FOREWORD

Air quality is affected not only due to conventional air pollutants but also due to unpleasant odour. Odour has distinctly different characteristics and is undoubtedly the most complex of all the air pollution problems. Till date, not much attention has been paid towards odour problems in India.

The present issue of 'Parivesh' newsletter is an attempt to throw some light on the causes and processes of odour formation as also sampling, measurement and control technologies.

The information in this issue has been compiled and collated by *Ms Anjna Singh, Dr. M. Sundaravadivel* and *Ms Meetu Kapoor* under the guidance of *Shri Lalit Kapur* and *Dr. B. Sengupta.* We hope, the information contained in this issue will be useful to all concerned.

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1.0 INTRODUCTION

Odour can be defined as the "perception of smell" or in scientific terms as "a sensation resulting from the reception of stimulus by the olfactory sensory system". Whether pleasant or unpleasant, odours are induced by inhaling air-borne volatile organics or inorganics.

With growing population, industrialization and urbanization, the odour problem has been assuming objectionable proportion. Urbanization without proper sanitation facilities is a major cause of odour problems. Rapidly growing industrialization has aggravated the problem through odorous industrial operations. Undesirable odours contribute to air quality concerns and affect human lifestyles. Odour is undoubtedly the most complex of all the air pollution problems.

Unlike conventional air pollutants, odour has distinctly different characteristics, which, to an extent, can be comparable with noise pollution. Similar to noise, nuisance is the primary effect of odour on people. Some of such characteristics are:

- Substances of similar or dissimilar chemical constitution may have similar odours. Nature and strength of odour may change on dilution.
- Weak odours are not perceived in presence of strong odours.
- Odours of same strength blend to produce a combination in, which one or both may be unrecognizable.
- Constant intensity of odours causes an individual to quickly loose awareness of the sensation and only noticed when it varies in intensity.
- Fatigue for one odour may not affect the perception of dissimilar odours but will interfere with the perception of similar odours.
- An unfamiliar odour is more likely to cause complaint than a familiar one.
- Two or more odorous substances may cancel the smell of each other.
- Odours travel downwind.
- Person can smell at a distance.
- Many animals have keener sense of olfaction than man.
- Likes and dislikes often depend on association of the scent with pleasant or unpleasant experiences.

2.0 EFFECTS OF ODOUR

Odour affects human beings in a number of ways. Strong, unpleasant or offensive smells can interfere with a person's enjoyment of life especially if they are frequent and/or persistent. Major factors relevant to perceived odour nuisance are:

- Offensiveness
- Duration of exposure to odour
- Frequency of odour occurrence
- Tolerance and expectation of the receptor

Though foul odour may not cause direct damage to health, toxic stimulants of odour may cause ill health or respiratory symptoms. Secondary effects, in some, may be nausea, insomnia and discomfort. Very strong odour can result in nasal irritation, trigger symptoms in individuals with breathing problems or asthma. On the economic front, loss of property value near odour causing operations/ industries and odorous environment is partly a consequence of offensive odour.

3.0 SOURCES OF ODOUR

Most commonly reported odour-producing compounds are hydrogen sulfide (rotten egg odour) and ammonia (sharp pungent odour). Carbon disulfide, mercaptans, product of decomposition of proteins (especially of animal origin) phenols and some petroleum hydrocarbons are other common odorants. Most offensive odour are created by the anaerobic decay of wet organic matter such as flesh, manure, feed or silage. For example, odour originating from livestock manure are a result of a broad range of over 168 odour-producing compounds. Warm temperatures enhance anaerobic decay and foul odour production, as represented in Figure 1.

Odour sources can be classified as:

- **Point Sources:** Point sources are confined to emissions from vents, stacks and exhausts.
- **Area Sources:** Area sources may be unconfined like swine operations, sewage treatment plant, waste water treatment plant, solid waste landfill, composting, household manure spreading, settling lagoons or a cattle feedlot etc.
- **Building Sources:** Building sources of odour may like from hog confinement chicken and pig sheds.
- **Fugitive Sources:** In this source of odour, emissions are of fugitive nature like odour emissions from soil bed or bio-filter surface.

Odour can arise from many sources. Most of the sources are man-made. Garbage/improper dumping in vacant land is a common phenomenon. It leads to foul smell due to putrefaction of dumped garbage, which lies uncollected for days together. Unscientific design of landfill, increased sewage production & improper sewage treatment practices produce unpleasant odour.

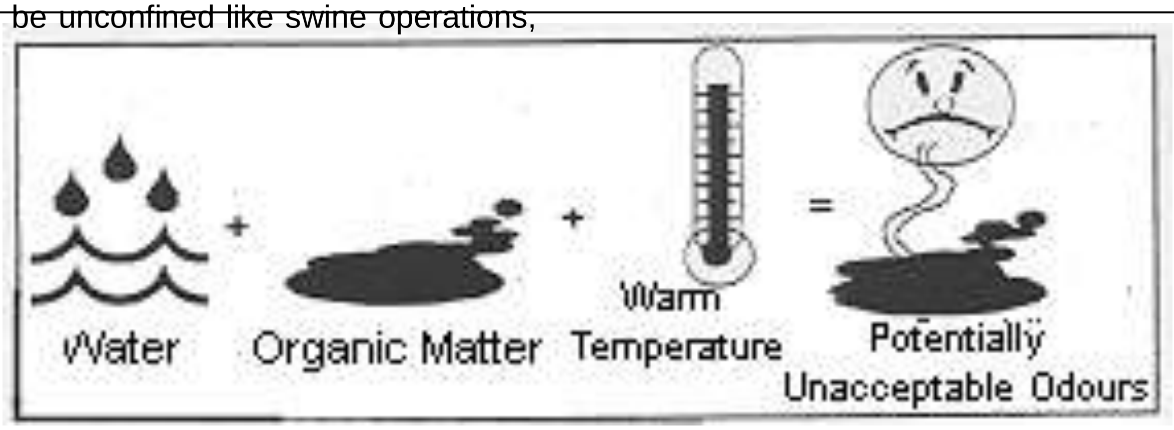

Figure 1. Conditions for Potential Foul Odour

Large livestock operations, poultry farms, tanneries, slaughterhouses, food and meat processing industries, and bone mills are among major contributors to odour pollution. Agricultural activities like decaying of vegetation, production and application of compost etc. also contribute to odour pollution.

In urban areas, improper handling of public amenities like toilets of cinema hall, bus/railway stations, hospitals, shopping complex etc. generate pungent odour, which affects the users as well as neighborhood residents. Congested markets do not allow the escape of odour from markets products, thus causing problems to shop-owners as well as to customers.

Vehicular sector also has its share in odour pollution. Rapidly growing vehicular population as well as harmful pollutants emitted by them generate very harmful and pungent odour that have marked effects on pedestrians as well as near-by residents.

Table 1 indicates the various odorous chemicals emitted from industrial operations.

Table 1. Sources of Odour

S. No.	Industry	Odorous Material
1.	Pulp & Paper	Mercaptans, hydrogen sulfide
2.	Tanneries	Hides, flesh
3.	Fertilizers	Ammonia, nitrogen compounds
4.	Petroleum	Sulphur compounds from crude oil, mercaptans
5.	Chemical	Ammonia, phenols, mercaptans, hydrogen sulfide, chlorine, organic products
6.	Foundries	Quenching oils
7.	Pharmaceuticals	Biological extracts and wastes, spent fermentation liquors
8.	Food	Cannery waste, dairy waste, meat products, packing house wastes, fish cooking odours, coffee roaster effluents
9.	Detergent	Animal fats
10.	General	Burning rubber, solvents, incinerator, smoke
11.	Swine Operations	Hydrogen sulfide and ammonia
12.	Waster Water Treatment Plant	Hydrogen sulfide
13.	Municipal Solid Waste landfill	Hydrogen sulfide

4.0 MEASUREMENT AND MONITORING OF ODOUR

4.1 Terms associated with odour measurement

For better understanding of the methods of measurement of odour, definition of following few terms is required:

- **Odour Intensity:** Odour intensity is the strength of the perceived odour sensation. It is related to the odorant concentration. The odour intensity is usually stated according to a predetermined rating system. Widely used scale for odour intensity is the following:

  0 - No odour
  1 - Threshold level
  2 - Definite odour
  3 - Strong odour
  4 - Overpowering odour

(Half score is used when the observer is undecided)

- **Odour Detectability or Threshold:** Odour detectability or threshold is a sensory property referring to the minimum concentration that produces an olfactory response or sensation. With odour intensity at or just above “threshold” odour become difficult to perceive.

- **Odour Character:** Odour character or quality is the property to identify an odour and to differentiate it from another odour of equal intensity.
- **Hedonic Tone:** Hedonic tone is a property of an odour relating to its pleasantness. When an odour is evaluated for its hedonic tone in the neutral context of an olfactometric presentation, the panelist is exposed to a controlled stimulus in terms of intensity and duration. The degree of pleasantness or unpleasantness is determined by each panelist experience and emotional associations.

4.2 Sampling of odours

Odours are measured adopting ***olfactometric testing methods***, which are psycho-physical methods. Olfactometery employs a panel of human noses as sensors. In these methods, the olfactory responses of individuals sniffing diluted odour presented by an olfactometer to determine odour strength or odour concentration.

Odour measurement requires representative samples of the air to be drawn into a sample bag and rapidly transported to an odour laboratory for olfactometric testing. Sampling strategies and techniques depends on emission sources characteristics. Each type of source has special requirements for sampling and sample collection.

Point Sources: Typically, a point source will be a stack with a known flow rate. Odour samples are taken into Tedlar sampling bags loaded in a vacuum drum through Teflon tube inserted into the stack at different points.

Area Sources: Area source will be water or a solid surface. A portable wind tunnel system can be used to determine the specific emission odour rate (SEOR). The specific emission odour rate (SEOR) may be defined as the quantity of odour emitted per unit time from a unit surface area. The quantity of odour is not determined directly by olfactometry but is calculated from the concentration of odour (as measured by olfactometry), which is then multiplied by the volume of air passing through the hood per unit time.

Building Sources: Building sources, such as chicken and pig sheds, have a number of openings. For animal sheds odour samples are normally taken from several points within a shed. Experience indicates that one composite sample is sufficient to represent a single shed at a particular time.

Fugitive Sources : Typically fugitive sources include odour emissions from bed or bio-filter surface. The emission normally has an outgoing or upward gas flow. Odorants in the atmosphere or gas stream can be collected by passing known volume of air or gas through a column of activated carbon or by condensing techniques.

4.3 Odour measurement

The olfactometric methods of odour measurement falls into two categories:

a. Determination of the threshold concentration of odoriferous gases:

For determining threshold concentration by the olfactometery testing procedure, a diluted odorous mixture and an odour free gas (as a reference) are presented separately from two sniffing ports at 20 lpm to a group of eight panelists in succession. In comparing the gases emitted from each port, the panelists are asked to report the presence of odour together with confidence level such as guessing, inkling or certainty. The gas dilution ratio is then decreased by a factor of two. The panelists are asked to repeat their judgment. This continues for six different dilution levels, resulting a total of 8x6x2 = 96 judgments (sniffing) from eight panelists. Using panelist responses over a range of dilution settings, odour concentration expressed as odour unit per cubic meter (ou/m^3) can be calculated from individual threshold estimates. European threshold concentration ranges for some unpleasant odours are presented in Table 2.

Table 2. European Threshold Concentration Ranges

Compound	**Detection threshold (mg/m^3)**	**Compound**	**Detection threshold (mg/m^3)**
Acetic acid	25-10,000	Indole	0.6
Propanic acid	3-890	3-Methyl indole	0.4-0.8
Butanoic	4-3,000	Methanethiol	0.5
3-Methyl butanoic acid	5	Dimethyl sulphide	2-30
Pentanoic acid	0.8-70	Dimethyl dislphide	3-14
Phenol	22-4,000	Dimethyl trisulphide	7.3
4-Methly phenol	0.22-35	Hydrogen sulphide	0.1-180

b. Determination of the type and intensity of odour:

For odour intensity measurement, generally a panel of 6 to 12 persons of normal health are employed. The panel members sniff the air at a given location at the same time and report individually the nature and intensity of the odour. By averaging the values recorded by members of the panel, a single value can be assigned to the odour intensity at a given location.
Generally odour intensity increases with the odorant concentration. The relationship between intensity and concentration can be expressed as:

$$P = K \log S$$

where : P = Odour Intensity
K = Constant
S = Odour Concentration

Currently, the preferred and internationally standardized methods of measuring odour are the Dutch Standard Method (NVN 2820) and the more recent European Standard Method

(CEN TC 264). A joint Australia New Zealand standard based on the draft CEN standard is in the process of preparation.

4.4 Critical factors in measurement of odour concentration

A dynamic olfactometer is a gas diluting apparatus and an interface between a panel of human observers and an odorous gas sample diluted at various concentrations. Olfactometery requires very high standards of testing conditions. These include following requirements:

- **Odour free testing:** An odour free testing environment is an important element in the olfactometery testing process.

- **Olfactometer calibration:** The olfactometer must be calibrated against a tracer gas to check the dilution setting of the olfactometer.

- **Panelist management:** Panelist should be trained and screened using reference air incorporating certified butanol at a concentration of 60 ppm.

4.5 Limitations in odour measurement

- Odour concentration is only one of the four dimensions that are used to express odour sensation as experience by humans. The odour concentration is determined in an odour free environment and do not reflects the actual perception of the odour.

- Common standardized instrument calibration and panel selection procedure are a pre-requisite for comparison of odour concentration data reported in the literature. In the absence of standardized procedures, odour concentration levels reported might simply reflect the experience of the operator, the design of the olfactometer, its operational mode, its mixing method, the flow rate presented to panelist and the number of panelist employed.

5.0 ODOUR IMPACT ASSESSMENT

Wind movement in the atmosphere carries away odorous gases emitted from a source. Odour annoyance occurs when a person exposed to an odour perceives the odour as unwanted. Using an air dispersion models, it is possible to predict the downwind odour concentration on the basis of odour emission rates, topography and meteorological data. The results can be used against odour impact criteria to derive an odour impact area.

Odour impact assessment is an effective tool for the following purposes:

- Preparation of environmental management plans
- Development of appropriate regional and local planning and development control instruments
- Odour regulation

In essence, odour impact assessment uses inputs of source odour concentration, ventilation rate and odour emission rate, topography information together with meteorological data (one-year data), dispersion model to model odour dispersion about the source. Odour impact area is defined by plotting isopleths of odour concentration corresponding to same value for odour impact criteria. The approach to odour impact assessment is illustrated in Figure 2.

Within an odour impact area, typical receptors (eg. residents) may be expected to experience a certain degree of odour nuisance. Odour impact criteria are not ambient air quality standards but rather provide a scientifically derived benchmark for making of informed decisions in planning, design, environmental management and regulation.

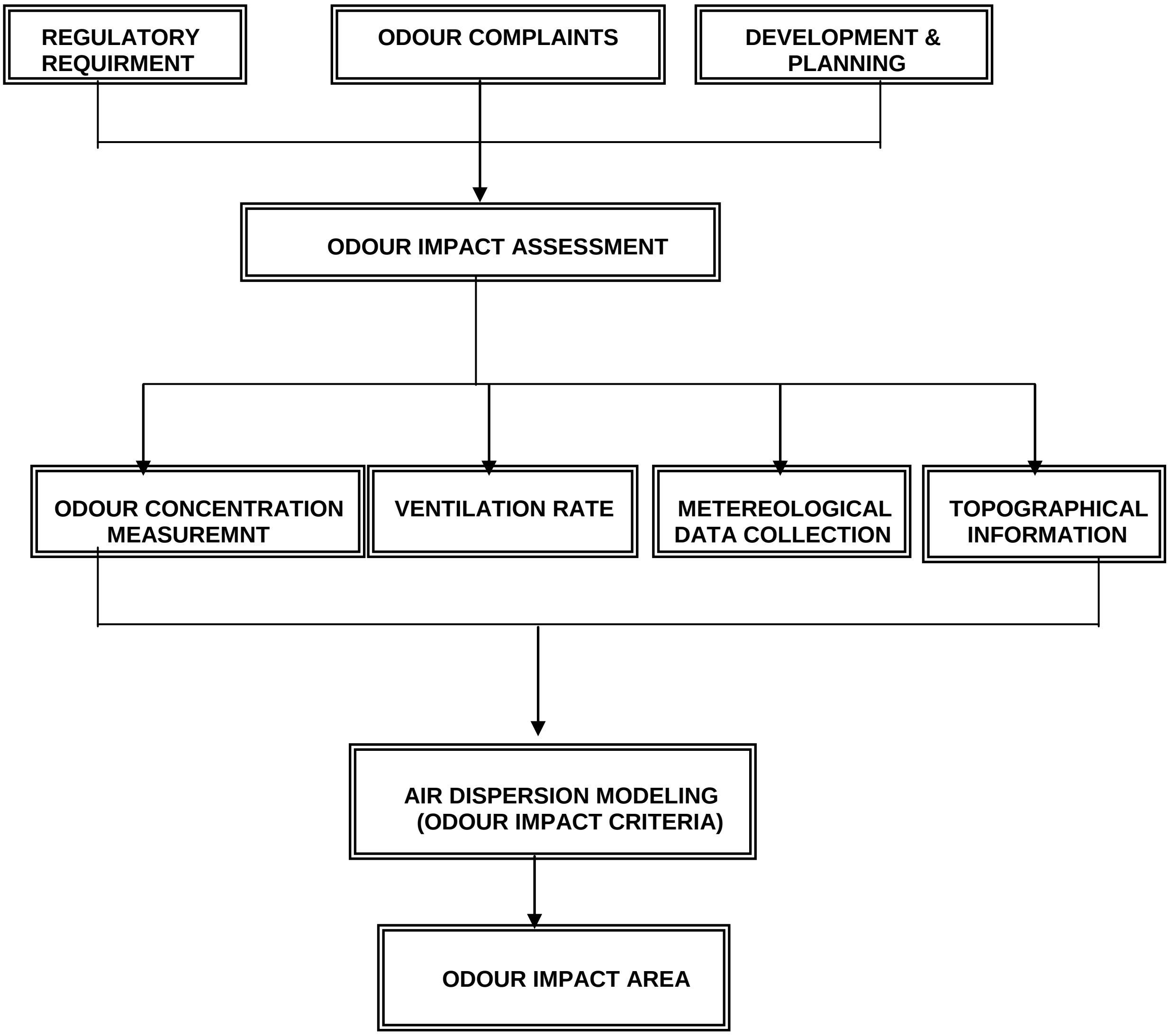

Figure 2. Odour Impact Assessment Flow Chart

6.0 ODOUR CONTROL TECHNOLOGIES

Odour control depends on type of sources and are discussed below:

6.1. Odour control from area sources

For large area sources following methods can be used to reduce odour complaints.

i) **Excluding development close to the site**

Development close to the site is to be excluded. A reasonable “buffer zone” around the area sources has to be determined. The actual size of this zone will depend upon a number of factors, including the size of the area from which odours emanate, the intensity of the odours being emitted, the duration and frequency of the odour emissions, the actual process being undertaken, the topography of the site, the weather conditions that prevails at the site. Green belt development in the buffer zone may help at least partially to obfuscate the odour.

ii) **Ensuring that the operation is carried out under the best management practice**

Best management practices (BMP) will vary according to the industry producing the odour. However, for all new developments, BMPs will start with the site selection and the building of the facilities.

iii) Nozzles, sprayers and atomizers that spray ultra-fine particles of water or chemicals can be used along the boundary lines of area sources to suppress odours.

Rotary atomizer is one such technique widely recommended for adoption for effective control of odour in case of area sources. The Atomizer uses centrifugal action by a spinning inner mesh to force droplets on to an outer mesh which "cuts" the water into atoms (Figure 3). The rotary atomizer produces millions of microscopic droplets of water -- up to 238 billion from a single litre droplets that are thinner than a human hair and a fine spray which covers up to 30 linear metres. This creates a fine mist, which is more effective with minimal use of water and electricity. A typical installation of rotary atomizer is shown in Figure 4.

There are a large number of chemicals and proprietary products that claim to reduce odour when they are applied to area sources. Atmospheric odours that are contained in a restricted area can be oxidized by atomization of the chlorine dioxide. Odour from sources such as holding ponds, lagoons, and sewage pre or post treatment effluent can be controlled by atomized spray of chlorine dioxide.

To reduce odour, chemicals have to be applied over very large area, the cost of materials and labors would be very high. The large quantity of these compounds required could themselves cause pollution. The spray/ atomizer techniques are used to conceal odours also from building and fugitive sources.

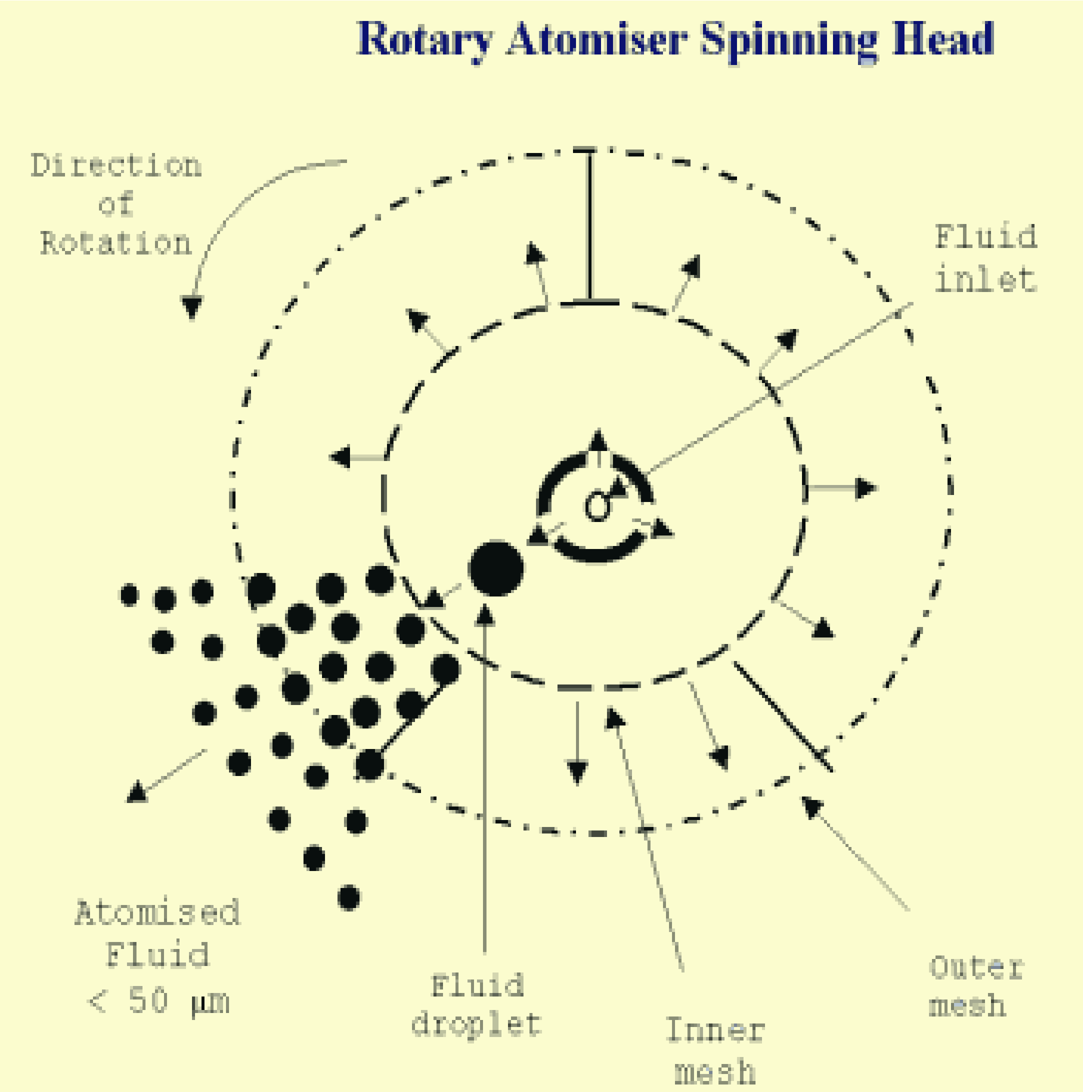

Figure 3. Working of a rotary atomizer

Figure 4. A typical atomizer installation for odour control

6.2 Odour control from point sources

In case of point sources such as that of industries, the odour-causing gas stream can be collected through piping and ventilation system and made available for treatment. Dispersion method is the simplest of the methods that can be adopted for odour abatement. This is nothing but to release odorous gases from tall stack. It results in normal dispersion in the atmosphere and consequent decrease in ground-level concentration below the threshold value. Dispersal by stacks requires careful consideration of the location & meteorological parameters, etc. In general, dispersion of odour emissions via chimneys is not a recommended method.

An array of treatment technologies is available for control of odour from gas streams collected through process ventilation systems. These include are:

i) Mist filtration
ii) Thermal oxidation/ Incineration
iii) Catalytic oxidation
iv) Biofiltration
v) Adsorption
vi) Wet scrubbing/Absorption
vii) Chemical treatment
viii) Irradiation

The choice of the technology is often influenced by the following factors:

- The volume of gas (or vapor) being produced and its flow rate
- The chemical composition of the mixture causing the odour
- The temperature
- The water content of the stream

6.2.1 Mist filtration

While gases cause most odour, problems may also result from aerosols in the fumes. Odorous air streams frequently contain high concentration of moisture. If these vapour discharge can be cooled to less than 40°C, a substantial quantity of the water vapour will be condensed and so reduce the volume of gases to be incinerated. Mist filters can be used for this purpose. Mist filters can also remove solids and liquids from gas stream; if the odour is caused by these particles, then it will result in odour reduction.

6.2.2 Thermal oxidation/ Incineration

Thermal oxidation/ incineration is the oxidation of the odour into carbon dioxide and water by the combustion of the odour with fuel and air. The reaction takes place at temperatures ranging from 750^{o}C to 850^{o}C. This is generally above the auto-ignition temperature of most solvents and other VOCs and is a reflection of the heat required to maintain the reaction at dilute concentrations with additional process heat losses. In this regime, the destruction efficiency is almost 100%, assuming adequate oxygen supply. In some cases, other compounds may be formed depending on the mixture of fuel and air used, the flame temperature and the composition of the odour. These compounds may include carbon monoxide, oxide of nitrogen and sulfur oxides.

Thermal oxidizer is a refractory-lined furnace fitted with one or more burners. The furnace consists of two chambers- mixing chamber and combustion chamber. There are 3 types of thermal oxidizer:

a) Direct-fired thermal oxidizer

b) Recuperative thermal oxidizer

c) Regenerative thermal oxidizer

Direct-fired thermal oxidizer is effectively a combustion chamber with a burner and the appropriate control system. The exhaust from a direct-fired unit is typically at the combustion temperature with no primary or secondary heat recovery. This is used where heat recovery is not required (e.g. when fuel for the burner is free or very cheap). In many cases the fuel cost of heating a process stream to the combustion temperature leads to the inclusion of some sort of heat recovery mechanism.

Where the level of VOC is significant, then the heat release from the VOC can be recovered to improve the cost effectiveness of the system. Both recuperative and regenerative thermal oxidizer technologies include heat recovery systems to recover heat as a utility for other energy requirements.

Recuperative systems are basic thermal oxidisers with built-in primary shell and tube heat exchangers. A primary heat exchanger can recover up to 70% of the heat input by the burner or released during the oxidation process by heating up the inlet stream thus reducing the required burner load to maintain the required oxidation temperature (typically 750^{o}C-800^{o}C). These are a simple, cost effective, means of destroying VOC where the inlet concentration is relatively high or particularly where heat can be usefully recovered for other processes.

Regenerative thermal oxidizer (RTO) is the most often used type of thermal oxidizer because of its robust performance and its ability to operate at high thermal efficiency. The RTO utilizes beds of ceramic media to provide the thermal efficiency. Two or more beds are used in a controlled cycle and alternatively operate to heat incoming air and to cool exit air. The unit can operate at thermal efficiencies of between 80% and 98% and can handle most types of fume. This means that where an exhaust stream contains a significant level of VOC, then auto-thermal burning (without the use of burners) is possible. At lower concentrations also, the RTO often provides cost-effective operation because of its very high thermal efficiency.

6.2.3 Catalytic oxidation

Catalytic oxidation reaction can be forced to proceed at much lower temperatures (e.g. 200^{o}C) in the presence of a catalyst (Figure 5). Thus, the advantage of this process over thermal oxidation is the reduction in required energy input. Catalytic systems are therefore more favourable where auto-thermal operation is not practical and heat cannot be economically used elsewhere.

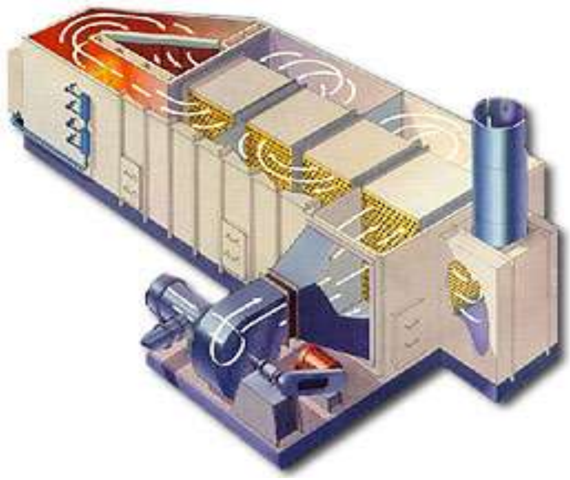

Figure 5. A catalytic oxidizer system

A number of transition and precious metal catalysts can be used in catalytic oxidizer to destroy various VOCs over a wide range of process conditions.

6.2.4 Biofiltration

This method is becoming an acceptable and successful way of reducing odours from biological process. Biofiltration is a natural process that occurs in the soil that has been adopted for commercial use. Bio-filters contain micro–organisms that break down VOC’s and oxidize inorganic gases and vapors into non–malodorous compounds such as water and CO_2. The bacteria grow on inert supports, allowing intimate contact between the odorous gases and the bacteria. The process is self-sustaining.

Bio-filters constructed of various materials including compost, straw, wood chips, peat, soil, and other inexpensive biologically active materials. Two typical arrangements of biofilters for odour control is shown in Figure 6.

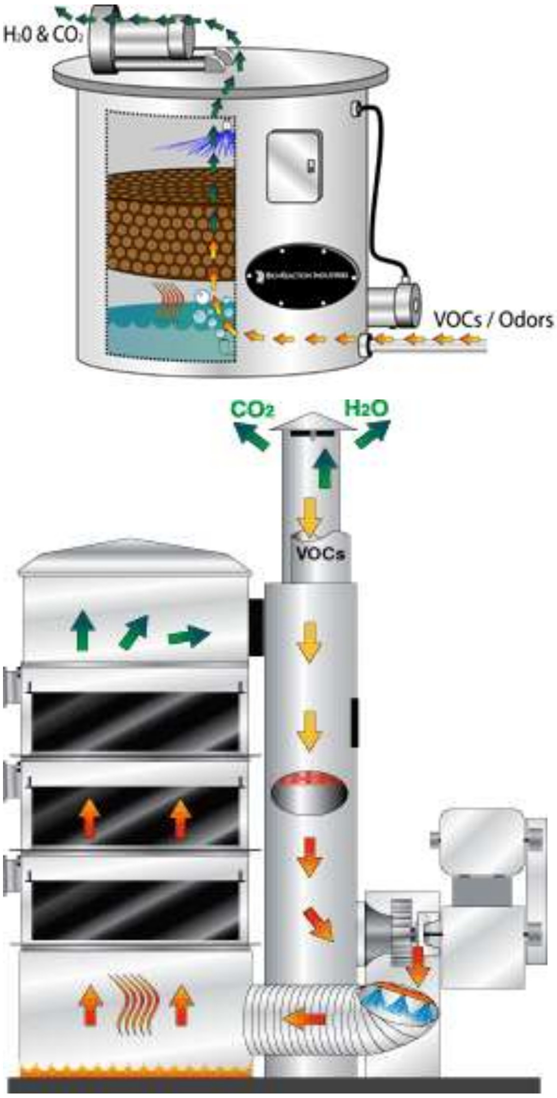

Figure 6. Biofilters for odour control

Another type of bio-filter is the soil-bed filter. Here the odorous gas stream is allowed to flow through a porous soil with a typical depth of 60 cm. The bacteria in the soil are responsible for the destruction of the odorous compounds.

6.2.5 Adsorption

A method that is suitable for controlling odorous substances, even at low concentrations, is adsorption on to activated carbon. For effectivity, the contaminated air stream must be free from dusts and particulates that might clog the carbon particles. Regeneration of carbon for re-use will produce either waste water, which will require further treatment before disposal, or a concentrated vapour stream, which can be incinerated more cheaply than the original air stream.

There are also systems that use activated alumina impregnated with potassium permanganate for adsorption. The alumina absorbs the odorous substances so that the permanganate can oxidize them, usually to carbon dioxide, water, nitrogen and sulfur dioxide, depending on their composition. The alumina bed is replaced progressively as the permanganate is exhausted. This has an advantage over carbon because no further treatment is needed; this may offset the cost of alumina.

6.2.6 Wet scrubbing/ Absorption

Wet scrubbing of gases to remove odour involve either absorption in a suitable solvent or chemical treatment with a suitable reagent. It is important that hot, moist streams are cooled before they contact scrubbing solutions. If this is not done the scrubbing solution will be heated and become less efficient, the scrubbing medium will become diluted from condensation of water vapour.

Wet scrubbing or absorption systems can be either **ventury systems or**

packed tower systems. Venturi systems are co-current scrubbers that accelerate the gas stream into a high density liquor spray. The aqueous droplets then impinge or impact at high relative velocity with solids in the gas stream. The resulting conglomerated particle is then separated from the gas stream in a disengagement tower by virtue of inertial forces. The high density spray also provides reasonable mass transfer to the absorption of gaseous contaminants. **Packed Towers** are typically counter current scrubbers that utilise high surface area media as a contact zone for the gas stream with suitable scrubbing liquor. The media facilitates high efficiency mass transfer to provide >99.9% removal of gaseous contaminants.

When the odour is caused by the presence of unsaturated organic compounds, it may be necessary to use an oxidizing agent such as chlorine, diluted sulfuric acid and sodium hydroxide to treat odour.

Absorption is applicable when the odorous gases are soluble or emulsifiable in a liquid or react chemically in solution. Wet scrubbing is a useful process to handle acid gas streams, ammonia or streams with solids that might foul other equipment. It has been suggested that liquid scrubbing becomes economically attractive compared to incineration and adsorption on activated carbon when the volume of odorous gas to be treated is greater than 5000 cubic meters per hour.

6.2.7 Chemical treatment

Injecting controlled quantities of chemicals such as chlorine or ozone into process-gas stream can control odour. Similarly, unlike various other "odour control" treatments, chlorine dioxide will destroy the odour at source. Chlorine dioxide is several times more effective than chlorine and other commonly used treatments, and will not form hazardous by products, such as chlorinated organic, which can cause more problems than the original odour itself.

Odours arising from water bodies can generally be eliminated by adding the chlorine dioxide solution directly to the odoriferous fluid. The first action of chlorine dioxide is to rapidly oxidize the vapor gases dissolved in the fluid to their oxide form. As the dissolved gases are oxidized and the amount of chlorine dioxide will increase, next action of chlorine dioxide is the oxidation of small molecular material (micro-organisms), and, as the amount of chlorine dioxide will further increase, the larger molecules and compounds are oxidized.

Due to this versatility, chlorine dioxide can be used in all aspects of the odour control process, from air scrubbers and wastewater treatment with stabilized chlorine dioxide solutions.

6.2.8 Irradiation

Ultra-violet irradiation can be used to control of odour. Here, the action is probably due to ozone formation or bactericidal effect.

7.0 LAWS AND REGULATIONS

Generally, most regulatory organizations/municipal authorities resort to nuisance prevention law to abate odour, but it is being followed more in breach than in practice. Perhaps the most effective method of overcoming the problem is to have regulation, which can be directed towards specific emissions from specific industries. For example, regulation of pulp mills odours which limits emission of mercaptans.

The development of odour measurement, regulation and control technique has been greatly progressed in most of the countries. In Australia, several states are reviewing the existing regulations on the control of odour from various source based on a forthcoming Australian–New–Zealand standard of odour measurement using dynamic olfactomerty. In Europe, the official standard for odour measurement is expected to be published in 2002.

In the USA, odour has been listed as one of the key area to be dealt with the Agriculture Air Quality Task Force. There are some State regulations in the US to address the odour from some specific sources. In **Minnesota**, the Feedlot Hydrogen Sulfide Program administered by the Minnesota Pollution Control Agency is in vougue since July 1997. The hydrogen sulfide standard works in the following way: each gas sample represents an average value of the gas over a continuous 30-minute period. A violation occurs if the hydrogen sulfide ambient air quality exceeds 30 and 50 ppb within certain time period. **Iowa's "manure law"** was enacted in 1995, to create a system of setback distances for lagoons and buildings, depending on the nature of the surrounding area. Also Iowa Department of Natural Resources has proposed new regulations for swine producers, which require manure injection rather than spreading.

Europe is more active than the United States in addressing gaseous and odour problems from large-scale swine facilities. Europe has focussed on two primary areas of concern – nitrogen emissions and odour prevention. **The Netherlands** has "an extremely strict approach" for regulating nitrogen emissions. By 2010, farmers must reduce their emissions by 70 % of 1980 levels, with an assumption that a 10 % reduction rate in ammonia emissions will result in a 7 % reduction of odour. In **Denmark**, odour laws were established during 1950 to 1980. These laws required ventilation chimneys and setback distances from houses. By the end of 1980s, it was felt that the general code of good agricultural practice had not reduced odour to acceptable levels. The Ministry of Environment then imposed restrictions on the construction and location of manure storage and swine buildings, as well as on the land application of manure. **Germany** focuses more on managing nutrients than on paying specific attention to ammonia odour emissions. The Fertilizer Ordinance enacted in July, 1996, requires manure to be worked into non-tilled soils immediately after application. Producers have to send records of both manure storage and cropland application to the government. There are strict controls on lagoons as well – they must be lined, covered and equipped with underground pipes for the detection of leaks.

In India, Schedule II and Schedule VI (General standards for discharge of effluents) under Environmental (Protection) Rules, 1986 prescribes that all efforts shall be made to remove unpleasant odour as far as practicable. Nonetheless, there are only two industries, wherein industry specific standards under Schedule I of these Rules mandate odour removal. These are the fermentation industries and the natural rubber industries. The standards for many other major odour pollution causing industries such as pulp and paper mills, tanneries, meat processing industries, bulk drug and pharmaceutical units, food and fruit processing units, dairies and milk plants etc. do not specify odour control.

8.0 CONCLUDING REMARKS

Controlling odour is an important consideration for protecting the environment and our community amenity. Since there are neither indicative compounds within odour plumes nor electronic or other devices for measuring odour emissions, it is difficult to develop meaningful regulatory threshold limits for odour. However, based on the international experience on odour control, our country also needs to adopt effective odour control policies.

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Published By : Dr. B. Sengupta, Member Secretary, Central Pollution Control Board, Delhi – 32
Printing Supervision & Layout : P.K. Mahendru, M. Panddey, Anamka Sagar and Mohd. Javed
Fax : 91-11-2217079/2204948 EPABX : 2225792, 2222073, 2222856 TELEX : 031-66440 PCON IN
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Printed at : M/s