# A SURVEY OF THE CURRENT INDUSTRIAL POLLUTION PROBLEMS: A PERSPECTIVE FOR CHEMICAL ENGINEERS

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ABSTRACT

A survey on the current and the anticipated pollution problems in various industries in West Malaysia was carried out recently. About 60 percent out of the 113 industries investigated are facing various pollution problems. The main types of the problems in descending scale include air(21.4%), noise(19.8%), water(18.3%), solid wastes(18.3%), and toxic and hazardous waste(12.0%). The study indicated that Chemical Engineers, to a greater extent, can play an important role in solving the multitude local industrial pollution problems. In developed countries such as the United States of America with a marked concern for environmental protectionism, the industrial related pollution problems are often tackled by Chemical Engineers. This is because the Chemical Engineers have a sound knowledge on the industrial processes which can further enable them to minimize the generation of pollutants from industries, and also to treat and dispose of such pollutants securely. Details of the survey and the possible future roles of Chemical Engineers in solving such problems are highlighted further in this paper.

(17)

## INTRODUCTION

A survey on the current industrial pollution problems in various industries was carried out recently. Questionaires covering a broad spectrum of questions in several areas ranging from general perspectives to a more defined areas such as pollution control were sent to various manufacturing companies in West Malaysia. The responses received from companies were however anonymous to keep the information confidential. From a total of 450 industries that were surveyed, 113 industries (25%) responded to the questionaires.

From the survey, it can be concluded that 68 out of 113 industries (60%) were facing pollution problems. The main types of problems faced by industries were air(21%), noise(20%), water(18%), solid wastes(18%), and toxic and hazardous wastes(12%). A summary of the types of pollution problems in industries is further shown in Table 1. The remaining 10 percent of the pollution problems in industries anticipated mainly odour and in-door type pollution problems.

Table 1: Types of Industrial Pollution Problems

| Type of pollution | | Percentage(%) |
|---|---|---|
| Air | | 21.4 |
| Noise | | 19.8 |
| Water | | 18.3 |
| Solid wastes | | 18.3 |
| Toxic and hazard. wastes | | 12.0 |
| Others | | 10.2 |
| | ----- | ------- |
| | Total | 100 |

### Air Pollution

Apart from natural causes, air pollution is caused by anthropogenic sources including processing industries such as sulphuric acid plants, power-station boilers, nitric acid plants, cement plants, foundaries and etc.Air pollution mainly occurs as a result of dispersion of particulate or gaseous pollutants completely miscible with air in varying proportions. Particles obtained during the process of grinding, atomization, or operations involving sudden disintegration of solid or liquid phases are nonuniform, covering a wide distribution of sizes. Equipment to separate them must be designed on the consideration of the size distribution of the particles. Dust refers to coarser sizes of solids (1 - 100 microns) that are carried away due to the turbulent force of flow. This can happen in channels, chimneys and flues in process industries. Aerosols refer to particles smaller than 1 micron. The small sizes of the particles keep them suspended in air even at very low air velocities. Smoke is obtained during incomplete combustion of organic material such as wood, coal, diesel and etc. The sizes of particles vary between 0.01 and 1 micron. Brownian movement keeps them suspended in air or gases. Fumes are formed as a result of sublimation, condensation or cracking of high-molecular-weight organics at comparatively high temperatures. Mists are obtained when there is a direct contact between a vapour or gas and liquid, accompanied by temperature inversion.

Gaseous pollutants are gaseous solutes (molecular size) such as SO2, Cl2, NOx, CO2, CO, mercury or organic vapour dispersed in air. They are miscible in air in varying proportions and at all velocities. The major source of SO2 is from the sulphur contained in the raw materials used. For example, if the fuel oil used in thermal stations contains 2 percent sulphur, the percentage of SO2 in the exit gases will be of the order of 0.12 when 15 percent excess air is used for combustion.

Noise Pollution

Noise has recently been recognized as a pollutant. There is ample medical evidence to support that it affects speech, hearing, general health and behaviour of people exposed to it over extended periods of time. The measurements designed to determine noise levels include the intensity and frequency of the noise and duration of exposure. The community noise level is expressed in decibels (dBa). The background noise level of quiet surrounding, with no specific source of noise may vary berween 30 and 40 dBa. A boiler-house compressor can give between 80 and 95 dBa.

Water Pollution

Water pollution due to the presence of dissolved inorganic materials, organic materials such as protein found in domestic and industrial waters, and physical factors such as turbidity, colour and temperature of the effluent.

Alkalis, acids, inorganic salts and other chemicals formed during processing generally lead to inorganic pollutant. Besides causing corrosion of metals, these chemicals are toxic to aquatic life. Inorganic chemical such as free chlorine, ammonia, hydrogen sulfide and etc. are usually found in metal-plating liquid wastes, alkali producing units, polyvinyl chloride and fertilizer industries. Pharmaceutical industries also produce large quantities of free acids and neutralized chemicals during different unit processes.

Organic pollution is due to the presence of high molecular weight compounds such as sugars, oils, and proteins obtained from distillery, canning, sugar and other food processing industries. They impart a high BOD load to the liquid waste. These organic compounds are readily degraded in aqueous medium by soil and micro-organisms present in the sewage. During this process, dissolved oxygen in the stream is depleted. When the dissolved oxygen is reduced below a certain limit. aquatic life is affected adversely. Some wastes from pharmaceutical industries contain phenols which are toxic to aquatic life.

Turbidity of waste water due to the presence of colloidal matter which does not settle readily. This comprises fine clay particles, milk waste, sewage, free peroxide formed from metal salts, ceramic industries or paper-and-pulp industries. Turbidity can inhibit the penetration of light, limiting photosynthetic activity and thereby adversely affecting oxygenation of water. Another form of physical pollution is thermal pollution which is due to the high temperatures of liquid wastes from applications such as power stations. When the hot liquid is discharged into a river, the temperature of the water increases, therefore decreasing the equilibrium content of dissolved oxygen.

Solid Waste

Garbage, waste paper, packing materials, and `reject' from industries constitute solid wastes. These are scattered in different localities and need to be collected and disposed off. Improper disposal such as burning such wastes in open dumps adds to air pollution. Proper management of solid wastes is required to prevent environmental pollution.

## Toxic and Hazardous Waste

Toxic and hazardous waste can be defined as waste which by nature (physical, chemical, and biological) may be potentially detrimental to human health and/or the environment that require special handling and disposal procedures[1]. The definition of the term `toxic and hazardous' still sets a great deal of ambiguity. The dificulty arises in distinguishing between a `hazardous waste' and `nonhazardous waste'. In the guidelines, however, the wastes listed in the First Schedule of the Environmental Quality (Scheduled Wastes) Regulations May 1989 are classified as toxic and hazardous wastes. Basically this list covers all waste products that are potentially toxic and hazardous in nature, which are meant to be discarded and disposed of in accordance to the Regulations. Similar legislations covering toxic ang hazardous wastes have already been enforced in most developed countries.

## INDUSTRIAL POLLUTION CONTROL ASPECTS

Industrial pollution problems are caused by wastes generated from industrial processes whether they are in gaseous, liquids, or solids form. Most of the industrial wastes are classified as toxic and hazardous which can be harmful to public health and environment[2]. In fact, wastes from industries are the main sources of air, water, and land pollutions when these wastes are released to the environment. For example, when flue gases that contain dust, fly ash, toxic gases and smoke are emitted into environment, air pollution problem will occur.

Basically there are three general options in managing industrial wastes: minimization of waste generation; conversion of the hazardous waste into nonhazardous; and perpetual storage. The U.S. EPA and European Agencies generally list "Waste Minimization" at the top of the hierachy of waste management practices, followed by "Waste Treatment" as the second alternative and finally "Waste Disposal" of the remaining residues[3]. Optimum, successive utilization of the three general options would result in a decreasing amount of hazardous waste as treatment proceeds in the direction of the hierachy shown in Figure 1. Only small volumes of the more inert materials should be considered for a perpetual storage.

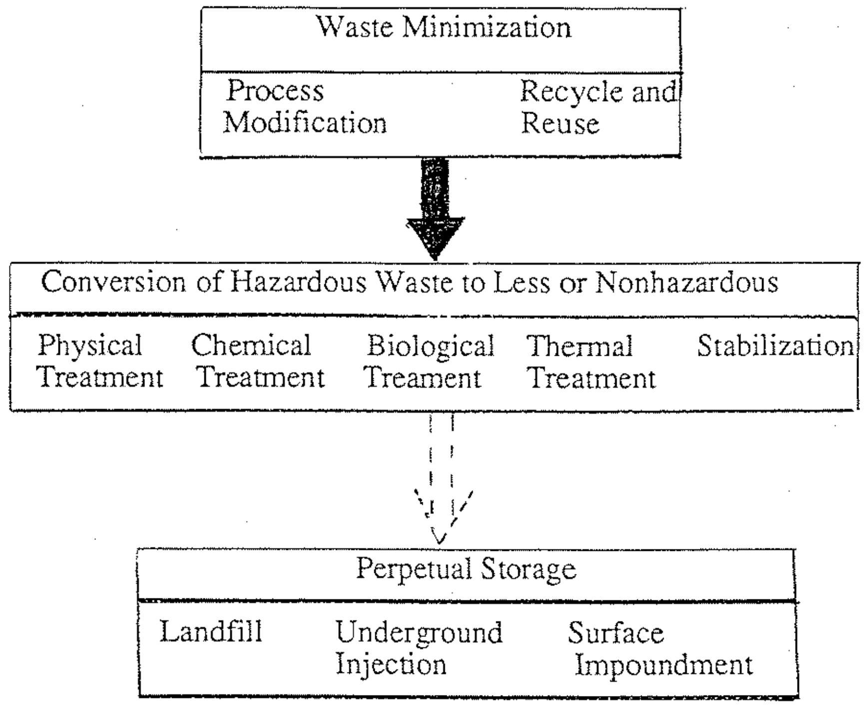



Figure 1: Hierachy of Hazardous Waste Management Alternative

The hierachy identified in Figure 1 represents a preferred path in the management of hazardous wastes as follows:-

1) In-plant options should be used to reduce the volume toxicity of the generated hazardous wastes

2) Wastes that are generated should be converted to less hazardous forms and should further be reduced in volume

3) The remaining residues and wastes that are hazardous should be stored in a manner that minimizes risks to the environment and the public.

Identification and undestanding of the hierachy permits rational decisions to be made. The management approaches outlined in Figure 1 also stress that no single approach is sufficient to solve all hazardous waste management problems. The concepts identified emphasize prevention and reduction rather than treatment and storage; and emphasize the goal reducing the risk to the environment and public. Thus, the emphasis is on positive rather than negative management options.

## WASTE MINIMIZATION OPTIONS

The best way to deal with industrial pollution problems is still to prevent the generation of pollutant materials from the industrial processes. The adage `prevention is better than cure' also applies in dealing with pollution problems. As a means of pollution prevention, reduction of the generation of hazardous waste at its industrial sources is still the most effective and economical way of managing hazardous waste. A survey of the U.S. organic chemical plants indicated that the adoption of waste minimization initiative did manage to reduce hazardous waste streams by 50 - 80 percent [4]. Waste reduction techniques applied to such plants are:-

1. Process modification in reaction temperatures which can further alleviate higher conversion rates.

2. Product formulation changes such as in raw materials which produce toxic substances.

3. Replacing toxic chemicals with harmless ones such as substitute benzene with touluene as a solvent.

4. Plant equipment changes such as replacement of old equipment with a new one which is more effective.

5. Application of waste recovering methods such as recycling and reusing processes to prevent materials from being discharged from a plant as waste. The hazardous components of wastes may be usable reactant materails in other production processes.

6. Simple operating and housekeeping changes which involve improvements in housekeeping and the separation of hazardous and nohazardous waste streams.

Developing countries generally look toward the industrialized countries to resolve problems on environmental protection. Adoption of `waste minimization' in reducing industrial pollution problems should be no exception. The American and European industries have long accepted `waste minimization' as an essential objective. In the last ten years, laws and regulations were passed to prevent unsafe disposal of hazardous waste and encouraging `waste minimization' at source options. The new laws and regulations also result in perpetual storage such as landfill disposals and also transportation of wastes becoming more difficult and expensive. In fact, Malaysia followed the same course by passing the Environmental Quality (Scheduled Wastes) Regulations in May 1989 to regulate the emissions of pollutants into the environment. The regulations specifically cite that the generation of wastes should be reduced to the maximum extent practicable.

As the cost of waste treatment and disposal increases, cost reduction achieved through recovery of chemicals from a waste stream prior to disposal will become more important. The value of reclaimed chemicals together with the savings in not having to dispose these materials could match or exceed the original costs. The substantially increased costs of secured landfill under new regulations make waste minimization option more cost-effective. As a matter of fact, prevention is always the most cost-effective strategy. Realizing that, industries in U.S. adopted wastes reduction option not only to comply with stringent new laws and regulations but also in order to remain competitive. Some European countries that compete with U.S. internationally are a decade ahead in waste reduction[5].

## RELATIONSHIP OF WASTE MINIMIZATION TO INTEGRATED INDUSTRIAL POLLUTION CONTROL

The discussion on the industrial pollution control is focussed on hazardous waste because the same rationals apply for nonhazardous industrial wastes, industrial air emissions and industrial wastewater effluents. The major pollutants contribute to air pollution are particulate matter, gaseous pollutants such as SO2, and vapours such as benzene. One method that can be used to minimized localised problems is to make use of metereological parameters to dilute and disperse them to get ground level concentrations within acceptable limits by using tall stacks. This is a rather costly method and no recovery of useful chemicals is possible. A better way to control the pollution-control problem is to reduce the concentration of pollutants, at the point source, by incorporating process changes and making judicious choices of raw materials used. For eaxample, SO2 and acid mist in sulphuric acid plants can be reduced by making used of DCDA (Double Conversion Double Absorption) process and mist eliminators. This not only reduces the pollution problems but also increases the output of sulphuric acid substantially. Sulphur dioxide content of the flue gases can be reduced by using fuels of low sulphur content or funaces with improvised designs[2].

In the field of wastewater the choice are between to prevent and to treat of wastewater effluents. The preventive choices which are generally more favourable are made up of volume reductions and strength reduction of wastewaters. Volume reduction can be achieved by conservation of water used in the process, segregation of different stream in the process, recycling and re-using of water used in the process and avoiding slug or batch discharges. Strengh reduction can be achieved by equipment modifications, process changes, and recovery of important by-products from waste streams. Thus, the role of pollution prevention should be intepreted in the broadest context of the entire range of industrial wastes and discharges.

## WASTE MINIMIZATION: PERSPECTIVE FOR CHEMICAL ENGINEER

The fact that the best environmental protection measure which is not producing wastes and pollution at all is definitely undisputable. Up to this date, practically no technology exists that can ideally remove all the wastes and further ensuring the safety of health and the environment. Waste prevention also has been proven as the single most cost-effective strategy in controlling industrial pollution problems.

It is important to understand that most people in industries are more accustomed to thinking in terms of `end-of-pipe' pollution control or the management of wastes after being generated. The tendency of incorporating end-of-pipe management in industries is proven as shown in the survey. Industries claim that the natures of the pollution problems are the lack of treatment and disposal facilities as shown in Table 2. If the industries incorporate waste prevention option, the amount of waste generated and needed to be treated will be reduced. Then the lack of disposal and treatment facilities should no longer be a problem. However, it is not realistic to think that the generation of all wastes and pollutants can be totally eliminated. So the wastw minimization option does not suggest that traditional pollution control measures can altogether be replaced. Waste minimization is in no way a replacement to waste treatments and disposals, but rather as a complement to them.

Table 2: Nature of the industrial pollution problems in Malaysia.

| Nature of the problems | | Percentage (%) |
|---|---|---|
| Lack of disposal facilities | | 32.2 |
| Lack of available appropriate low-cost technology | | 29.1 |
| Lack of secured landfills | | 11.8 |
| Lack of available sites for treatment facilities | | 9.7 |
| Lack of storage facilities | | 8.6 |
| Others | | 8.6 |
| | --------- | ------- |
| | Total | 100 |

Traditional waste management approaches which focus on treatment and disposal options are routine for environmental engineers or regulatory compliance departments. Implementation of waste minimization technologies, however, is more appropriately a task of chemical engineers. Waste minimization is much more a thought process or problem solving sequence which attemps to go further back into the source of waste and to employ engineering principles that are used to minimise waste or recover useful material from such wastes. The description of waste minimization would involve details of design criteria, flow rates, operating conditions, and a multitude of chemical engineering considerations that are part of industrial processing operations[3]. Examples of implementation of waste minimization techniques are shown in the case studies. It involves in-plant modifications, formulation changes, and operating conditions modifications which are within the capability of chemical engineers.

## WASTE MINIMIZATION: STUDY CASES

### 1. Metal Oxide Recovery Filtration/Recycle [3]

The old process of dust recovery using cyclone and fume boxes to separate metal dust from the furnace flue gases is replaced by a handle filter. The new process is actually efficient since almost all of the pollution previously emitted is suppressed compared to the old process which only recover 50 percent of dust particles in the flue gases. From the economic standpoint, the value of the recovered metals makes it possible to recover the investment within two years (refer Table 3). The use of handle-filters is now very widespread in the metallurgical industry even if in most cases the conditions are not as good as those of the case introduced in this paper, from the economic standpoint.

Table 3: Pollution and economic analysis for old procedure and new procedure in metal oxide recovery process.

Basis: Ton of metal oxides

| | Old Proc. | New Proc. |
|---|---|---|
| Pollution Balance: | | |
| Dust particle in air (kg/ton) | 1.75 | 0.035 |
| Economic Balance: | | |
| Investment (differential) | | 119,000 |
| Annual Cost (differential) | | 31,000 |
| Annual Return (differential) | | 160,800 |

2) Process Control for Enhanced Product Recovery in Fertilizer Manufacturing.[3]

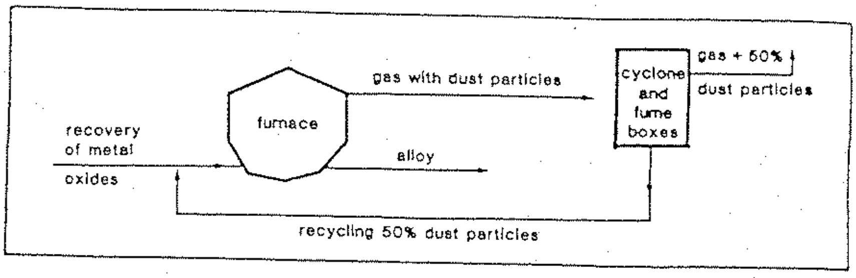
Feedback control system in old process of manufacturing fertilizer has been replaced with feedforward control system as shown in Figure 3. Feedback control loops can never achieve perfect control of a chemical process, that is, keeping the output of the process continuously at the desired setpoint value in the presence of load. The reason is simple: A feedback controller reacts only after it has detected a deviation in the value of the output from the desired set point.

Unlike feedback system, a feedforward control configuration measures the disturbance directly and takes control action to eliminate its impact on the process output. Therefore, feedforward controllers have the theoritical potential for perfect control. In addition to the reduction of pollution, the new process control in fertilizer manufacturing leads to a slight rise in production which quickly balances the investment as shown in Table 4. This is due to the better control system that results in lesser amount of products being rejected as defects.

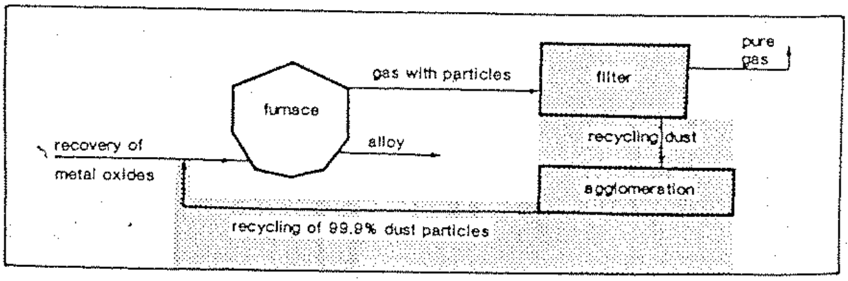
Table 4: Pollution and economic analysis for old procedure and new procedure in fertilizer manufacturing process

Basis: Ton of product (ammonium nitrate)

| | Old Proc. | New Proc. |
|---|---|---|
| Pollution balance: (g/ton) | | |
| Ammonia in water effluent | 3,700 | 280 |
| Nitrate in water effluent | 3,500 | 160 |
| Economic balance: 1982 Dollars | | |
| Investment (differential) | | 152,000 |
| Annual costs (differential) | same | same |
| Annual return(differential) | | 292,000 |

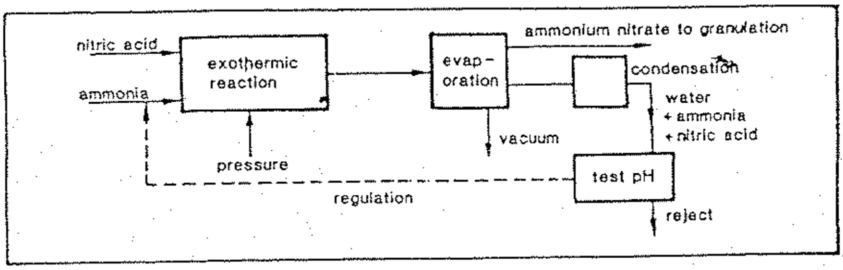



a) Old procedure

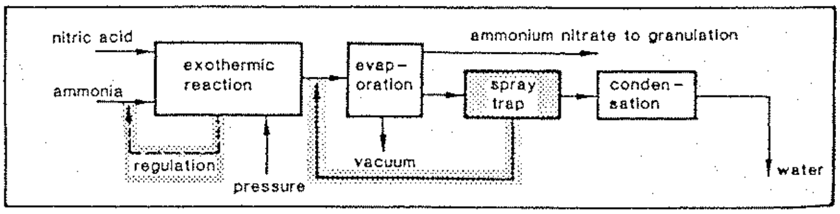



b) New Procedure

Figure 2: Schematic diagrams of metal oxides recovery process.




a) Old procedure




b) New procedure

Figure 3: Schematic diagrams of process control in fertilizer manufacturing.

## CONCLUSION

In concluding, it can be said that the role of chemical engineers is very much diverse and is also responsible for ensuring minimization and mitigation of pollution from industries. A sound knowledge on industrial processes such as plant designs, product formulations and operating conditions enable chemical engineers to implement waste minimization techniques in processing industries. Waste minimization options has been proven as the most cost- effective strategy in controlling industrial pollution problems. In addition, chemical engineers are also capable of treating and disposing of the wastes enevitably generated from the industrial processes. A more diverse and dynamic role of chemical engineers is not only to produce better but also to pollute less.

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