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The opening ceremony of the 26th ACHEMA was performed in the Congress Center at the Frankfurt Exhibition Grounds. From Monday, May 22, 2000 the gates to the world's biggest chemical engineering Exhibition–Congress and International Meeting on Chemical Engineering, Environmental Protection and Biotechnology was opened to the public for 6 days.

The special trend reports of ACHEMA 2000 exibition (no 1–19) were prepared for publication by authorities from DECHEMA. In this issue of Chemical Industry Jl. (Hemijska industrija) trends covering Packaging (Materials and Technologies) and Enviromental management are given. Trends covering Proces Identification (PI), Process Instrumentation and Control, Process Safety, and Plant Engineering Tools were published in No 6 of Chemical Industry Jl., while trends covering the Pumps and valves, Pumps, fitting and seals, Compressors, drives and seals, and Trends in Automation in No 7–8 are presented as prepared by DECHEMA for the presse–information. Others informations of these type will be published in the next issues of Chemical Industry Jl.

PACKAGING: NEW MATERIALS, NEW TECHNOLOGIES

Packaging is increasingly responsible for the product it contains, the process in which it is used and the impact of its disposal on the environment. These trends are driving innovations in packaging technology, handling and distribution.

Some of these efforts have been prompted by the European Union's directive packaging and packaging waste. By July 2001, EU countries must recover 50% of their used packaging, and recycle 25% of the material. European manufacturers that do not comply with their country's guidelines for meeting the directive face stiff penalties. Exporters to Europe must comply with strict packaging guidelines, or risk having their shipments rejected and returned.

To compete in a global marketplace, companies in the chemical processes industries (CPI) must be knowledgeable of packaging regulations, and the impact of they will have on product quality, the supply chain and ultimately, the bottom line. Consultants and engineers in the plan–design business often speak of hybrid processes – ones that are partly continuous, and partly batch. A food processing plant that starts with railcars of soybeans and ends with bottles of cooking oil and containers of tofu is a good example. These hybrid businesses are becoming commonplace and more and more parts of the CPI integrate downstream, providing not only product, but also packaging, labeling and all the other features that meet customer delivery demands.

To reduce packaging costs and waste, packaging suppliers are converting from rigid and semi–rigid packaging, to flexible packaging, say market analysts at Frost & Sullivan (Mountain View, California). Cardboard and recyclable plastics are made stronger, but lighter in weight and thinner in gauge. New coatings, additives and manufacturing methods enhance the quality of packaging materials.

In Europe, a popular packaging material is polyethylene terephthalate (PET). Demand is growing at an annual rate of about 15%, according to Pet Packaging, Resin & Recycling Ltd. (Derby, U.K.), and is expected to total 1.6 million tons in 2000, and double to 2.8 million tons by 2007. Beverage bottles are and will continue to be the major end use. By 2007, 70% of PET consumption is expected to be equally divided between the carbonated soft drinks and mineral water sectors. Throughout Europe, PET is expected to find widespread acceptance as a packaging for beer.

Longer shelf life for beverages

An major challenge for beverage packagers has been to successfully bottle beverages, including carbonated soft drinks, juices and beer in single–serve plastic containers. Though it has been long predicted that polyethylene terephthalate (PET) would soon overtake metals and glass in this category, it has not happened yet, according to Gordon J. Bockner, president of Business Development Associates, Inc. To maintain their freshness, oxygen–sensitive beverages packaged in PET containers require greater gas barrier protection when the ratio of bottle surface area to content, or liquid volume, increases.

At DrinkPac '99, he reported that while PET has captured a growing share of the cold–fill ready to drink (RTD) tea market, it is only 15%. Furthermore, PET's share of the multi–billion–unit hot–fill portion of this market is negligible. Bockner cites five changes that will cause the PET single–serve beverage packages to grow explosively over the next three years:

- Wider (and therefore more competitively priced) availability of improved barrier single–serve containers. This will be the result of both technical and commercial development
- Improving ability to manufacture cost–competitive hot–fillable PET containers.
- Alternative closing systems, which could further increase the cost competitiveness of PET containers
- Increasingly accessible integrated container manufacture and filling systems
- Continuing shift in packer perspective in response to the continuing availability of PET packaging

In 2000, Bockner expects to see the commercial introduction of at least two alternative ways to provide improved barrier performance. The first is Plastipak's Exxipak system, which will permit the use of up to 85% post consumer resin while selectively improving a container's gas barrier properties. As a result, it addresses both the cost and environmental recycling issues.

Both Husky and Tetra Pak have reintroduced the injection–over–injection concept originally introduced many years ago by Nissei for integrated manufacturing systems. This two–layer concept, in effect, coats a standard PET container without the need to install a separate coating line or process. Tetra says that the combination of these two innovative and proprietary steps may resolve many of the cost issues that were inherent in initial efforts.

New barrier materials developments within existing multilayer constructs offer potential cost–performance advantages. For example, Amcor recently produced a multilayer container for Anheuser–Busch that relies on an oxygen–scavenger barrier layer.

ICI Melinex markets an oxygen–barrier film for packaging applications. The film contains no aluminum, halogens or heavy metals, making it an environmentally sound alternative to aluminum foil, metallized PET and polymeric systems. The barrier is made by coating ICI's Melinex polyester film with inorganic platelets from natural minerals, mixed with a suspension of a proprietary organic binder. The coating is applied by gravure–printing methods at atmospheric pressure, and is protected by an overcoat. The resulting transparent film has an oxygen permeation rate of 1 $cm^3/m^2/d$, or about 6–8 times that of PET films coatined with polyvinyl dichloride.

The interest in innovative material developments for multilayer containers extends as well to exterior coatings for standard containers, says Bockner. Several companies, including Constar, Amcor and Graham Packaging have invested in outside coating capacity. PPG (Pittsburgh Plate Glass Industries, USA) recently announced that Graham will use its Bairocade coatings to coat to the exterior of 16– (about 0,5 Liter) and 20–ounce (about 0,6 Liter) bottles for juices. Over the last five years, the coatings have been applied to 1 billion bottles for carbonated soft drinks in the Middle East and beer in Australia.

PPG says its coating provide that protection, increasing shelf life by as much as 300%. Suitable for single–serve containers ranging from 8–20 ounces (0,2 – 0,6 Liter), the coatings are applied after the bottles are molded. Infrared ovens cure the coating, creating the gas barrier. These coated bottles can be processed through existing recycling systems.

On the paper side, International Paper is marketing a beverage for juice and milk products that helps to retain flavor and vitamins. The juice packaging, called Tru–Taste Gold, features multiple layers of protective material that enables the juice to retain 15% more vitamin C. A similar product for milk is constructed of paperboard to keep the milk fresh.

Hot–filled PET containers

The big challenge for PET packaging is the hot–filled containers market. To compete, PET must provide thermal stability, says Bockner. This can be obtained through heat setting. The two most significant components of the cost of manufacturing a heat–set container are the extra weight of the container and the cycle time of the heat setting process. Though the cost to produce a heat–set bottle will never be as low as the cost to produce a cold–filled container, the gap will narrow over the next few years. Bockner expects that by mid–to–late 2000, heat–set, single–serve 16–ounce containers will be available in the 27–28 gram range, compared with the current 32–33 gram range. The cost impact of such a change will be \$5–7 per thousand.

Active packaging

Packaging that has a function or purpose other than to provide an inert barrier between the product inside and the external environment, is called active packaging. An example is a barrier coating, applied to polyethylene terephthalate (PET) containers to preserve the freshness of carbonated soft drinks and other oxygen–sensitive beverages. Among the major markets for active packaging are vegetables, meat and dairy products, soft drinks and beer, pharmaceuticals and other products that are perishable or have a short shelf life.

Considerable research is focused on oxygen absorbing technologies that counter the deteriorating effects of oxygen by removing it from the headspace of packages, according to Michael Rooney, senior principal research scientist for Food Science Australia (Sydney).

Packages can be supplied with sachets containing iron powders, or the iron powders can be dispersed in the plastic packaging. Activated plastics, such as thin films based on the transition–metal–catalyzed process patented by W.R. Grace, offer an alternative form of oxygen–absorbing packaging, particularly for meats with a short shelf live. The Cryovac division of Sealed Air Corp. recently introduced "stealth" polymer–based scavenging film used within a multilayer format. Plastics that can provide sterile packaging and protect contents from microbial contamination is another area of ongoing research and development.

Japan's plastics producers are considered the leaders in oxygen scavenging technology. Among them is Toyo Seikan, which markets Oxyguard, a heat–resistant system for sterilized flexible and rigid packaging for food and pharmaceuticals, and Mitsubishi Gas Chemical, which introduced its Ageless oxygen absorbers more than 20 years ago. A major customer for oxygen–absorbing packaging is the U.S. military.

Meanwhile, a new French company, Anlyzee S.A. (Albi, France) a subsidiary of Biotel S.A. is commercializing Osmofilm, a polar gas– and vapor–permeable plastic film for CPI applications. Made from a polymer that has been approved for food use and is rated USP 23 Class VI for pharmaceuticals, the film is permeable to vapors and impermeable to liquids and microbes. The film is resistant to strong acids and most commercial solvents, with the exception of methylene chloride.

The film is made into bags capable of holding quantities ranging from grams to hundreds of kilograms of materials. The bags allow thixotropic or temperature–sensitive products, or powders that tend to agglomerate, to be dried within their packaging.

Materials containing 4–5% solvent, such as centrifuged materials, can be completely dried in the package, a relatively hygroscopic materials containing up to 15% water can be dried to 1–2% moisture. Field trials at a German yeast manufacturer, meanwhile, showed that storing waste sludge in the bags for several weeks reduced moisture content from 94% to 15%.

Water–soluble packaging

Makers of process additives are evaluating packaging that does not get recycled because it is eliminated in the process. These include drop–in packages made of water–soluble film. For example, Chemenergy (Albany, N.Y.), a manufacturer of chemicals for facility water–treatment, encapsulates its liquid water treatments in solid form and packages them in water–film by Chris–Craft Industrial Products. This eliminated shipping chemicals in drums (about 220 L) weighing about 227 kg. To package a 0.45 kg block of chemical, Chemenergy uses pre–formed bags. The bag film is appropriate for alkaline products up to a pH of 14. The bags are heat–sealed closed and packed into 20 L, 30 blocks to a pail. Total weight is about 13.5 kg. Application requires no mixing and worker safety is assured since the film encloses the chemical until it is added to the boiler. The system also reduces shipping as well as disposal costs. Instead of disposing of a contaminated drum and intermediary mixing containers, customers only have to recycle a plastic pail.

European directive on packaging

For shipping equipment and dry bulk materials, some companies are switching from containers made of polyurethane foam or other nonrecyclable material, to those constructed of cardboard, recyclable plastics or water–soluble film. Typical of the many options available is a box made of cardboard and polyethylene. Interlocking slots and tabs, instead of adhesives and glues hold the box together. After use, customers snap apart the cardboard and PE forms and put them into recycling bins. Micro Motion, Inc. (Boulder, Colo.), a supplier of instrumentation and controls, designed the box for shipping its instrumentation and controls after receiving notification from a Finnish client that it would no longer accept packaging that is nonrecyclable.

Another cardboard option is an octagonal box, by Georgia Pacific (Atlanta) that can be set up manually in about four seconds. The box's design reduces setup labor and eliminates the need for assembly equipment, which is often required for other bulk–box designs. Made to hold up to about 1000 kg of bulk dry products, the container uses less material to provide the same packaging volume as competing designs, reducing freight costs and easier handling.

Bulk containers

While about 210 L drums are the primary vessels for nonbulk and semi–bulk transport, international bulk containers (IBCs) with capacities to about 1000 L, are making steady inroads. They offer economies of scale, returnability and reusability, and have lower distribution costs per gallon, compared with smaller drums. Recyclable IBCs further enhance the appeal of IBCs. For example, an IBC made of 100% high–density polyethylene holds liquids and dry products, acids and alkalis.

Also finding increased demand are bulk bags. These flexible polypropylene bulk containers carry dry bulk powders in weights of 230–1800 kg. Transportation and storage of the bags is becoming easier with some of the bulk bag dischargers that are now available.

Outsourcing

As chemical processors look globally for business, more of them are deciding to let outside firms manage the logistics of shipping, cleaning, picking up and recycling IBCs and drums. Networks of reconditioners and distributors are growing throughout the world.

Companies can use their own units, or rent the containers. There are three basic types of logistical services:

- Casual hire. Bulk containers can be rented on a daily basis. Containers with disposable liners are delivered to the customer's site
- Term hire. Use of bulk containers from 90 days to 1 year, at a reduced daily rate. Either the customer or the service firm manages the logistics
- Lease. Bulk containers can be leased for up to 5 years at the lowest rate, avoiding capital investment and depreciation. As with term hire, the customer or the service firm can manage the fleet.

ENVIRONMENTAL MANAGEMENT

For manufacturing facilities throughout the global chemical process industries, managing waste streams in a way that economically meets corporate and regulatory mandates is an ongoing challenge. Such plants typically have two options for reducing pollution to acceptable levels: Install end–of–pipe treatments to destroy, neutralize or minimize the volume of waste generated, or implement pollution–prevention steps to prevent the formation of waste in the first place.

Pollution prevention

Regardless of its type, waste generated during chemical process operations almost always represents purchased raw materials that did not become part of the final product. By rethinking and improving process design, piping and vessel design, material–handling techniques, and operating procedures, engineers can improve process efficiency and boost yield, thereby reducing the formation of waste.

Improved design often attempts to separate various process and effluent streams into a relatively concentrated stream of non–useful byproducts, which will ultimately be discharged for disposal, and any valuable components, which can be reused within the process. To do this, engineers typically rely on mass–exchange equipment, such as absorbers, strippers, liquid–liquid extraction units, adsorbers, ion exchangers and leaching systems. Such systems often employ mass–exchange agents, such as solvents, granulated activated carbon, and ion–exchange, to enhance the separation of effluents into reusable versus disposable components.

Other source–reduction efforts often involve the replacement of toxic chemicals with less–toxic alternatives. In recent years, supercritical fluids have emerged as an environmentally friendly replacement for toxic and highly regulated chlorinated solvents, and their use has been proven in a range of applications by semiconductor fabricators, pharmaceutical manufacturers, textile processors and waste–treatment operators.

Straddling the line between a liquid and a gas, supercritical fluids are often touted as a natural alternative to methylene chloride, trichloroethane, fluorocarbons an other ozone–depleting and smog–causing compounds. To produce supercritical fluids, water or carbon dioxide is typically compressed and heated beyond its critical pressure and critical temperature, yielding a fluid with both liquid and gas properties and excellent solvency in a single phase.

Meanwhile, in a process known as supercritical water oxidation (SCWO), water is heated beyond its critical temperatures (374.2°C) and critical pressure (222.3 bars), dropping its density dramatically to about 0.15–0.20 g/cm^3. With these changes in density and hydrogen bonding, unwanted organic compounds become highly soluble, rapidly decomposing by oxidation into harmless components, such as carbon dioxide, nitrogen and water.

Modeling and simulation

The ability to design or modify chemical processes in a way that minimizes the formation of unwanted byproducts is an ongoing goal for process engineers. Today, more and more engineers are using simulation and other modeling programs to systematically analyze the intricate relationships among flow streams, unit operations, operating parameters and performance requirements. With improve data collection and analysis capabilities, the engineer can use this improved knowledge of key relationships during process design, to determine the ideal order of the unit operations, and calculate mass and energy balances for proper equipment sizing. Similarly, existing processes can be optimized to increase product flow, and reduce energy use and waste generation.

Many of today's simulation programs have a user–friendly interface that lets engineers easily construct flowsheets and simulate their operation. These simulators have access to large databases of chemical and physical properties for numerous compounds, as well as libraries of mathematical models for commonly used process units.

Cost–benefit analysis

Chemical process operators must carefully review the cost–benefit analysis of competing pollution–prevention and source–reduction options. The goal is to gather enough information on incremental costs versus the potential savings associated with pollution reduction, and to use this information to evaluate alternative designs.

A comparison of prices for various end–of–pipe treatment technologies can serve as the benchmark for evaluating pollution–prevention alternatives, and vice versa. In conducting a cost–benefit analysis, process operators should keep in mind that both pollution prevention, and the use of end–of–pipe treatments, can help facilities not only reduce their environmental impact on the surrounding community, avoid potential regulatory penalty and fines, minimize disposal costs, protect workers, but reduce manufacturing scrap, and lower energy and raw–material use. Safety and quality issues, while difficult to put a price tag on, are critical considerations during such an evaluation.

Treating gaseous waste streams

No matter how successful the pollution–prevention effort, it is nearly impossible to completely avoid the formation of some waste during process operations. To destroy solid, liquid and gaseous effluents, or reduce the volume or toxicity of the waste produced, process engineers rely on a variety of physical, chemical and biological treatment methods – collectively referred to as end–of–pipe treatment schemes.

Many chemical process plants routinely generate effluent streams containing volatile organic compounds (VOCs). For these, the available end–of–pipe treatment schemes fall into two categories: Those used to recover or recycle valuable components, and those used to destroy unwanted components.

Recovery technologies include condensation, carbon adsorption, pressure and temperature–swing adsorption and membrane separation. Destruction technologies include conventional thermal oxidation, flameless thermal oxidation, catalytic oxidation, and biological treatment schemes.

Organic vapors can be condensed by cooling the waste stream to below the dewpoint temperature of the contaminants. The condensed organics can then be sent for disposal, or recycled for reuse by the process.

Similarly, airborne organics can be removed by passing an effluent stream over a bed of highly porous activated carbon. Carbon's contaminant–removal efficiency is a function of the boiling point and molecular size of the compounds being adsorbed.

Once the carbon bed is saturated, the collected organics are liberated by heating the bed. The VOC stream liberated during desorption is then condensed for reuse or disposal.

In recent years, pressure– and temperature–swing adsorbers have emerged as viable alternatives to carbon–based systems. They rely on synthetic polymeric adsorbents, which also recover organic contaminants from a vapor stream. These polymeric adsorbents are typically hydrophobic; therefore, their adsorption capacity is unaffected by streams with relative humidity greater than 50%; this is not the case for carbon–based systems. To liberate adsorbed organics, the polymeric bed is periodically regenerated by applying a vacuum, heat or nitrogen back–purging.

Another relatively recent addition to the end–of–pipe treatment arsenal is membrane–based separation. At the heart of such a system are organophilic membranes that are designed to be 10 to 100 times more permeable to organic compounds than to air. As organics–laden fluegas passes over the membranes, it is separated into two streams: an organics–rich permeate stream, and an organics–depleted residual stream. The concentrated mixture of organics can then be condensed, and either collected for reuse or sent for disposal.

When destruction of organic pollutants is the goal, a variety of oxidation technologies may be employed, including thermal, catalytic and flameless oxidation. Traditional thermal –oxidation systems use a refractory–lined vessel equipped with a burner, which thermally decomposes volatile organics in a gas stream that has been heated, typically to 870–1100°C. Thermal oxidizers can be designed as straight–through oxidizers (which do not recycle heat energy), or as regenerative or recuperative thermal oxidizers (both of which do recycle heat energy for greater energy efficiency).

Regenerative thermal oxidizers make use of ceramic heat–exchange media to improve heat transfer and efficiency. Such systems typically have a heat–recovery efficiency of 95% or greater.

Recuperative thermal oxidizers use shell–and–tube heat exchangers to transfer heat from the exhaust to incoming process gases. Heat recovery of such systems is typically around 70%.

Catalytic versions of both regenerative and recuperative oxidizers are also available. They operate at less than half the peak operating temperature of conventional burners. However, they may not be able to accept as wide a range of compounds or constituents, due to the increased potential for catalyst poisoning or deactivation.

With the help of a bed of catalysts, catalytic oxidizers increase the rate of reaction, and enable organics destruction at lower temperatures than in conventional thermal oxidizers. While catalytic units are typically more costly than their traditional thermal counterparts, they typically reduce operating costs in the long run, by trimming overall fuel requirements.

In recent years, flameless thermal oxidizers have become viable alternatives to traditional thermal and catalytic oxidizers. At the heart of the flameless oxidizer is a heated ceramic bed, whose heat–transfer properties promote oxidation at organic concentrations below the lower explosive limit (LEL). And, by storing and releasing large amounts of heat without rapid temperature changes, such units can buffer fluctuations in stream flowrate and concentration.

Finally, biological treatment can be used to treat organics–laden fluegas streams. This approache relies on the natural metabolism of microorganisms to remove organic contaminants from air or wastewater streams. In general, microorganisms in a reactor consume organic contaminants for food, degrading the hazardous or toxic compounds into carbon dioxide, water and other inorganic constituents.

Treating wastewater

In the realm of wastewater treatment, oxygen has proven itself to be a powerful process–enhancement agent in recent years. During biological wastewater treatment , for example, boosting the level of oxygen (by adding air or pure oxygen) and nutrients can dramatically improve the microorganisms' ability to metabolize biodegradable contaminants into water and carbon dioxide.

Oxygen levels in the activated–sludge process can be increased in several ways. Typically mechanical or compressed–air systems are used to introduce dissolved air or pure oxygen to the activated–sludge reactor.

Mechanical systems entrain atmospheric air using impellers, propellers or turbines. Compressed–air systems introduce air or oxygen to the tank bottom, through the use of porous diffuser plates, spirally wound tubes, spargers, nozzles and injection jets.

In addition to adding oxygen and nutrients to stimulate the growth and activity of the biomass (a process referred to as biostimulation), a tailored array of microbes can also be introduced, to better target specific compounds. This process, known as bioaugmentation, aims to fortify the biomass by adding microbes that have been isolated and selectively adapted to degrade specific target compounds.

Added to a wastewater–treatment system, the tailored microbes enhance the ability of the biomass to respond to certain process conditions, or to tackle contaminants not broken down by their indigenous counterparts. This results in improved treatment.

Properly applied, bioaugmentation has demonstrated the ability to reduce process instability caused by fluctuations in organic loadings, improve the degradation of target substrates, improve the removal efficiencies for biochemical oxygen demand (BOD) and chemical oxygen demand (COD), prevent plant upsets (and speed recovery from them), and reduce sludge and scum formation in microbial–digestion units and lagoons.

Similarly, oxygen can be used to improve the oxidation of organic waste using ozone treatment and wet–oxidation systems. Wet–oxidation systems combine a high–activity catalyst with an oxidizing agent, such as pure oxygen, to break down hard–to–degrade organic contaminants.

Meanwhile, ozone, one of the most powerful oxidizing agents, is finding increased application in industrial wastewater treatment for the removal of phenols, cyanides and other toxic substances. In recent years, the technology has been made economically feasible for industrial use by the commercialization of reliable, standalone ozone generators. Today, system capacities ranging from ca. 7,5 to 7500.000 L/h and larger are available. Ozone treatment is considered to be an environmentally friendly alternative to chlorine–based oxidation systems.

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