln dust appears to cause little damage if deposited on a leaf surface. Yet in the presence of moisture, such dust imparts damage and consequential growth inhibition to plant tissues. The dust coating on leaves reduces photosynthesis and increased plugging of stomata reduces plant growth. Animals who eat plants coated with particulates containing fluorides, arsenic or lead may suffer some ill effects.

Primary pollutants of nitrogen have no desirable effects on vegetation. But secondary pollutants PAN, O_3 are more likely to be damaging to plants.

High concentration of sulfur dioxide causes chlorosis (*i.e.*, disappearance of chlorophyll), plasmolysis, membrane damage, metabolic inhibition and death. Plants are particularly sensitive to SO_2 during periods of intense light, high relative humidity, adequate moisture and moderate temperature. Alfaalfa, cotton, soyabeans, lettuce, spinach, apple and pine are particularly sensitive to SO_2 while potatoes, onions, corn are more resistant to SO_2 damage.

Effect on Materials: Exposure to high levels of NO_2 can cause fading of textile dyes, yellowing of white fabrics and oxidation of metals.

Ozone is an extremely active compound and readily oxidizes paints, elastomers (such as rubber), textile and dyes.

Particulate matter can damage materials by soiling clothing and textiles, corroding, metals, eroding building surfaces, discolouring and destroying painted surfaces.

SO_2 and SO_3 react with water to form sulphuric acid (H_2SO_4). These readily attack building materials, especially those containing carbonates such as marble, limestone, roofing, slate and mortar.

$$\underset{\text{(Limestone)}}{CaCO_3} + H_2SO_4 \rightarrow \underset{\text{(Cal. sulfate)}}{CaSO_4} + CO_2 + H_2O$$

The calcium sulfate formed in this process is washed away leaving a pitted, discoloured surface. This phenomenon also known as acid rain or acid precipitation. This also damages cotton, linen, rayon and nylon.

Effect on Climate: Visibility is the ability to distinguish and identify a distant object. Reduced visibility is one of the noticeable effects of air pollution on meteorological phenomena. It creates safety hazards and is aesthetically displeasing.

Air contaminants in the atmosphere can result in increased precipitation. This phenomenon occurs because small particles act as nuclei. This increase in precipitation has already been noticed.

Fog over cities is double the incidence of fog over undeveloped areas.

Air pollutants are also responsible for reduction of solar radiation over cities. This is called the Urban Heat Island Effect because it mainly affects urban areas.

EXPERIMENTAL

The suspended particulate matter (SPM) was collected using Envirotech APM-610 stack monitoring kit. The schematic diagram of the kit is shown in diagram-1.[1] The study was carried out in the following way:

Temperature: The ambient air temperature (TA) was noted by pressing the temperature knob present on the left corner of the stack monitoring kit. The stack flue gas temperature (TS) was displayed on the digital screen when thormocouple was put into the stack. The temperature was displayed in the centrigrade scale which was converted into kelvin scale for calculation purposes.

Measurement of Flow-Rate: A pitot-tube along with an inclined vertical manometer was used to measure the velocity of air stream inside the chimney or duct. The pitot tube was inserted into the stack, developed a differential pressure proportional to the kinetic head of the smoke-stream. This pressure difference P was measured by the inclined vertical manometer in water gauge scale limits. The air velocity was calculated from the relation:

$$V = K\sqrt{(2GH\,D_m/D_s)}$$

where, V = velocity of air in m/s

K = pitot tube constant (0.840)

G = gravitational constant (9.81 m/s^2)

D_m = density of manometer fluid equal to 800 kg/m^3 for red oil

D_s = stack gas density in kg/m^3

The stack gas density being a function of molecular weight of gases comprising flue gas, the static pressure inside the duct/chimney and temperature of flue gas.

However in most of the cases molecular wt. of stack gas is practically the same as that of air while the static pressure is close to the atmospheric pressure.

Hence
$$D_s = D_a \frac{T_a}{T_s}$$

where, D_a = density of atmospheric air

T_a = ambient air temperature in Kelvin

T_s = stack temperature in Kelvin

D_a = 1.25 kg/ m^3 at 298 K

$$D_s = \frac{1.25 \times 298}{T_s}$$

Substituting this value in velocity equation,

$$V = K\sqrt{\frac{(2 \times 9.81 \times D_m \times H \times T_s}{1.25 \times 298}}$$

$$= K\sqrt{(0.0527 D_m \times H \times T_s}$$

Taking H in centimetres,

$$V = C\sqrt{(H \times T_s)}$$

where,
$$C = 0.02295 \times K \times \sqrt{D_m}$$

So, velocity of flue gas V (for red oil) $V = 0.542\sqrt{(H \times T_s)}$ (1)

Calculation of Isokinetic Flow Rate

The rate of sampling to achieve the isokinetic conditions for the nozzle of cross-sectional area A_n (0.68) was calculated using the equation

$$Q_s = V \times A_n \times 60 \times 1000$$

where, V = stack velocity in m/s

A_n = cross sectional area of the nozzle (0.68)

Normalising the gas conditions using the equation

$$Q_s' = \frac{Q_s \times T_a}{T_s} \quad (2)$$

Q_s' denotes the flow rate of the gas to be fixed for sampling the suspended particulate matter (SPM). The units of Q_s' is litres per minute (LPM).

As the flow rate of the stack gases varies across the cross-section of the duct/chimney, so the particulate concentration is likely to vary and hence was sampled at different traverse points with corresponding change in sampling rate to maintain isokinetic conditions.

Selection of Filter Medium

Temperature of the flue gases is the major factor in determining/selection of the type of filter medium to be used. The filter medium is of two types: (a) cellulose filtration thimbles (b) glass microfibre thimbles. For stack temperature upto 300°C the cellulose filter thimbles are used and for higher temperature the glass microfibre thimbles are used.

Preparing the Thimble

Prior to sampling, the filter medium was dried in an oven and weighed. Cellulose filtration thimbles particularly are quite hygroscopic, hence were dried in an oven at 100°C for 30 min. The dried thimbles were allowed to cool in the desiccator until these were weighed. After sampling, both cellulose and glass microfibre thimbles must be dired prior to final weighment.

Loading of the thimble

The thimble once selected after looking into the temperature conditions were kept in a safe area. Preweighed thimble was loaded into the filter holder for particulable matter sampling.

Sampling Procedure

Stack kit, cold box and sampler probe assembly were taken to the platform of the stack. Initially the ambient air temperature was noted on the screen and afterwards the stack temperature was noted by inserting a thermocouple inside the chimney/duct.

The differential pressure (H) was noted using pitot tube and red oil in the inclined vertical manometer. Using the differential pressure and temperatures noted, the velocity of the flue gas was calculated using equation (1).

From the velocity determined, the flow rate was calculated using equation (2).

The connections were done in accordance with the schematic diagrams (Fig. 1). Calculated flow rate (LPM) was adjusted on the scale and the thimble holder assembly having preweighed sampling thimble was inserted in the chimney for a particular time to collect the particulate matter sample present in the flues gases of the chimney/duct. The filtration assembly was cooled down and sample thimble was taken out. The cooled sampled thimble was weighed again to note the final weight of the thimble. The concentration of particulate matter was calculated using the following calculating procedure.

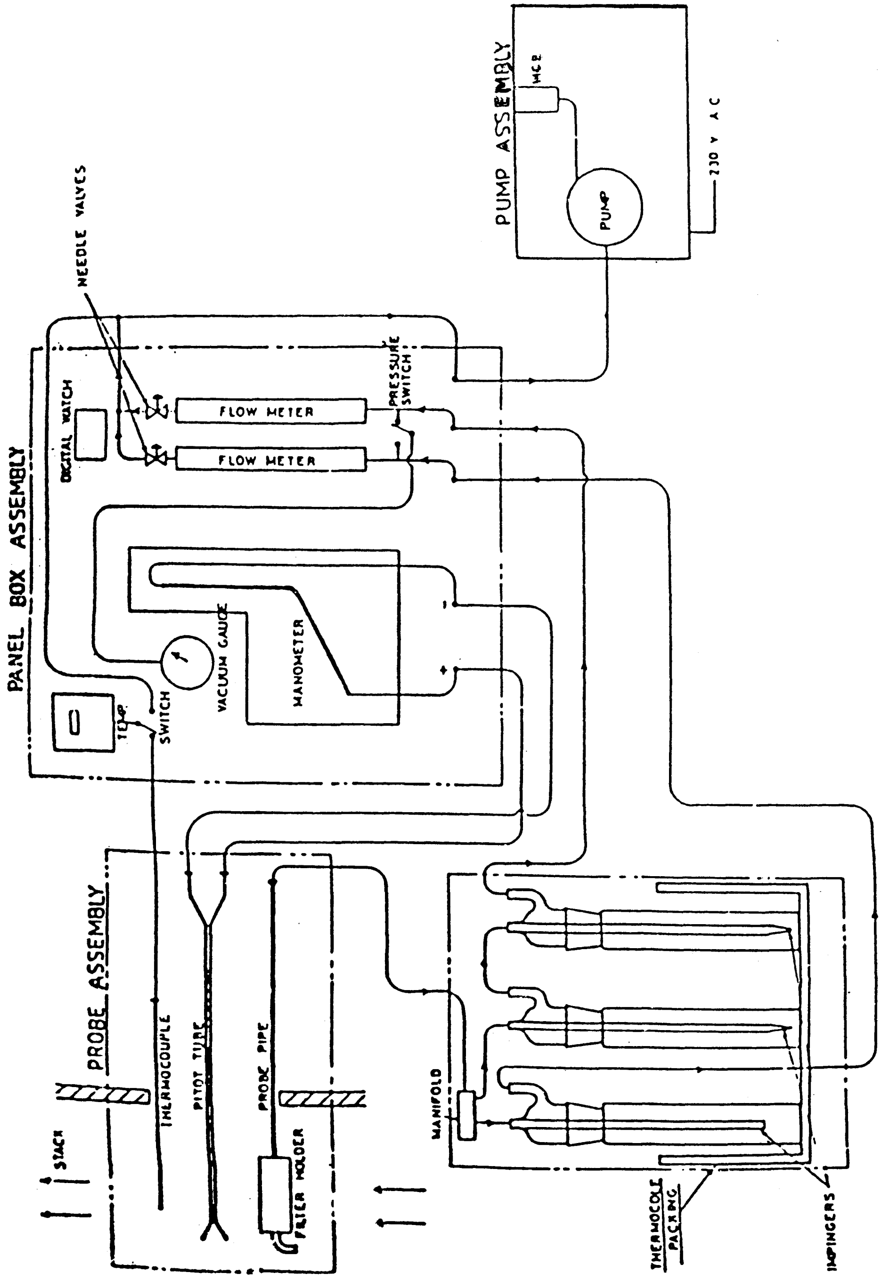

Fig. 1. System configuration of APM-610

Calculation

Net initial weight of the thimble $= W_1$ g

Final weight of the thimble $= W_2$ g

Weight of the particulate matter sampling collected $= (W_2 - W_1) = W$ g

Time of sampling $= t$ min

Concentration of particulate matter:

$$SPM = \frac{W \times 1000 \times 1000 \times 298}{Q_s' \times t \times T_s} \text{ mg/Nm}^3$$

The stack samples of the following Industries were collected which have installed different air pollution control devices (APCD) and using different fuels.

	Industry	Fuel	APCD
(i)	Hindustan Milkfood Manufacturers (HMM), Nabha	Coal	Multicyclone
(ii)	Milkfood India Ltd., Bahadurgarh	Rice husk	Bag filter
(iii)	Rasan Detergents, Bahadurgarh	Wood	—

RESULTS AND DISCUSSION

The samples were drawn from the stacks of the earlier mentioned industries. The samples were taken from the inlet and outlet of Air Pollution Control device so as to find out the efficiency of the control device. The samples were taken after every 1 h for 24 h/8 h, so as to take into consideration different aspects of the manufacturing process and heat load desired at that particular time.

The growing industrialisation and developing urban areas has led to the general awareness among the masses about the pollution aspects of the society. It may be air, water, noise, soil, etc. But air pollution being more visible and distinguished made it more pinching to the eyes of the residents. The Bhopal disaster in which thousands were killed induced health consciousness towards the disastrous effects of air pollution, particularly the dangerous gaseous pollution. The Central Government acted promptly to put to end this growing slow poisoning trends in the society and the Air (Prevention and Control of Pollution) Act 1981 came into being. Though it was only on papers till the Bhopal Gas Tragedy but afterwards it was enforced and the industrialists were forced to act as per the provisions of the Act.

Under this Act, the air pollution areas were earmarked and the industrialists were persuaded to install the control devices. They were given time and general awareness campaigns were launched by the social welfare organisations, State and Central Pollution Control Boards. Their efforts had very good and enthusiastic results. Mandi Gobindgarh and Ludhiana cities were under the action plan of the state to make these cities free from pollution by 1995 only with the help of the general public, social organisations and industries. The education and awareness among the young industrialists has played a great and commendable role in this direction to end this evil from society. But there are black sheeps among them who are not convinced about this. Even they are not ready to accept the truth that the money earned by them will be useless if they were unable to leave fresh air and pollution for their future generation. The coming generations will curse us for this disaster. For such persons the law take its own course and criminal proceedings are launched against them by the State Boards, as no single person of the society can take the whole nature at the verge of the death end.

To bring it on a strong footing, the Environmental Protection Act, 1986 was passed in the Parliament and enforced strictly. Under this Act, the State Board authorities can even visit their secret points and trade secrets to find out the percentage loss of their raw material, intermediates and by-products. The environmental auditing is a new trend in this field.

For the defaulting industries, environmental laboratories are established and State Board Analysts are notified in the gazette for analytical purposes. The sample of the defaulting industry is taken and analysed. If the results do not meet the technical specifications prescribed by the Board, criminal proceedings against are launched the owners of industry and the State Board is empowered to close the industry at a 24 h notice.

Due to these strict laws and the general awareness campaign, maximum control devices have been installed but the Board is facing the problem of round the clock running of these devices because these are considered liabilities by the industry and morally they do not feel committed to this cause.

Three industries specified earlier were taken into consideration for experimental studies.

Smith Kline Beecham Consumers Brand Ltd. (HMM), Nabha

The industry is situated on the Nabha-Patiala Road and is engaged in the manufacturing Horlicks, Boost and Ghee which is a by-product. The raw-material used by the industry are malted barley, wheat flour and milk. About 8400 MT/year of Horlicks and 2600 MT/year of Boost is manufactured here. About 550 MT/yr of the by-product (ghee) are produced. The flow diagram of the process is shown in flow sheet diagram (Fig. 2).

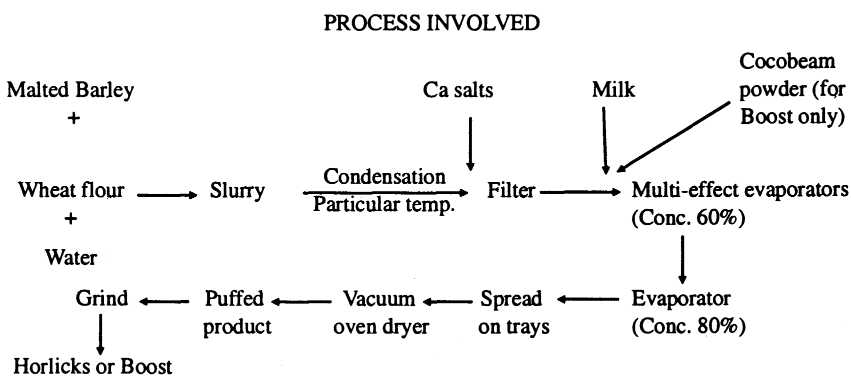

Fig. 2. Flow Sheet Diagram

TABLE-3
SUSPENDED PARTICULATE MATTER (SPM) BEFORE APCD (H.M.M., NABHA)

Initial wt. of thimble (g)	Final wt. of thimble (g)	Wt. of particulate matter (g)	Time (min)	Gas flow rate (LPM)	Stalk temp. T_s (K)	Conc. of particulate matter (SPM) mg/Nm^3
3.4765	3.7740	0.2975	10	30	415	712.6
2.9846	3.3267	0.3421	10	30	415	818.7
3.1567	3.1439	0.2572	10	30	414	617.9
3.5642	3.9555	0.3913	10	30	415	936.8
3.4216	3.7700	0.3484	10	30	413	838.1
2.9888	3.3566	0.3678	10	30	414	930.7
2.9145	3.2023	0.3878	10	30	413	967.5
3.0002	3.4024	0.4022	10	30	418	978.9
3.7141	4.1260	0.4119	10	30	415	868.4
3.2421	3.6049	0.3628	10	30	414	714.5
3.1999	3.4976	0.2977	10	30	413	1006.9
3.2987	3.7173	0.4186	10	30	415	978.1
3.1999	3.6085	0.4086	10	30	416	999.9
3.5432	3.9619	0.4187	10	30	418	964.8
2.9987	3.4046	0.4059	10	30	413	936.7
3.6215	4.0109	0.3894	10	30	419	848.9
3.4114	3.7694	0.3580	10	30	415	871.1
3.2257	3.5898	0.3641	10	30	414	899.7
3.1587	3.5336	0.3749	10	30	416	980.8
3.1281	3.5321	0.4040	10	30	413	971.9
2.9699	3.3667	0.3668	10	30	413	931.9
2.9999	3.3861	0.3862	10	30	413	929.1
3.1875	3.5535	0.3660	10	30	414	878.2
3.2463	3.6518	0.4057	10	30	415	971.3

The industry being multinational one is maximum conscious about the pollution matter. The direction from the High Command in U.K. is for maximum pollution abatement. The industry is a large scale industry and hence is also in the red list of the State Board.

The samples from inlet and outlet of the APCD are taken. The device installed is multicyclone and the fuel used is coal. The perusal of Tables 3 and 4 indicates that the multicyclones are working very effectively. Table 3 reported the suspended particulate matter (SPM) with APCD and Table-4 reported the SPM with APCD after passing the flue gases through multicyclone. The per cent efficiency of the multicyclone is also worked out to be around 80–82% . The reason for such a high efficiency of multicyclone installed is the fuel used. The unburnt coal particles being heavier, the velocity of these particles is slowed down by the multicyclone. These are settled here, combustion rate of coal being high.

TABLE-4
SUSPENDED PARTICULATE MATTER (SPM) AFTER APCD (HMM. NABHA)

Initial wt. of thimble (g)	Final wt. of thimble (g)	Wt. of particulate matter	Time (min.)	Gas fow rate (LPM)	Stalk temp. T_s (K)	Conc. of SPM (mg/Nm^3)	% cfficiency of APCD
3.1999	3.2586	0.0587	10	30	415	140.6	80.26
3.2112	3.2694	0.0582	10	30	415	139.5	82.96
2.9879	3.0411	0.0532	10	30	414	127.8	79.31
2.9536	3.0085	0.0549	10	30	415	131.6	85.95
3.1456	3.1994	0.0538	10	30	413	129.5	84.64
3.3651	3.4199	0.0548	10	30	414	131.6	85.86
3.8254	3.8829	0.0575	10	30	413	138.5	85.68
2.9871	3.0436	0.0565	10	30	418	134.5	86.26
2.9949	3.0544	0.0595	10	30	415	142.6	83.63
2.9158	2.9664	0.0506	10	30	414	121.6	82.98
3.4321	3.4861	0.0540	10	30	413	129.3	87.15
3.2587	3.3140	0.0553	10	30	415	132.4	86.46
3.5639	3.6196	0.0557	10	30	416	133.1	86.66
3.2187	3.2778	0.0591	10	30	418	140.5	85.43
3.2816	3.3402	0.0586	10	30	413	141.1	84.93
2.9916	3.0461	0.0545	10	30	419	129.4	84.75
2.9329	2.9882	0.0553	10	30	415	132.6	84.77
3.5101	3.5659	0.0558	10	30	414	134.1	85.09
3.2987	3.3510	0.0523	10	30	416	125.1	87.24
3.1829	3.2383	0.0554	10	30	413	133.3	86.28
3.2154	3.2712	0.0558	10	30	425	133.1	86.00
3.2002	3.2573	0.0571	10	30	413	137.4	85.21
3.0146	3.0714	0.0568	10	30	414	136.3	84.42
3.1444	3.2009	0.0565	10	30	415	135.3	86.07

TABLE-5
SUSPENDED PARTICULATE MATTER (SPM) BEFORE APCD (MILKFOOD INDIA LTD., BAHADURGARH)

S. No.	Initial wt. of thimbal (g)	Final wt. of thimbal (g)	Wt. of particulate matter collected (g)	Time (min)	Gas flow (LPM)	Stalk temp. T_s (K)	Conc. of SPM (mg/Nm^3)
1.	3.2875	3.8044	0.5169	10	30	401	1280.6
2.	3.1414	3.6254	0.4840	10	30	403	1193.1
3.	3.2157	3.7613	0.5456	10	30	402	1348.4
4.	3.2687	3.7483	0.4796	10	30	400	1199.1
5.	2.9875	3.4988	0.5113	10	30	401	1266.7
6.	3.1871	3.7311	0.5440	10	30	402	1344.7
7.	3.3471	3.9171	0.5700	10	30	401	1412.1
8.	3.3002	3.8196	0.5194	10	30	403	1280.8

Fuel: Rice husk

TABLE-6
SUSPENDED PARTICULATE MATTER (SPM) AFTER APCD (MILKFOOD INDIA LTD., BAHADURGARH)

S. No.	Initial wt. of thimble (g)	Final wt. of thimble (g)	Wt. of particulate matter collected (g)	Time (min)	Gas flow rate (LPM)	Stalk temp. (K)	Conc. of SPM (mg/Nm^3)	% efficiency
1.	3.1429	3.1674	0.0245	10	30	401	60.86	95.24
2.	3.2179	3.2471	0.0292	10	30	403	72.14	93.95
3.	2.8799	2.9068	0.0269	10	30	402	66.57	95.06
4.	3.4100	3.4342	0.0242	10	30	400	60.11	94.95
5.	3.2121	3.2408	0.0287	10	30	401	71.21	94.34
6.	3.1875	3.2153	0.0278	10	30	402	68.79	94.88
7.	3.2265	3.2531	0.0266	10	30	401	66.11	95.31
8.	3.2562	3.2853	0.0291	10	30	403	71.87	94.38

Fuel: Rice husk

Table-7
SUSPENDED PARTICULATE MATTER (SPM) RASAN DETERGENTS (BAHADURGARH)

S. No.	Initial wt. of thimble (g)	Final wt. of thimble (g)	Wt. of particulate matter	Time (min)	Gas flow rate (LPM)	Stalk temp. (K)	Conc. of suspended particulate matter (mg/Nm^3)
1.	3.2987	3.4012	0.1025	10	30	1007	101.2
2.	3.1418	3.2474	0.1056	10	30	1004	104.5
3.	3.2143	3.3143	0.1000	10	30	987	100.7
4.	2.9871	3.1119	0.1248	10	30	1020	121.6
5.	3.1149	3.2264	0.1115	10	30	1010	109.7
6.	3.2018	3.3053	0.1035	10	30	988	104.1
7.	3.4211	3.5270	0.1059	10	30	996	105.7
8.	3.3219	3.4299	0.2080	10	30	1005	106.8

Fuel: Wood, APCD; Not installed

Little particles like ash are thrown away through the chimney which has a specified height as reported in Annexure-II. The results are meeting the prescribed limits enforced by State Pollution Control Board as reported in Annexure-I.

Milkfood India Ltd., Bahadurgarh

The industry is located on the Patiala-Rajpura Road about 10 km from Patiala and is engaged in various products like ice-cream, milk powder etc. The industry is a limited company and is in large-medium category of the State Board.

The fuel used by the industry is the rice husk. the control device installed by the industry is bagfilters which are more effective pollution control device. The rice-husk being light, the combustion rate is very low but this fuel is a cheaper one and hence the industry is using it keeping in view the economic statistics.

When burnt, being light the suspended particulate matter is very high as reported in Table-5. If the pollution control devices are not used, such a high concentration particulate matter may cause irrepairable damage to flora and fauna and human beings.

The results obtained after the use of air pollution control device: bag filter are very low (Table-6). Hence it is clearly established that these are giving better results than even multicyclone. The rice husk ash contains silica, Al_2O_3, Fe_2O_3, CaO, MgO, etc. Such a high quantity of these inorganic components in this ash has led to the conclusion that the most effective device is needed and bag filters are the best one for such a high pollution causing fuel.

Rasan Detergents, Bahadurgarh

The industry is located on the Patiala-Rajpura Road about 10 km from Patiala. The industry is a small scale industry and is engaged in soaps and detergents manufacturing. Captain Chander Surya Cakes and Captain Detergent Powder are their main trade products.

The industry is producing sodium silicate within its own premises from sand using wood as fuel. For the formation of sodium silicate high temperature about 1100 K is needed. So, the thimble used is glass-microfibre thimble. Wood being highly combustible, the contents are the lowest. The sampling results are reported in Table-7. The result of the suspended particulate matter (SPM) is very low, meeting the standards prescribed by the State Board reported in Annexure-I.

Conclusion

From the above discussion it is concluded that it is the fuel which determines the type of air pollution control device needed. For rice husk ash pollution, bag-filters are the best while for coal, multicyclones are effective devices. Wood being highly combustible, its combustion is complete and if used as fuel may not need any control device and the results may meet the prescribed limits.

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ANNEXURE-I

TOLERANCE LIMITS OF SPM EMISSIONS FOR BOILER PLANTS

Steam generating capacity	Required particulate matter	
	Area up to 5 km from the periphery of Class I and II cities	Other cities
Less than 2 T/h	800 mg/Nm^3	1200 mg/Nm^3
2 T to less than 10 T/h	500 mg/Nm^3	1000 mg/Nm^3
10 T to less than 15 T/h	350 mg/Nm^3	500 mg/Nm^3
15 T or above	150 mg/Nm^3	150 mg/Nm^3

All emissions are normalised to 12% carbon dioxide

ANNEXURE-II

RECOMMENDED STACK HEIGHTS FOR CHIMNEYS

Steam generating capacity	Stack heights
Less than 2 T/h	9 m or $2\frac{1}{2}$ times of the height of the neighbouring building
2 T to less than 5 T/h	12 m
5 T to less than 10 T/h	15 m
10 T to less than 15 T/h	18 m
15 T to less than 20 T/h	21 m
20 T to 25 T/h	24 m
25 T to 30 T/h	27 m