Air pollution and the metallurgical industry

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SYNOPSIS

The meteorological conditions in South Africa are not conducive to the effective dispersion of air pollutants. In the light of this, and because of the magnitude, concentration, and future growth potential of the metallurgical industry, control of air pollution is essential. Methods of abatement are discussed for each branch of the metallurgical industry, as well as for open-cast mining and bulk ore storage. Some recommendations are made regarding potentially rewarding research and development.

SAMEVATTING

Die meteorologiese toestande in Suid-Afrika is nie bevorderlik vir die doeltreffende dispersie van lugbesoedelstowwe nie. In die lig hiervan, en vanweë die grootte, konsentrasie en toekomstige groeipotensiaal van die metallurgiese nywerheid, is die beheer van lugbesoedeling noodsaaklik. Metodes om dit te verminder word vir elke vertakking van die metallurgiese nywerheid, asook vir oopgroefmynbou en massaertsopberging bespreek. Daar word sekere aanbevelings gedoen oor navorsing en ontwikkeling wat moontlik lonend kan wees.

Introduction

Around the middle of the present century, a number of words entered the vocabulary of the peoples of industrialized countries and rapidly came into common use. Most conspicuous in this context are the words *environment*, *pollution*, *ecology*, and *dwindling resources*. However, they do not represent new concepts; their use merely indicates an awareness of problems and conditions that have grown over the ages as man strove for higher standards of living. Air pollution, if defined as foreign material introduced into the atmosphere by man, started effectively with the first use of fire, but only became recognized as a problem with the growth of cohabitation.

The first recorded legislation to curb the offensive phenomenon was enacted in London in 1306 and prescribed capital punishment for any 'artificer' (metal worker) using coal impregnated with sea water in his furnace[1]. Thus, the metallurgical industry has been identified as a contributor to the problem of air pollution for the past six centuries and more.

Without entering into argument about the principles of legislation, one can rightly state that prohibition is normally an admission of inability to come to grips with a problem in a more satisfactory manner. In particular, this is true of air-pollution control. The evolution of air pollutants is an integral part of metallurgical processes and, as such, cannot be avoided. The continuation of such processes is therefore unavoidably linked with the evolution of both gaseous and finely divided particulate pollutants carried in a gas stream, but not necessarily with its discharge to the free atmosphere.

Air Pollution in South Africa

It has often been argued by the industry that there is no need for air-pollution control in this country because of the wide open spaces, and that conditions here do not compare with those in Europe, America, or Japan. Just as vehemently, the press and the public assert the opposite. The truth is to be found somewhere between these extreme viewpoints. South Africa has a lower population density than the industrialized countries, but it also has a poorer potential for the atmospheric dispersion of pollutants.

In South Africa, emissions of ferro-alloy and iron oxide fumes to the atmosphere were 8,4 and 88,0 kg/km^2 in 1970[2], while the corresponding figures[3] for the U.S.A. were 16,1 and 216,0 kg/km^2 respectively. It must be appreciated that the South African sources are heavily concentrated in the southern Transvaal, and a comparison of this region alone with the U.S.A. would be most unfavourable. Local factors contribute to the problem, notably the nature of the rainfall, altitude, and meteorology. South Africa is a relatively arid land with the exception of parts of Natal and the Cape coast[4], and such precipitation as occurs often takes the form of short downpours, so that there is very little effective scrubbing of the air.

The main industrialized area of the country is on the Highveld of the Transvaal at an altitude of more than 1300 m, with an associated decrease in the density of the air[4]. This means that a larger volume of air is required for any combustion and cooling operation and for lung ventilation. The altitude also has a significant effect on the ability of the atmosphere to disperse pollutants. The most important parameter in this process is the stability of the atmosphere[5]. In this regard, analysis of balloon flights has revealed that, for the Highveld, surface inversions[6] occur up to heights of 350 m, and with a frequency of 87 per cent in winter and 64 per cent in summer[7]. At altitudes of 1100 m and more, subsidence inversions with a depth of 250 m occur 44 per cent of the time in winter and less than 1 per cent in summer[8]. This means that emissions at low level have very little chance of dissipating freely for most of the time, while high-energy emissions penetrating the surface inversion are trapped for about half the time below the subsidence inversion[9].

Industrial Growth

South Africa is richly endowed with mineral resources, and it is normal to expect a high growth rate in this sector. As support for this expectation, the growth rate of the ferro-alloy industry over the period 1954 to 1975 was an average of more than 12 per cent or a doubling of capacity every six years[10]. This should be compared

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with the stagnation of the industry in the U.S.A., and only marginal growth in Germany, Japan, Sweden, and Norway.

The steel industry grew at an average annual rate of more than 6 per cent during the period 1955 to 1975[11], and additional capacity came into operation shortly after the last date. With the reserves known at present, even if there is a sharp increase in ore export, such a growth rate can be maintained until well into the next century.

In addition, the discovery of large reserves of lead, zinc, and to some extent copper in the northern Cape has paved the way for appreciable growth in these sectors when economic conditions permit. This growth is likely to be much more than that required to meet the normal increase in internal demand, and may have to fulfil the requirements of the world market.

Primary Iron and Steel Industry

The conventional installations of this industry consist of blast furnaces, with their associated coke production, and various types of refining equipment.

As the normal practice on blast furnaces includes gas scrubbing so that the clean gas can be used as fuel, the only remaining air pollution of significance originates at the tapping floor and during slips. Beyond improvements in raw materials, careful operation, and enlargement of gas off-take and holding facilities, very little can be done on blast furnaces.

Sintering of fines creates an effluent gas with particulates as the main pollutant, and this can be dealt with by any of the dry methods of abatement that give a satisfactory reduction in particulate load.

Coking operations are notorious for pollution, but this need not necessarily be so. The use of double mains on batteries is considered essential to cope with the generation of fume during charging. Another important facet is the method of charging. Both sequential and pipe-line charging offer avenues for damping severe surges in the evolution of fumes and extraction through the mains. Scrubber cars have inherent operational problems and are therefore not favoured. Discharge of the ovens has always been a problem, and, while inert-gas quenching is a potential solution, the cost is still prohibitive at this stage. Water-quenching towers have considerable merit provided the water does not contain undesirable components like particulates or organic material that will be volatilized. Not enough stress can ever be put on proper sealing of charging lids, discharge doors, and good housekeeping in general.

Bessemers, Tropaenas, rotors, tandems, and open hearths have all truly earned their place in museums and should be allowed to retire gracefully. They do not lend themselves to air-pollution abatement. The choice of equipment for the refining of iron includes oxygen-blown vessels like the LD (Lintz–Donewitz) and BOF (basic oxygen furnace) and the electric-arc furnace. The LD is logically cleaned by scrubbing because of the fuel value of the off-gas, while the BOF could be handled by either electrostatic precipitation or bag filtration. Likewise, the arc furnace offers potential for any of the three modes of cleaning, but the bag filter appears to be the most suitable.

Emissions during ladle transfers, tapping, and casting have not been solved satisfactorily except at very large installations where roof extraction is practised.

Secondary Iron and Steel Industry

In grey-iron foundries, the cold-blast cupola is used extensively. It is a production unit of low capital cost and therefore ideally suited to smaller operations. This represents a serious difficulty because highly efficient air-cleaning equipment may well represent an investment of an order of magnitude larger than the cupola. The emissions normally consist of ash-like particles in the range 5 to 100 μm, making up between 75 and 90 per cent by mass, and of smoke in the sub-micrometre particle-size range. As it is essential to conserve the heat content of the plume to aid in dispersion, wet scrubbing is not favoured, and mechanical collectors that improve in efficiency with increase in production unit size are advocated.

Steel foundries, particularly those handling special steels, are normally equipped with arc furnaces that emit a very fine fume in the sub-micrometre range when unagglomerated. Scrubbing, electrostatic precipitation, and bag filtration are all effective, but the first is often not practical because of water-treatment difficulties.

The use of induction furnaces for melting, alloying, and holding is increasing and, when clean raw materials are used, present no serious air-pollution difficulties.

Ferro–alloy Industry

Except for one blast furnace, all the ferro-alloys in South Africa are produced in electric-arc furnaces, with their associated high temperatures and evolution of fine fumes. This discussion applies also to the production of calcium carbide, which is similar to that of ferro-alloys.

In completely closed furnaces, mainly furnaces for charge chrome and ferromanganese, a gas rich in carbon monoxide is generated that presents a serious explosion risk, and high-energy water scrubbing is therefore indicated.

The fumes are normally high in silica and, with the exception of ferromanganese fumes, are not amenable to electrostatic precipitation. Baghouses have been constructed extensively both overseas and locally on open and semi-open furnace configurations, and appear to offer the most practical solution.

Smelting of Sulphide Ores

The conventional treatment of flotation concentrates of sulphidic ores containing copper and platinum-group metals includes reverberatory smelting to a matte and converter blowing of the matte. From the reverberatory furnaces, a gas containing approximately 0,75 per cent sulphur dioxide and some particulates is derived, and, except when the dust contains high pay values, is emitted to the atmosphere with only cursory cleaning.

At the converter stage, the concentration of sulphur dioxide rises to 8 per cent in the off-gas, which also contains particulates in both the dust and fume sizes.

The removal of particulates is usually achieved by electrostatic precipitation, although bag filtration is used when, for instance, arsenic is involved. The removal of sulphur dioxide is achieved where possible by conventional catalytic oxidation and the production of sulphuric acid. However, this is not feasible with single and intermittent two-converter operations or where there is no market for the acid.

In the case of zinc sulphide, a continuous process of smelting is possible and the production of acid is therefor more viable.

Secondary Non-ferrous Industry

The recovery of non-ferrous metals, often intended for direct foundry use, is practised widely. The impurities are usually lead, tin, zinc, and to some extent cadmium. Except when high-quality raw material is melted for casting, the use of fine-fume arrestment equipment is indicated, particularly where lead and cadmium volatilization or zinc fuming occurs.

Aluminium Industry

In the smelting of bauxite, the use of cryolite (aluminium fluoride) as an electrolyte leads to an off-gas containing limited particulates but a significant concentration of fluoride. Although absorption on lime is feasible, the disposal of the waste presents a problem. Similarly, scrubbing with water is practical only if disposal of the effluent is possible. Except where discharge into a large dilution sink like the sea is possible, neutralization and precipitation of the fluoride are essential.

During the recovery of aluminium waste, care must be exercised that any organic material like paint is completely burnt. Where purification is practised by the addition of chlorine, scrubbing of the off-gas is required.

Fugitive Emissions

The most intractable air-pollution aspect of metallurgical processes is the countless number of small in-plant sources like ladling, burning off of lubricants, and mould wipes and wisps bypassing the extraction hoods. These cannot be covered by any general guidelines or requirements, but can be reduced very significantly by good practice and housekeeping. The proper engineering of systems and installations also reduces the number of potential sources.

Mining

Air pollution originating from underground mining falls within the jurisdiction of the Government Mining Engineer. Because of the strict requirements necessary to safeguard the miners, the above-ground exhausts present no problem.

However, with open-cast mining, the situation is much less satisfactory. The drilling of blasting holes is a source of considerable concern, particularly as dust-collection technology, although available, is seldom practised. During the actual blasting operation, very little more can be done than to limit the fragmentation due to over-charging and poor blasting practice. The major source of air pollution in open-cast mining, however, is transportation out of the pit. The proper construction of roadways and suitable precautions like sweeping, wetting down, and other forms of dust suppression will require far more attention in future.

Bulk Ore Handling

The suppression of dust from waste dumps, in particular from gold mining, was considered so important that a special part of South African legislation was dedicated to it. In general, the best practicable means has been found to be grassing.

The dust from bulk ore dumps presents a completely different problem as the intention in creating the dump was to have it available for further transport or processing; thus permanent measures cannot be taken. Tipplers unloading rail cars must be housed tightly and extracted through either wet scrubbers or bag filters, except where a very clean, coarse ore is handled.

The second source of dust is piling, when the wind has an opportunity to disperse the finer fraction. A luffing boom piler is essential, and wetting of the ore should be practised whenever quality requirements permit. Normally, a coarse aggregate is immune to wind action once it is stacked, but for finer material the use of binder sprays to secure the surface is advocated.

Bucket wheel reclaimers represent the next stage of dust evolution, and in this case very high-pressure water sprays have been found to be effective, particularly if directed at the bucket tips, the shute, and the belt transfer. The shielding of conveyor belts and extraction or water sprays at belt transfer points are also now becoming normal practice, particularly in areas known to be windy.

Availability of Equipment

Installations for the abatement of air pollution normally consist of a motor and fan, a unit to remove the pollutants, ductwork, and a stack. Failure of any of these units disables the whole installation. In addition to this, the discontinuance of services like water or electricity supply also disrupts the operation. While duplication could overcome the loss of individual units of a cleaning train, cost rules this out in smaller operations. In medium and large installations, splitting into separate streams is very desirable.

In addition, the use of sufficiently tall stacks to dissipate the remaining pollutants, as well as the whole load for short periods during malfunction of the abatement unit, is necessary.

Conclusions and Recommendations

The control of air pollution from the metallurgical industry and mining is necessary in South Africa because the atmosphere is not capable of dispersing the discharges satisfactorily. It is not lack of technology but rather cost that limits the extent of air cleaning, and avenues of reducing this factor should therefore be sought. The abatement equipment available represents a high level of engineering and expertise, and only marginal improvement in both technology and associated cost can be expected in the future.

An avenue that remains open, and has often been neglected in the past, is a change of approach with regard to the production process itself. It is important to regard air cleaning not as an additional unit but as part of the production operation. Various examples are given below to illustrate the potential that can be developed.

Iron production is feasible via the sponge iron process followed by arc-furnace melting and, if required, refining. This would obviate the need for coking and sintering with their attendant emissions.

Flash smelting of sulphidic ores offers a continuous one-stage operation that would make the recovery of sulphur possible even on relatively small operations. It is appreciated that a recent exercise in Southern Africa along these lines did not meet with unqualified success, but the principle is sound and may be viable if developed further.

Hydrometallurgy has made rapid progress in the last few decades, but its application to the treatment of sulphide ores has not been realized. If this can be achieved, the need for extensive and costly air-pollution control installations will be largely avoided and could thus introduce a modified cost structure.

The bonding of fluoride on bauxite in the aluminium industry could offset some of the present importation of cryolite while solving the disposal problem with collected fluoride. An additional supply of fluoride for make-up is readily available from the phosphate-fertilizer industry, while the recovery of aluminium from power-station ash may also warrant additional attention.

While only a few of the possibilities have been touched on to illustrate the potential, extensive research and development will have to precede implementation. However, it is firmly believed that the revaluation and modification of processes constitute an important approach to the achievement of clean air at lowest cost.

References

1. STERN, A. C. (ed.). *Air pollution*, Volume 1, New York, Academic Press, 2nd edition, 1968.
2. BOEGMAN, N. Unpublished data.
3. VANDEGRIFT, A. E., SHANNON, L. J., SALLEE, E. E., GORMAN, P. J., and PARK, W. R. Particulate air pollution in the United States. *J. Air Poll. Control Assoc.*, vol. 21, no. 6. 1971. pp. 321–328.
4. INDUSTRIAL DEVELOPMENT CORPORATION. *Yearbook 1973*. Johannesburg, the Corporation, 1974.
5. BRIGGS, G. A. Plume rise predictions. Oak Ridge (Tenn.), National Oceanic and Atmospheric Administration, *Report* 75/15. 1975. 56 pp.
6. LANGENBERG, H. M. *Ventilation potential of the atmosphere over Nelspruit, eastern Transvaal*, Pretoria, C S I R, *Report* APRG/74/5. 1974. 46 pp.
7. TYSON, P. D., PRESTON-WHYTE, R. A., and DIAB, R. D. Towards an inversion climatology of Southern Africa: Part I, Surface inversions. *S. Afr. Geograph. J.*, vol. 58, no. 2. 1976. pp. 151–163.
8. TYSON, P. D. Meteorological factors in the dispersion of air pollution in South Africa. *Public Health (Johannesburg)*, vol. 75, no. 2. 1975. pp. 35 *et seq.*
9. VENTER, G. P. N. *Die bepaling van die styging van nywerheidspluime*. Pretoria, C S I R, *Report* APRG/75/4. 1975. 92 pp.
10. Archives, Ferro Alloy Producers' Association, Johannesburg.
11. Archives, Steel and Iron Engineering Federation of South Africa, Johannesburg.

Solvent extraction

International conferences on solvent extraction have become well-established events of world-wide appeal to the scientific and technological community. ISEC 77, which is the first such conference on the North American continent, is to be held in Toronto from 9th to 16th September, 1977. As well as covering basic chemical and engineering aspects of solvent extraction, it will be concerned with the practical side in areas such as equipment performance and process development. There will be a strong emphasis on the solvent extraction of metals.

About 150 papers have been selected on the basis of submitted extracts, and they will be presented in sessions on the following topics:

Extractants and diluents
Environment
Mass transfer
Organic reagents
Equipment
Modelling
Physical and inorganic chemistry
Dispersion and coalescence
Inorganic processes
Organic processes
Base metal processes
Analytical topics
Nuclear processes
Uranium processing
Chemistry of solvent-extraction systems
Copper processing.

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