INDUSTRIAL STACK EMISSIONS AND AIR QUALITY

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SINOPSIS:

Die probleem met die bepaling van perke vir die vrylaattempo van enige nywerheidsuitlaat word uiteengesit. Die rol wat die hoë skoorsteen speel in die vermindering van grondvlakkonsentrasie nadat vrylaattempo's effektief beperk is, word bespreek.

SYNOPSIS:

The problem of deciding upon limits to the emission rate of any industrial effluent are set out. The role of the tall stack in reducing ground level concentrations after effective emission limitation has been achieved, is discussed.

INDUSTRIAL STACK EMISSIONS AND AIR QUALITY

Today industry is expected to take steps to ensure that it conducts its operations in harmony with the environment and in conformity to recognised employee and community standards. To protect air quality the Atmospheric Pollution Prevention Act No. 45 of 1965 provides for control and prevention of the escape into the atmosphere of noxious or offensive gases from industrial processes which have been scheduled in terms of the Act. The Act stipulates that "best practicable means" should be used. This means the effective operation of plant, as well as the provision and maintenance of appliances. It also recognises that suitable technology for preventing emissions should be available at a reasonable cost.

If the discharge of noxious or offensive gases cannot be prevented then it is important to render these harmless and inoffensive. One way of achieving this is by suitable dispersion from a tall stack.

In considering dispersion it is assumed that "the best practicable means" for preventing emissions has been considered: The next step is to set a realistic target for the permissible effects of the emission on the community and the environment. The ideal situation in looking at effects would be to examine all the information on toxicity to humans, identifiable effects on plants, animals, materials and community amenities (including such things as nuisance deposits and reduced visibility) and then to take the most significant as the goal.

We all know that information covering all of these aspects is not always available and the industrialist may have to rely on his own estimation of the risks involved. In looking at the overall situation, employee and public health is usually considered to be the most important. The evaluation of the contribution of particular pollutants to health problems, however, is complicated by the apparently endless number of pollutants to which people can be exposed. It is generally recognised that the problem of fixing limits particularly for the general public is both difficult and controversial.

Although "noxious and offensive gases" have been defined in the broadest terms in the Atmospheric Pollution prevention Act, the Act does not lay down any limits of concentration at which the gases become noxious, offensive, or a danger to health.

"Threshold limit values" which may be regarded as useful guides rather than clearly defined boundaries between safe and unsafe conditions, have, however been drawn up by the American Conference of Government Industrial[1] Hygienists (ACGIH) for many of the substances encountered by workers in industry.

The ACGIH defines three categories of threshold limit values (TLVs) for airborne contaminants namely:

TLV-TWA (the Threshold Limit Value – Time Weighted Average) is "the time-weighted average concentration for a normal 8 hour work day or 40 hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect."

TLV-STEL (The Threshold Limit Value – Short Term Exposure Limit) is the maximum concentration of contaminant for a continuous exposure period up to 15 minutes: Effects such as irritation and narcosis must not occur during the exposure period. No more than 4 exposures are allowed per day with at least 1 hour between exposure periods. In addition the TLV-TWA must not be exceeded.

TLV-C (Threshold Limit Value – Ceiling) is the concentration that should not be exceeded even instantaneously.

The ACGIH values have gained fairly widespread acceptance in industry and are often used for purposes of deciding the target for acceptable maximum ground level concentrations for employees in the working environment.

For community exposure suggestions have been made by controlling authorities from time to time that the threshold for 24 hour exposure of the general public should be anything from 1/50 to 1/100 of the worker TLV.

It is interesting to compare the 1/50 TLV values for SO_2 and NO_2 with ambient air quality standards which have been established in the U.S.A. The American standards are divided into two kinds, primary standards for public health and secondary standards for public welfare:[2]

where x = max. ground level concentration on the centre line of the plume in g/m^3.
Q = mass emission rate g/sec.
u = mean wind speed m/sec.
H = effective stack height m.

Pollutant	Averaging time	Primary standards	Secondary standards	1/50 TLV (1979) —TWA	1/50 TLV Intended —TWA Change from 1979 value
Sulfur Dioxide	Annual (arithmetic mean)	80 $\mu g/m^3$ (0,03 ppm)	–		
	24-hour	365 $\mu g/m^3$ (0,14 ppm)	–	260 $\mu g/m^3$	100 $\mu g/m^3$
	3-hour	–	1300 $\mu g/m^3$ (0,5 ppm)		
Nitrogen dioxide	Annual (arithmetic)	100 $\mu g/m^3$ (0,05 ppm)	(same as primary)	180 $\mu g/m^3$	120 $\mu g/m^3$

Other national standards may differ — for instance Sweden works to a 24 hour average for SO_2 of 300 $\mu g/m^3$. It can be seen that if the rule of thumb 1/50 of worker threshold limit is applied then the limit for SO_2 based on the intended change from the 1979 adopted value would be 100 $\mu g/m^3$ which is far more stringent than the 300 $\mu g/m^3$ and 365 $\mu g/m^3$ 24 hour limit values for Sweden and the USA. It is clear that although there is reasonable agreement among air pollution control people that human health is harmed by pollutant concentrations above a certain level, there is not necessarily agreement as to what that level is and the situation is still clouded because of the state of our knowledge of effects of low concentrations of pollutants over long periods of time.

There is, however, a considerable amount of data in the literature on levels of various pollutants which have caused health effects, damaged to vegetation etc. and a compendium of all such data would be an extremely useful reference document and would assist the industrialist in setting proper targets for acceptable ground level concentrations. Perhaps the National Association of Clean Air could play a role in generating and disseminating this information.

As previously mentioned one method of achieving the required ground level concentration is to make sure that the emission is at such a height that atmospheric dispersion produces the required reduction under the most adverse meteorological conditions.

As a first step the industrialist can make use of the relevant equations devised by sutton and others to make an estimate of the required height of stack. The basic equation for the centre line maximum ground level concentration is:

$$x\,\max = \frac{2Q}{e\pi u H^2}\,(\sigma_z/\sigma_y)$$

$\sigma_z\ \sigma_y$ are vertical and lateral dispersion parameters which are dependent on conditions measured on site but can be taken as about 0,8 for neutral Highveld conditions.

The effective stack height in the above equation is the sum of the actual stack height and the plume rise resulting from the buoyancy and upward velocity of the gases.

It can be seen that if a target for the maximum acceptable ground level concentration is available it is possible to calculate the effective stack height and by subtracting the plume rise the actual physical stack height. Conversely if the emissions rate and effective stack height is known it is possible to calculate the maximum ground level concentration. Numerous equations for calculating plume rise have been developed, the Briggs equation being one example.

$$H = \frac{1{,}6\,F^{1/3}\,x^{2/3}}{u}$$

H = rise of plume m at distance x downwind
u = wind speed m/s.
x = distance downwind m

The buoyancy flux F is given by[3]

$$F = 3{,}7 \times 10^{-5}\,\frac{P_{sea}}{P_o}\,Q_h$$

Q_h cals/sec) $= Q\,c_p\,\Delta T$ where $\Delta T = (T_g - T_o)\ ^{\circ}C$
Q = mass emission rate g/sec
Tg = temp gas
To = ambient temp.
Po = ambient pressure
$Psea$ = pressure at sea level

A look at the above equations reveals the following:

1) The maximum ground level concentration downwind is directly proportional to the mass emission rate.

2) The maximum ground level concentration is inversely proportional to the wind speed. Doubling the wind speed cuts pollution concentration to a half. In practice due to roughness and turbulence this could be a half to a quarter.

3) Pollutant concentration is inversely proportional to the square of the effective stack height. Doubling the effective stack height reduces the maximum ground level concentration to one quarter.

4) The plume rise is inversely proportional to the wind speed. The effect of increasing wind velocity is to reduce plume rise and hence effective stack height. This in fact could have a greater effect than the increased dissipation that the wind produces.

5) The higher the temperature of the gas above ambient the greater the buoyancy of the gas, the greater the plume rise and the greater the effective stack height.

When considering a new plant or an extension to an existing manufacturing facility there is a need to:

1) Reduce the mass emission rate whenever possible by integrating a low emission philosophy into the basic design and engineering of the plant.

2) Emit at sufficient height to meet ground level concentration targets.

3) Consider wind direction and velocity. This is important as it not only affects ground level concentrations but also determines where the air will transport the pollution.

4) Consider the likely frequency, intensity and duration of inversions. This condition represents the highest pollution potential as warm light air overlies relatively dense cold air. In winter the frequency of surface inversions exceeds 80% over most of the country and in both winter and summer the average depth of the midnight surface inversion is of the order of 300–400 m[4]. Under severe temperature inversion conditions a plume can travel long distances without gaining height and with only little dissipation.

5) Look at topography as this can influence wind behaviour. Channelling of pollutants in a populated valley and high land which could intercept a plume are potential trouble spots.

6) Consult the controlling authorities or organisations such as the Air Pollution Research Group of the CSIR. These can and do play an important role in advising on planning and siting of new projects.

If a locality away from residential areas can be chosen then obviously this is advantageous if not then the likely attitude of the general public must be considered. Often the reason given by the public for objecting to a plant is air pollution and the only way to show that no appreciable level of pollution is occurring is to monitor.

Although the industrialist is mainly concerned with local monitoring the use of tall stacks does give rise to transport of pollutants, and monitoring to determine how quality of air further away is affected is also necessary. In recent years much attention in Europe has been given to "acid rain" and likely consequences. The current position is that acidification of rain is tought to have no effect on human health and insignificant effects on agriculture. There is evidence that acidic precipitation has in fact increased forest growth rather than decreasing it, probably due to the increased uptake of nitrogen. Scandinavian countries in particular are still concerned, however, about possible effects on aquatic systems and continue to press other European countries to reduce their SO_2 emissions. Most countries are still looking for an "export market" for air pollutants and some idea of the South African man-made SO_2 and NO_x emission requiring assimilation compared with USA and West Germany is given in the following table:

	SO_2 million tons p.a.	NO_x million tons p.a.	*Comments*
USA	32,9	24,2	SO_2 predominantly from fuel combustion
West Germany	3,9	2,1	NO_x predominantly from fuel combustion and vehicle sources.
South Africa	1,4	0,8	

Although the use of tall stacks reduces local effects it has been established that long range movement of SO_2 and $SO_4^=$ is taking place and this background contribution to local sources will have to be considered in the future.

The question arises as to what is the situation with regard to tall stacks under South African conditions. Whilst it is recognised that the ultimate aim is to minimise overall emissions, the immediate goal is usually to ensure that local air quality targets are met. In the case of gaseous products of combustion the processes for removing SO_2 from flue gas are not at a stage where they are considered "best practicable means" for prevention, and tall stacks are still used to reduce concentrations in the vicinity of large plants, an example being the 300 m multi-flue stack at the Escom Duhva power station. In some instances there has been a need for taller stacks but this has not necessarily been the case for all processes. The trend for example in nitric acid production has been to build larger plants, bu emissions have been reduced by improved absorptio column design. This is illustrated in the following table

Plant Capacity 100% HNO_3 Basis t/day	Concentration NO_x in Tail Gas g/Nm^3	Emission kg/t	Emission NO_x t/day
40 (1st AECI plant	6,14	25,0	1
650 (latest AECI plant)	0,14	1,2	0,8

It can be seen that for a 16 fold increase in plant capacity there has been a 20% decrease in daily emission. Oxides of nitrogen emission per ton of HNO_3 for the older plants is about 20 times higher than that of the newer plants. In this case stack heights have not increased significantly but absorption column highets have.

In the overall national picture the contribution of oxides of nitrogen from nitric acid manufacture is small when compared with vehicle sources and combustion processes which contribute more than 96% of the total. But, because oxides of nitrogen from nitric acid plants are point sources, highly visible at times, they attract public attention and the chemical industry in this case is often understandably but incorrectly labelled as the biggest polluter of the atmosphere.

Although NO_x from nitric acid manufacture is a localised pollution issue, the industrialist must concern himself with the broader issues of regional and even global effects of pollutants being emitted. Information on pollutant levels and trends together with a greater knowledge of pollutant removal mechanisms must obviously assist the industrialist and controlling authorities in setting the longer term emission targets.

CONCLUSIONS

1) The evaluation of pollution problems involves an estimate of the risks to human beings, plants, materials and community amenities, and ultimately the total environment. Any information which serves to clarify these risks enables the industrialist to set proper targets and so ensure that his pollution control efforts are directed towards the right priorities.

2) The ultimate objective is to limit overall emissions to atmosphere but the immediate goal is to meet agreed quality targets by the "best practicable means". Greater clarification of these targets is needed.

3) Tall stacks have been shown to be effective in reducing ground level concentrations in the vicinity of large plants and as an interim measure until reliable removal processes are available assist in reducing localised problems.

4) The industrialist is usually concerned with local pollution issues but must also concern himself with the broader regional and global issues.

5) The adoption of a tall stack policy could transfer some of the local problems further afield.

6) There is a need for continued monitoring by industry to ensure that the achieved local levels are satisfactory and for regional and global monitoring to provide information on levels of pollution and to establish trends. Longer term targets for emissions from all sources can then be considered by controlling authorities.

REFERENCES

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