Asian Journal of Water, Environment and Pollution, Vol. 5, No. 4, pp. 91-97.

Application of Pollution Prevention Programme in Bangladesh—Case Study on Cement Industry

Md. J.B. Alam, B.K. Banik, M.M. Hasan[1] and M. Majibur Rahman[2]

Civil and Environmental Engineering Department, Shahjalal University of Science and Technology, Dhaka, Bangladesh
[1]Industrial and Production Engineering Department, Shahjalal University of Science and Technology, Dhaka
[2]Civil Engineering Department, Bangladesh University of Engineering and Technology, Dhaka
✉ bijit_sustbd@yahoo.com

Received November 5, 2006; revised and accepted August 1, 2007

Abstract: In this paper, pollution prevention programme have been proposed for industries as a cost effective measure for minimizing waste problem. The steps and advantages of the programme have been discussed briefly in order to get idea about the pollution prevention programme. In this paper, case study on cement industry has been presented to illustrate the benefit of pollution prevention programme for industries of developing countries. Treatment cost and material cost has been reduced for heavy metal industries and health risk has been reduced for pesticide formulation industries. The associated risk from present condition has been discussed.

Key words: Pollution, prevention, cement industry, waste minimization.

Introduction

Industrial activities along with unprecedented urban growth have been causing an increasing pressure on ecological parameters such as air, water and soil in Bangladesh in last three decades. In Bangladesh, over the years the adverse environmental activities arising from the process of development and rapid industrialization and urbanization affected ecological balance. It is estimated that three-fourths by volume of the wastewater is generated from the municipal sources. Industrial waste water, although small in volume, contributes over one half of the total pollutant load mainly generated from the industries in the developing countries (Khan, 1996). For example, Shatu Pesticide Formulation Industry, Saver, Bangladesh discharged their wastewater directly in the nearby river without considering ISO-14000 (Alam, 1996). At this stage, there is a strong need to develop partnerships with different related stake holders which may be designed as Pollution Prevention Round Table to have more quick solution for handling their waste.

Lot of effort has been made so far in order to reduce environmental degradation but the same has been proved to be inadequate. Moreover industrial pollution is increasing with the industrialization and urbanization. In order to achieve and provide a suitable world for present and future generations, pollution prevention is needed in a cost effective way. Pollution prevention should be an integral part of the industries' main plan. The elements of pollution prevention programme are presented in Figure 1 (EPA, 1992). World Bank suggested to minimize the increase in ambient particulate levels by reducing the mass load emitted from stacks, from fugitive emissions and from other sources. For control of fugitive particulate emissions, ventilation systems should be used in conjunction with hoods and enclosures covering transfer points and conveyors (World Bank, 1998). Canadian company manufactured concrete by replacing cement in mixture. Depending on the application, 30-60% of the cement can be replaced with material such as flyash, rice husk ash and silica fune. It will reduce production of CO_2 (http://www.ecosmart.ca). The cement industry is an energy intensive industry with energy

accounting for 30-40% production cost. At present about 78% of Europe's cement production is from dry process kilns, a further 16% of production is accounted for by semi-dry and semi-wet process kilns, with the remainder of European production (EU-commission, 2001). EPA suggested injecting ammonia-based compounds into the exhausted gas to reduce NO_x to N_2 (EPA, 2006).

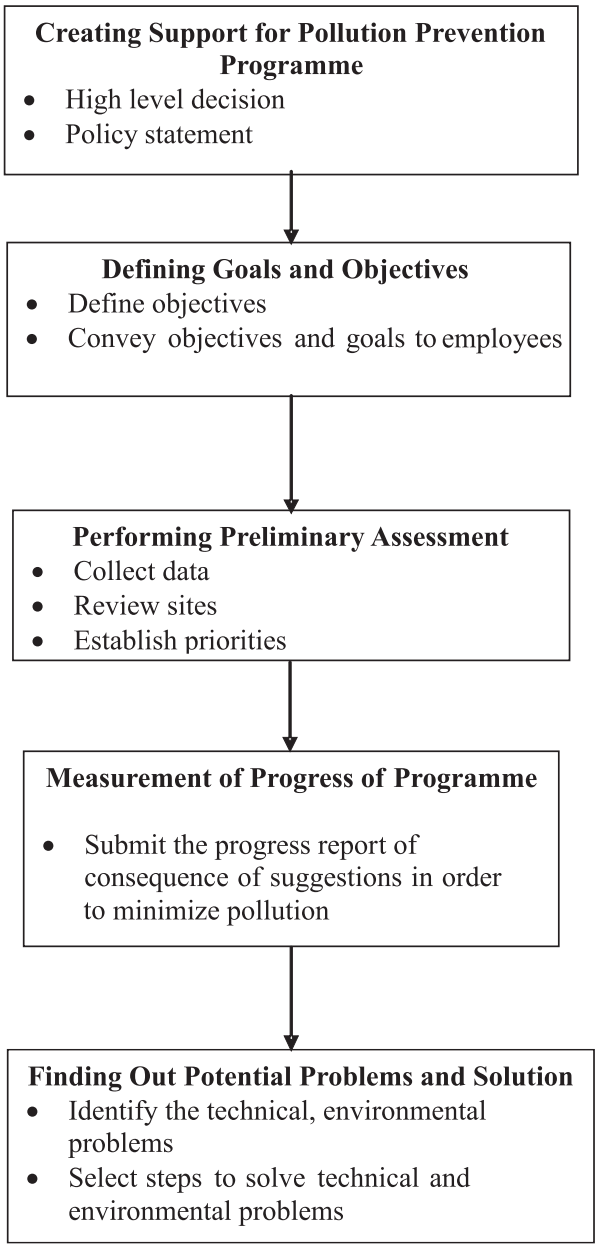

Figure 1: Flow diagram for pollution prevention programme (Alam and Rahman, 2002).

Elements of Pollution Prevention Programme

Pollution prevention is a process that reduces the creation of wastes at the sources. It includes processes that reduce the use of hazardous and non-hazardous materials. It also includes other processes that protect natural resources through adequate efficient management and conversion.

A pollution prevention programme (PPP) is an ongoing and comprehensive operational activity at the source level with goal of minimizing wastes. Effective pollution prevention will (i) reduce risk, (ii) reduce operational cost, (iii) increase employees commitment to serve the industry, (iv) improve healthy and effective workable environment and (v) protect public health and environment. Industries cause environmental degradation by generating hazardous wastes, although there are environmental law and regulation. So the industries should have to bear responsibilities for civil liabilities.

Creating Support for Pollution Prevention

Generally executives of industry will decide whether to implement the prevention programme based on available information related to existing prevention opportunities. One way to gather this kind of information is to perform a preliminary assessment. Executives should convey their decisions to all the employees through a policy statement. The policy statement is the main platform of the pollution prevention programme. This statement normally states the objectives of the programmes, the output of the programme in qualitative terms. For example, in the case of Tata-Bearing Industries, the objectives of study of environmental air pollution prevention programme are to find out air pollutants sources and stop them there itself (Pallab, 2000).

Manager and employees are the backbone of the industries. Employees will take responsibility of their pollution prevention role more seriously when management keeps them informed and encourages them to submit pollution prevention ideas. Employees feel committed to this programme when they are encouraged to (i) help define industry's goals and objectives, (ii) review process and operations to determine where and which toxic elements are used and hazardous wastes are generated, (iii) recommend ways to eliminate waste production at sources and (iv) to find out the ways to recycle the waste materials. The following steps can motivate employees and manager:

- Provide feedback and reinforcement of employees' pollution prevention performances.
- Incorporate employees' idea with accepted pollution prevention programme.
- Give enthusiasm about meeting goals of the programme.
- Explain details of the new measures or steps which will be taken for minimizing pollution.

Finding out Goals and Objectives

The goals depend on the size of industry. The number of members to be involved in goal-sitting process depends on industry's size. The programme leaders will need to develop goals that state the long-term direction for the pollution prevention programme. Specific goals and objectives help to focus the efforts and get support from the employees because their motivations to the programme depend on the extent and degree of understandability of its objectives. The goals should be mentioned in the policy statement more specifically keeping consistency with industry's pollution prevention policy.

Pollution prevention goals may be qualitative or quantitative. The executive and programme implementation team can develop a detail flow diagram of plan based on available data. This plan will address the extent to which external organizations such as Government, Department of Environment, Local Governmental Engineering Department will be involved and define pollution prevention programme objectives. In order to achieve, specific and defined goals should be mentioned. For example, in order to achieve goals reducing waste, the objectives should be reducing solvent, heavy metals, paper and packing wastes by specific amounts within a period. In USA, fertilizer industry wastes have been reducing by minimizing use of solvent and heavy metal by applying distillation apparatus for solvent and membrane for recollecting heavy metal (Sengupta, 2001).

Preliminary Assessment

Data collection, visiting sites and establishing priorities are the main parts of preliminary assessment. Trend, extent and complexity of data should be consistent with the goals of industry. The simplest system of the data collection coincides with industry's objectives. An all-media approach which deals with air, water and solid emissions and releases will be the best effective way. This involves considering all the waste streams, identifying their sources and quantifying cost of treatment and disposal. Data sources for facility information include regulatory information, process information, raw material information etc. The information should consists of regulatory report, engineering report etc. (EPA, 1992). The following should be kept in mind of members of task team:

- Current regulation (ISO-14000)
- Quantity of waste
- Hazardous properties of the waste
- Potential for pollution prevention
- Minimizing waste discharge
- Reducing energy use.

Identifying Potential Problems

The task force can develop a detail plan based on information collected during the pre-assessment. This plan addresses the extent to which external organizations will be involved, defines pollution prevention programme objectives, identify potential obstacles and solutions and defines the data collection and analysis procedures that will be used. Four broad categories in this identification of potential obstacles are economical, technical, regulatory and institutional. Proper anticipation, understanding the obstacles and taking steps to overcome them are essential parts of preparing programme plan.

Economic obstacles arise because standard accounting systems do not track environmental costs well because industries tend to incorporate environmental costs. Elements of total cost assessment (TCA) includes expanded cost inventory, extended time horizon, use of long term indicators, allocation of cost to processes and products. TCA analyzes direct cost such as building, equipment, installation etc. Information will be needed on alternative procedure that should be considered. How to integrate them in the production processes and what side effects are possible.

Methodology

Using a face-to-face technique, empirical data were collected for the study by sample survey method from all the sections of Chattak Cement Industry. Based on the information and the data collected from the first visit, several meetings of the team members were held and an interim test information-checklist was prepared. The information-checklist was pre-tested in the non-sampled area through a pilot survey before finalization.

Case Study

Evaluation of Existing Condition of Chattak Cement Industry

It is evident from the survey work for understanding the present manufacturing and discharge processes that the percentage of ingredients of Chattak Cement raw materials, composition and their percentage of Chattak Cement, clinker and mineralogical species are as shown in Tables 1and 2 (Islam, 2005).

Table 1: Ingredients of cement raw materials and their percentage

Compound	*Lime stone (%)*	*Clay (%)*	*Slurry (blended) (%)*
SiO_2	0.84	71.84	14.50
Al_2O_3	0.60	13.20	4.00
Fe_2O_3	0.32	7.68	1.52
MgO	0.50	0.32	0.65
Na_2O	0.10	0.10	0.20
K_2O	0.10	0.15	0.20
CaO	54.50	0.80	43.00
LOI	42.80	5.40	35.50
TOTAL	99.26	99.49	99.57

Manufacturing Process

The manufacture of cement at Chattak Cement Factory called "the wet process" consist of two stages:

1. Preparation of clinker and
2. Mixing of clinker with requisite amount of gypsum.

In the first stage slurry is made by adding 50% water to the clay (clay water ratio 50:50). Lime stone is fed into the crusher and it is crushed into 0.5 inch down size particle; then the slurry and crushed particles are mixed into the three chambered kiln. Mixed slurry is then stored in the three large silos; capacity of each silo is 600 M. The composition of the slurry is then analyzed and if any correction is needed, it is made here. The slurry mixture is then sent to large slurry basin. It is then agitated here by a mechanical stirrer as well as by air-blowing to make it homogenous as much as possible. It is then fed along to the kiln and fixed by counter current flow of natural gas at a temperature from 1400°C to 1500°C. During fixing removal of water, calcinations etc. take place. Resulting mixture after cooling is called clinker. Finally cement have mixing of 96% clinker and 4% gypsum; the mixture is then sent to a three chambered ball mill containing balls of 90 mm diameter in the first chamber, 50 mm diameter in the second chamber for grinding into fine particles. The cement is grounded to a specified quality of 7% residue retain in 170 mesh. It is then sent to cement silos.

Reaction in the Rotary Kiln

During the preparation of clinker in the rotary kiln many reactions occur. Some of important reactions are given below.

Stage 1: At 150-200° free water of slurry is evaporated and forms a jelly-like species which passes through chain zone to inhibit aggregation.

Stage 2: At 600-700°C combine water of clay is removed from slurry and forming metakaolite structure.

Stage 3: At 700-900° species of clay is converted to reactive oxide.

Stage 4: At 900-1000°C decomposition of limestone ($CaCO_3$) and $MgCO_3$ occur.

And simultaneous formation of calcium silicate and calcium acuminate with the reaction of calcium oxide, silica and alumina occurs.

Stage 5: At 1000-1300° C calcium silicate and calcium aluminate react with more calcium oxide to form dicalcium silicate and tricalcium aluminate and tetracalcium aluminoferrite with ferricoxide.

Stage 6: At 1250-1450° C the slurry reaches at firing zone and then some of the minerals also reach at their melting point and at this situation dicalcium silicate combines with more calcium silicate and tricalcium silicate.

$$2CaOSiO_2 + CaO \rightarrow 3CaO\ SiO_2(C_3S)$$

Table 2: Composition and their percentage of cement, clinker and mineralogical species

Clinker composition in%	*Cement composition in%*	*Mineralogical composition of cement in % (calculate)*
IR-0.25	0.25	C_3S-54.83
CaO-66.48	64.50	C_2S-19.71
SiO_2-23.30	21.30	C_3A-10.34
Al_2O_3-5.04	5.50	C_4AF-7.60
Fe_2O_3-2.80	2.50	—
LOI-0.25	1.80	—
MgO-0.50	1.20	MgO-0.29
Na_2O-0.40	0.38	Na_2O-0.38
K_2O-0.15	0.12	K_2O-0.18
CaO-0.58	0.50	CaO-0.50
SO_3-0.30	0.86	—

This tricalcium silicate is the most important compound of cement; it helps cement in quick hardening. After the formation of clinker, this is introduced into rapid cooling with the help of 12 coolers attached with the kiln. If the clinker is not introduced into rapid cooling, tricalcium silicate may undergo reverse reaction and breaks down into dicalcium silicate and free calcium oxide and ultimately declines cement quality.

If magnesium oxide remains in free state in cement it is called periclase. The free magnesium reacts with water and forms magnesium hydroxide, which may cause volumetric expansion.

Water Treatment Plant of Chattak

The raw water is taken from the in-take of the river Surma and is pumped to clarifiers by the in-take tower pump where the sand and the silt in the water will be removed by means of precipitation. Following are the sequence process for water treatment:

(a) Screening: Passing the water through a mixture or moving screens removes large quantities of floating particles.
(b) Skimming: Oil and grease by passing off the water through skimming tanks where oil and grease is skimmed off.
(c) Grit is removed by grit settling chamber by careful regulation of flow velocity in the grit tusks.
(d) Sedimentation: Suspended matter can be removed efficiently and economically by sedimentation. Finely divided suspended solids and colloidal particles cannot be removed by simple sedimentation.

Demineralization: Ion exchange resins are used for demineralization of water.

$$\text{Resins} + \text{water}\begin{cases} \text{NaCl} \\ \text{CaCl}_2 \\ \text{MgCl}_2 \end{cases} \rightleftharpoons \text{Resins}\begin{cases} \text{Na} \\ \text{Ca} + \text{HCl} \\ \text{Mg} \end{cases}$$

Regeneration of the resin is done by H_2SO_4. Similarly, hydroxide can be displaced from the anion exchange by some other type of anions.

In our country Chattak Cement Company Limited is the only one raw material based cement industry. It supplies one portion of the total consumption of cement in Bangladesh. A large number of people are engaged in this industry as employees and it provides their livelihood. The wet process is used for manufacture of cement in this industry. The clinker quality of wet process is better than that of dry process. In this industry natural gas is used as a fuel for burning of slurry. Many other countries use coal instead of natural gas in rotary kiln. Ultimately a portion of fly ash is combined with clinker. This fly ash is harmful, if in excess, for cement. It retards the setting time of cement.

Analysis of the Problems and Management

Improvement of Process

The energy consumption in wet process is much larger than dry process. The production cost of cement in this industry is large, because an enormous amount of natural gas is used for burning purpose. Pollution is another demerit of the industry. Compared to other industries, least quantity of pollution occurs here. Of them only air pollution is remarkable. Carbon dioxide (CO_2) is the chief air pollutant here. Beside, carbon dioxide (CO_2) least amount of other gases such as SO_x and NO_x may be liberated into the air by chimney. In bagging section dust particles of cement are thoroughly mixed into the air that is harmful for human body.

Dust is the main pollutant that is liberated from kiln by chimney. The industry has already set up electrolytic precipitator equipment. In this equipment several iron plates are arranged in a series, and it is electrically negative in charge. Smoke and dust liberated from klin are passed through these iron plates. Dust is the fine particles of slurry liberated from kiln along with the pressure of smoke. These dust particles are positive in charge and therefore attracted by the negatively charged iron plate and finally fall through the lower side where screw conveyor or an elevator into the kiln conveys them. In this recycling process production of clinker is increased keeping environment neat and clean.

Neutral dust particle may be controlled by using fabric filter as air dust collector. In bagging section fabric filter may also be used as dust collector. If it is not possible, ordinary gas mask may be offered for workers. In the interior of the industry noise pollution occurs continuously in limestone pulverizing, which is a usual phenomenon.

For sustainable production, the following steps should be considered:

1. Reduction of energy supply using catalytic reaction.
2. Reduction of transportation cost.
3. Automation of the factory.
4. Proper water treatment plant.
5. Application of dust reduction system.

Mechanism of Reducing of Pollution

The mechanism of absorption of species by water hyacinth from aquatic ecosystem has been explained on

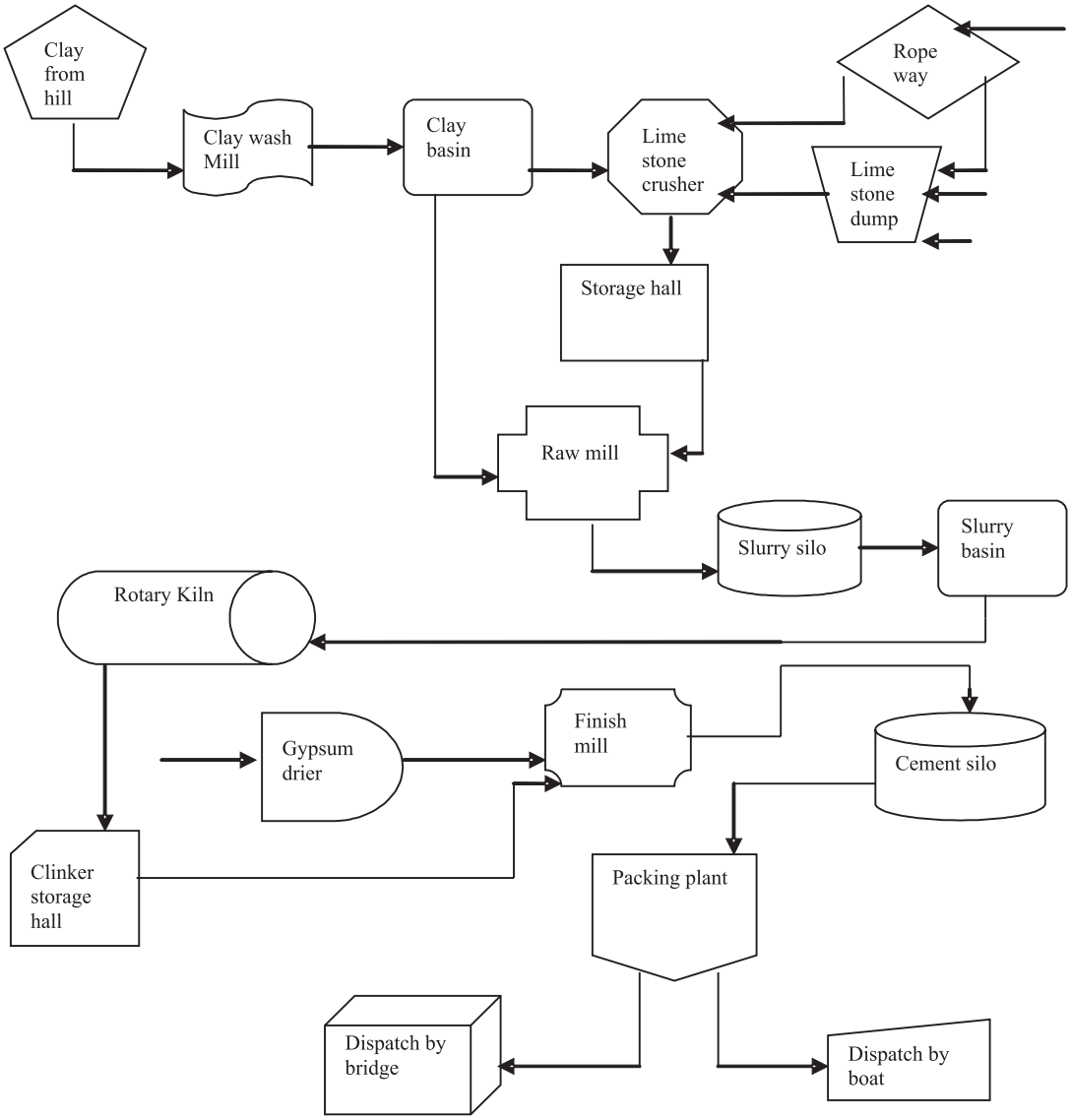

Figure 2: Production process and description of the flow diagram.

the basis of various physical, chemical and biological processes. The process of diffusion and osmosis through the epidermal surface of root hairs and ion-exchange phenomena especially involving metal ions and chemical species at the root interface may give rise to chemical selectivity, ion adjustment and also uptake of water possibly compete with one another at the epidermic surface. The transport process through simplest, vascular epithelium and cell walls may be accounted for on the basis of free diffusion and osmosis (Sutchiffe, 1962). Both fresh and dried water hyacinth function as ion-exchanger in presence of metal ions. It is possible that the metal ions, molecular species and anions are metabolized in presence of oxygen and respiration energy since acetates, formats, phosphates, carbonates, nitrates, phenols etc. are readily consumed giving the plant accelerated growth. Particularly phosphates are stored in plant tissues and about 60% more phosphorus concentrate in the leaves of water hyacinth and stems than in roots (Macrobbie and Dainty, 1962; Haller and Sutton, 1973; Wolverton and McDonald, 1979).

Total dissolved solids (TDS) denote the various types of minerals present in water in the dissolved form. This may also include organic substances. In polluted waters the concentration of other substances increases, depending upon the type of pollution. Higher TDS value indicates depletion of dissolved oxygen and an aerobic condition prevailing in the aquatic system and most flora

and fauna would disappear and some selective species will dominate there and may cause Eutrophication.

The primary anthropogenic sources of ammonium nitrogen include manufacturing processes and the dumping of sewage sludge. This is toxic for aquatic environment as it hampers the metabolism processes of flora and fauna and last long in the food chain which also affect the higher consumers.

McKee and Wolf (1963) observed that sulphides present in effluents reacted with iron and imparted colour and undesirable odour and taste to water. Cement waste contains valuable plant nutrients like nitrogen, potassium, calcium, phosphorus, sulphur etc. though their use needs proper dilution and elimination of toxicities for beneficial irrigation purposes (Thabaraj et al., 1964).

Conclusion

Conscious efforts have been made in the Constitution under the section on directive principles to assign the duties for the state and all citizens through Arts 48A and 51A. It stipulates that government should take proper steps to protect environment.

After the Stockholm conference in 1972, environment movement really picked up in Bangladesh. In order to implement the recommendations of the conference, Government of Bangladesh brought environmental law. Yet due to various management and technical problems, environmental pollution is increasing. Moreover, small and medium size industries have financial problem. Environmental pollution prevention programme is intended to promote employees and can arise awareness of environment-related activities by providing proper information and training.

Chattak cement factory's production improvement was suggested; the industry used wet process for production. The energy consumption in wet process is much larger than dry process. The production cost of cement in this industry is large, because an enormous amount of natural gas is used for burning purpose. For sustainable production, the following steps should be considered: (i) reduction of energy supply using catalytic reaction, (ii) reduction of transportation cost, (iii) automation of the factory (iv) proper water treatment plant and (v) application of dust reduction system.

References

Alam, J. B. and M.M. Rahman (2002). Necessity of Pollution Prevention Programme for industries in Bangladesh. National Conference of BAPA, Dhaka. Feb, 2002.

Asian Development Bank (ADB) (1996). Index for economical evaluation. ADB Publication.

Environmental Protection Authority (1992). Guideline for Environmental Pollution Prevention. EPA, USA.

EU-commission (2003). Integrated pollution prevention and control—References document on best available techniques in the cement and concrete. EU-commission report, December, 2003.

Haider S.Z. (1984). Some aspects of the chemistry of water hyacinth. *Chemistry Education,* **1(1):** 16-19.

Haller, W.T. and D.L. Sutton (1973). Effects of pH and high phosphorus concentration on growth of water hyacinth. *Hyacinth Control J*., **11:** 59-61.

Islam, S. (2005). Application of fly ash to reduce the cost of cement production. Undergraduate thesis. Civil and Environmental Engineering Department, Shahjalal University of Science and Technology, Sylhet.

Khan, P. (1996). Contribution of Industries to total pollution. *Indian J. of Environmental Protection*, **12(1):** 34-45.

Macrobbie, E.A.C. and J. Dainty (1962). Metabolism in aquatic plants. *J.Gen.Physiol***. 45:** 851-860.

Mckee, J.E. and H.W. Wolf (1982). Influence of exchangeable sodium on the growth and nutrient composition of sugarbeet. *Indian J. Pl. Nutr,* **1:** 63-71.

Pollab, C. (2000). Environmental Management for Tata-Bearing Industry. M. Tech Thesis: Institution of Public Health Engineering, Kolkata, India.

Sengupta, S. (2001). Removal of heavy metal and recovery. Seminar arranged by Civil Engineering Society, IIT, Kharagpur, India. 6th August.

Sutchiffe, J.F. (1962). Mineral Absorption in Plants. Pergamon Press, USA.

Thabaraj, G.J., Bose, S.M. and Y. Nayudamma (1964). Utilization of tannery effluents for agricultural purposes. *Environ. Hlht.,* **6:** 18-36.

Wolverton, B.C. and R.C. McDonald (1979). Upgrading facultative waste water lagoons with vascular aquatic plants. *J. Water Poll. Cont. Fed,* **51:** 305-313.

World Bank (1998). Pollution prevention and abatement handbook. World Bank report, July 1998.

http://www.ecosmart.ca

Calendar of Events

Water in Africa: Hydro-Pessimism or Hydro-Optimism?
2 to 3 October 2008
Porto, Portugal
Website: http://www.africanos.eu/ceaup/index.php?p=g&n=42
Contact name: Ana Elisa Cascão
Organized by: Center of African Studies, Porto, Portugal

Climatic Changes and Water Resources in the Middle East and North Africa
7 to 8 October 2008
Fez, Morocco
Website: http://www.german-arab-scientific-forum.de
Contact name: Lahcen Benaabidate
Organized by: Laboratory of Georesources and Environment, Faculty of Sciences and Technology

WaterTech Asia 2008
14 to 16 October 2008
Shanghai, China
Website: http://www.watertechsummit.com
Contact name: Grace Jiang
Organized by: Global Leaders Institute

Water 2008
22 to 23 October 2008
London, United Kingdom
Website: http://www.marketforce.eu.com/water/
Contact Name: Leon Linton
Organized by: The IEA & Marketforce

International Convention on Water Resources Development and Management
23 to 26 October 2008
Pilani, Rajasthan, India
Website: http://discovery.bits-pilani.ac.in/water_conference/
Contact name: Dr. Ajit Pratap Singh
Organized by: BITS, Pilani

Global Water Management Congress
26 to 27 October 2008
Dubai, United Arab Emirates
Website: http://www.globalwatercongress.com
Contact name: Teena Tolani
Organized by: naseba Communications

Water India V – 2008
3 to 4 November 2008
New Delhi, India
Website: http://www.waterindia-v2008.com
Contact name: Pritha Sanyal
Organized by: Council of Power Utilities & KW Conferences

Urban Water Infrastructure Projects
11 November 2008
Brisbane, Australia
Website: http://www.iqpc.com/au/urbanwater
Contact name: Mabel Iau
Organized by: IQPC

Asia Pacific Regional Water Conference 2008
18 to 19 November 2008
Kuala Lumpur, Federal Territory, Malaysia
Website: http://www.aprwc.com
Contact name: Noor Shahidah Salleh
Organized by: Water Association of Selangor, Kuala Lumpur & Putrajaya

Year of Water 2008
20 November 2008
Washington DC, District of Columbia, United States
Website: http://sigmaxi.org/programs/issues
Contact name: Katie Lord
Organized by: Sigma Xi, The Scientific Research Society

International Conference on Environment 2008 (ICENV 2008)
15 to 17 December 2008
Penang, Malaysia
Website: http://chemical.eng.usm.my/ICENV2008/
Contact name: Lee Keat Teong
Organized by: School of Chemical Engineering, Universiti Sains Malaysia

International Conference on Water Resources Policy in South Asia
18 to 20 December 2008
Colombo, Sri Lanka
Website: http://www.saciwaters.org
Contact name: Sreoshi Singh
Organized by: Saciwaters