Department of Chemical Engineering
Institute of Engineering & Science
IPS Academy
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B'Reactive

Dear Faculty members and friends

In continuation of our endeavors to inform, educate as well as provide an opportunity to deserving people.

This edition of Magazine '**B Reactive'** embodies myriad of articles from Chemical Engineering department IES-IPS. Newsletter through this edition attempts to diversify by dealing with various questions relating to chemical engineering, in the form of surveys which point to the general perception of people regarding these matters. Besides that it doesn't forget its primary objective that is to promote chemical engineering from its grass root levels.

We hope that this edition would be enjoyable as well as informative.

Editors...

Words from the desk of HOD

This decade is a time of unparalleled growth and change for India, with the opening up of the frontiers of the world through globalization, there is a need for efficient competence in the global scenario. This need for competence is what that drives our Department to strive for the pinnacle of success. Since its inception in the year 2004, the Department has always strived to create a cadre of professionals who are technically and professionally proficient.

The Department prides itself on preparing the students for creative careers in industries, academia and Government agencies. 350 numbers of students have successfully graduated and are catering to the needs of society.Our accomplished courses and adept faculties not only endeavor to cover the complete syllabus but to motivate students to learn beyond the syllabus which definitely develops complete knowledge of the subject (practical and theoretical) and develop skill sets of students to become promising engineers in future.

As per the need of current growing trend, the department have initiated post-graduation course from 2011 in Chemical Engineering with specialization “Computer Aided Chemical Process Plant Design”. The Department has been successfully carrying out testing & IEDC projects over last two years.

Prof. Rajesh Kaushal
HOD, Chemical Engineering
IES-IPS Academy

Message from the Principal

Technical Education is the most potential instrument for socio-economic change. Presently, the engineer is seen as a high-tech player in the global market. Distinct separation is visible in our education between concepts and applications. Most areas of technology now change so rapidly that there is a need for professional institutes to update the knowledge and competence.

Institute of Engineering and Science, IPS Academy is a leading, premium institution devoted to imparting quality engineering education since 1999. The sustained growth with constant academic brilliance achieved by IES is due to a greater commitment from management, dynamic leadership of the president, academically distinctive and experienced faculty, disciplined students and service oriented supporting staff.

The Institute is playing a key role in creating and ambiance for the creation of novel ideas, knowledge, and graduates who will be the leaders of tomorrow. The Institute is convinced that in order to achieve this objective, we will need to pursue a strategy that fosters creativity, supports interdisciplinary research and education. This will also provide the students with an understanding and appreciation not only of the process of knowledge creation, but also of the process by which technology and knowledge may be used to create wealth as well as achieve social economic goals.

I am delighted to note that the engineering graduates of this institute have been able to demonstrate their capable identities in different spheres of life and occupied prestigious position within the country and abroad. The excellence of any institute is a measure of achievements made by the students and faculty.

Dr. Archana Keerti Chowdhary
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IIChE STUDENTS' CHAPTER

EDITORIAL BOARD (2016-17)

Content

Nanostructured membrane forwater purification

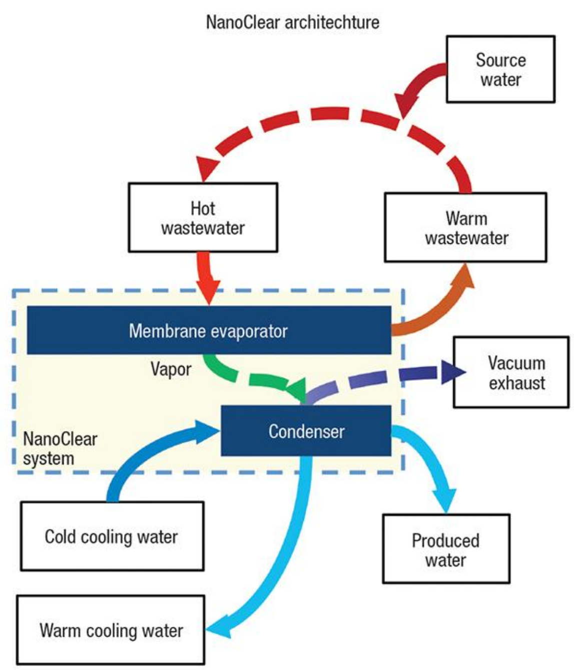
A new composite-membrane distillation process capable of removing salt, toxic elements and microorganisms from water is being offered commercially for the first time this month. The process, known as NanoClear, was developed by Dais Analytic Corp. for industrial wastewater treatment and desalination. The process is said to offer significant advantages in fouling resistance and eventually cost savings over reverse osmosis at similar flowrates.

The NanoClear process (diagram) leverages the unusual properties of Dais' patented Aqualyte membrane, which has been used commercially in HVAC (heating, ventilation and air conditioning) applications for over a decade. "Our nanostructured Aqualyte membrane is able to remove a wide range of contaminants to parts-per-billion levels, and is highly resistant to fouling," says Dais chief technology officer Brian Johnson.

The 25–30-micron-thick membrane is made from a block copolymer with regions of polystyrene and rubber. A polar functional group is added to the styrene to make those regions hydrophilic, while the rubber regions remain hydrophobic. As the polymer solidifies, it develops inherent structure at the nanometer scale: hydrophilic channels forms that allow water molecules to selectively pass through the membrane, while contaminants are retained. The channels are not open pores, Johnson says, but rather solid regions of hydrophilic plastic that interact with water molecules via hydrogen bonding to enhance their permeation between the polymer molecules.

Nano clear operates via evaporation process, in which heated wastewater is circulated on one side of the membrane, and water molecules are drawn through the membrane by a vacuum on the other side. The membrane allows significant surface area density while eliminating defects in the film of source liquid that lead to scaling in conventional evaporators.

Dais now operates two pilot-scale facilities using the NanoClear process and is working with partners to retrofit the system into existing facilities.



Pradeep Nagar (Final Year)

NFPA 652: Standardizing Combustible Dust Standards

The latest NFPA standard applies to many industry sectors, and aims to address the fragmented nature of the industry-specific standards currently in place

On September 7, 2015, the National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org) issued NFPA 652 (Standard on the Fundamentals of Combustible Dust) [*1*]. There were already several industry-specific NFPA standards for minimizing hazards associated with the handling of potentially combustible dust and fine particulate materials. However, these individual standards do not always align, and the presence of numerous, competing standards creates confusion among operators, and increases risk at chemical process industries (CPI) facilities.

The publication of NFPA 652 is the first step toward creating a single, unified combustible-dust standard that would apply to all facilities that handle potentially explosive dusts (Figure 1). In addition, NFPA has also stated that, through its Combustible Dust Correlation Committee, the group plans to reformat some of the current NFPA standards so they become more aligned with NFPA 652.

NFPA 652 is still in its infancy, and as with all NFPA standards, it will continue to be improved and developed during future revision cycles. This article provides an update on the ongoing activities by NFPA, and discusses what is currently included in the new NFPA 652 Standard.

Fundamentals of Dust Hazards

Flash fires and explosions resulting from potentially combustible dust are responsible for a significant number of industrial accidents. However, the potential for dust-related flash fires or explosions is often overlooked. The serious hazards associated with handling fine dusts and powdered materials may be overlooked by many plant personnel because they are not fully understood.

The Occupational Health and Safety Administration (OSHA; Washington, D.C.; www.osha.gov) has begun to increase awareness of the hazards associated with cobustible dust through its National Emphasis Program (NEP). The NEP often cites NFPA standards for combustible dust, as the NFPA standards have been written explicitly to both reduce the risk of a combustible dust incident, and minimize the hazards in the event of a flash fire or explosion. However, as noted, many of NFPA's existing standards related to dust-explosion hazards are industry-specific. For example, wood processing and woodworking facilities would refer to NFPA 664, while food-processing plants that handle flour and sugar (both of which are potentially combustible solids under the right conditions), would refer to NFPA 61. Often, the different NFPA standards directed at specific industry segments do not align with each other, creating confusion.

NFPA 652 aims to consolidate all of the various combustible dust standards, in order to create a single, overarching standard that addresses fire and explosion hazards associated with combustible dust of all types, in all industries. NFPA 652 lays the groundwork for a standardized format that all NFPA regulations relating to combustible dust will use. The new standard also implements methods that all facilities can use to evaluate and control hazards associated with potentially combustible dust. During the transition period (while NFPA is working on updating some of the current standards to align with NFPA 652), facilities should ensure that they are in compliance with both NFPA 652 and any applicable industry-specific NFPA regulations that pertain to their operations.

What Is Included In NFPA 652?

NFPA 652 was created to apply to "all facilities and operations that manufacture, process, blend, convey, repackage, generate, or handle combustible dusts or combustible particulate solids". In addition to the general requirements listed in the standard, NFPA 652 also directs you to any applicable industry-specific standards that would apply to different facilities. Over time these earlier, industry-specific standards will become more aligned with NFPA 652.

The primary focus of NFPA 652 is to help all facilities to identify where hazards exist due to the presence or handling of combustible or potentially explosive materials. In order to do this, a qualified person will need to conduct a dust hazard analysis (DHA). To conduct a DHA, a facility will need to develop a sampling plan to coordinate the collection and analysis of dust samples throughout the facility. This will allow the facility to identify and evaluate areas where combustible dust hazards exist.

Once all potentially hazardous areas and process equipment have been identified and a DHA has been completed, the facility should work to reduce the likelihood of a flash fire or explosion from occurring. It should also implement procedures or equipment to mitigate the hazards associated with a combustible dust fire or explosion.

If possible, the facility should work to contain and collect combustible dust, by both preventing fugitive dust from being discharged from equipment and by installing an effective dust-collection system throughout the process areas that handle combustible dust. The facility should develop a management system that monitors how hazards relating to combustible dust are being controlled.

Facilities should also provide training to employees and contractors. Such training should focus on both general safety regarding the hazards associated with combustible dusts, and on any job-specific training relating to their specific work environments.

Hazard Identification and DHA

NFPA 652 includes procedures that all facilities can follow in order to identify areas where potential combustible-dust hazards exist. Dust samples should be collected from throughout the facility (Figure 2), in order to determine the combustible or potentially explosive qualities of the dust. To carry out such sampling, all facilities are required to create a plan that should include the following.

- Identification of locations where fine particulate materials and dusts are present
- Collection of representative samples
- Methods to ensure preservation of sample integrity
- Communication with the test laboratory regarding proper sample-handling procedures
- Documentation of samples taken
- Safe sample-collection practices

Following a rigorous sampling plan will help facility operators to ensure that the dust samples are accurately analyzed to determine if they are combustible or potentially explosive.

Once dust samples have been collected and tested, if any of the materials are identified as being combustible or potentially explosive, the facility should then complete a DHA, to identify and evaluate the potential hazards associated with a fire or explosion due to the combustible materials handled throughout the facility. Inspections of areas where combustible dust is handled also allow facility operators to develop recommendations to minimize the risks of a combustible-dust incident.

Specifically, a DHA should include the following.

- Identification and evaluation of locations or processes throughout the facility where hazards resulting from a potential fire, flash fire or explosion exist
- Identification and evaluation of specific fire and deflagration scenarios where fire and explosion hazards exist
- Identification of safe operating ranges
- Identification of any safeguards that are in place to mitigate the hazards of a fire or explosion
- Recommendations for additional safeguards, where needed

The DHA must be completed or led by a qualified person who has demonstrated the ability to understand combustible dust and associated hazards through education or experience. This qualified person should inspect all buildings and processes to determine the potential likelihood of a fire or explosion due to the presence of combustible dust. This is determined by understanding the properties associated with the potentially combustible dusts that are handled in the building or process, identifying all potential ignition sources, and evaluating the effectiveness of any deflagration-suppression or protection systems that are currently in place.

Mitigating Hazards

Once a DHA has been completed by a qualified person, the facility should begin to implement any recommendations made, to prevent or minimize the hazards. Often times, updated housekeeping procedures are the first actions facilities can take for instance, to remove excessive dust accumulation in rooms and buildings (Figure 3). However, this requires extra labor and is often not as effective as expected.

For example, certain inaccessible areas (such as upper levels, rafters, beams and roofs) may not be inspected or cleaned often enough. Additionally, some housekeeping activities, such as cleaning dusty areas with compressed air, may pose additional (sometimes significant) hazards, as potentially combustible dust clouds are able to form in the areas that are being cleaned. Finally, housekeeping activities are often reduced or overlooked during periods of increased production or decreases in staffing.

Perhaps more importantly, facilities should make it a priority to take steps to contain and collect dust and powdered materials from the processes that handle or generate them. While conducting the DHA, facilities should try to identify any equipment where fugitive dust is being released into the work environment. Particular focus should be put on such systems and components as pneumatic and mechanical conveyance lines, sifters and screeners, bins and silos, dryers and cyclones, hammer mills and grinders, and unloading bins and stations. Once the leaks have been identified, plant engineers should work to repair the equipment to prevent fugitive dust from escaping from these systems and accumulating inside the facility.

Prevention and Capture

It is not always feasible to prevent the discharge of fugitive dust into a room or building, so other means of protection or hazard mitigation should also be implemented to reduce hazards and mitigate the risk of fire and explosion. Specifically, NFPA 652 states that any building or room where a dust deflagration hazard exists should be protected using venting systems that comply with NFPA 68. Also, pneumatic conveyance systems must be equipped with deflagration protection or suppression systems that will prevent a flash fire from traveling throughout the conveyance system and connected equipment; details are spelled out in NFPA 69.

Exhaust air from equipment should only be directed outside and not into the room unless specific guidelines are met. Facilities should also ensure that all central vacuum systems are equipped with tools and attachments that are constructed of metal or static-dissipative materials, and that all vacuum hoses are properly grounded.

While facilities should focus on prioritizing dust collection and containment from their processes, it is also important to implement safe housekeeping procedures in areas where dust accumulation cannot be avoided. Sweeping and water wash down are allowed under NFPA 652, but compressed air cleaning should only be used if certain requirements are met (NFPA 652, Chapter 8.4.2.6), such as the use of pressure-reducing nozzles and ensuring that no ignition sources are present in the area.

All housekeeping procedures implemented by the facility should be documented, and all employees and contractors should be trained on these procedures. Employee training should also include information regarding required personal protective equipment (PPE) to be worn during housekeeping operations, as well as instructions and training on how to properly use all equipment. In addition, the facility should ensure that all hot work being done onsite complies with NFPA 51B. The areas where hot work is being done must be cleaned before beginning the hot work, and all equipment in the area should be shut down.

NFPA 652 also states that facilities should conduct an assessment of workplace hazards, according to NFPA 2113, in order to determine if flame-resistant (FR) clothing is required. FR clothing is designed to not ignite when it comes into contact with a flame. If the assessment indicates that FR clothing is required, the facility must offer appropriate FR clothing to all affected employees.

NFPA 652 is the first step of many to consolidate and integrate a variety of NFPA standards that are intended to help reduce the risks for facilities producing or handling potentially combustible dusts and fine powdered materials. This new standard requires that all facilities create a sampling plan to test fine powdered materials from different locations and equipment, in order to determine if it is combustible or potentially explosive. If any of the dust samples pose a combustible dust hazard, a qualified person must conduct a DHA to determine how likely it is that a combustible dust incident will occur in a room or piece of equipment by evaluating the dust. Hazards assessments such as this are carried out by identifying any ignition sources, and evaluating any protection or suppression systems that have been implemented. Once the DHA has been completed, the facility should work to prevent or minimize the hazards. The facility should repair any leaks in equipment where fugitive dust is released into the work environment, and deflagration protection or suppression systems should be installed on at-risk equipment. Safe housekeeping procedures should be developed, and the facility should ensure that all employees and contractors have been trained. While there is still a lot of work to be done by the NFPA dust standards committees, facilities throughout the CPI should begin to familiarize themselves with the new NFPA 652 standard, to be in compliance with the new standard. It cannot be stated strongly enough that CPI facilities must work aggressively and consistently toward minimizing the risk of combustible dust fires and explosions wherever fine, powdered materials are produced or handled.

Mohak Maheshwari (First Year)

Measuring Exposures to Aerosols and Dust

Accurate measurements of exposures to aerosols and dusts by plant personnel can be tricky. Here is some help for determining exposures and addressing uncertainties

Uncontrolled aerosols (defined as suspensions of fine solid or liquid particles in gaseous media) in the chemical process industries (CPI) are of significant concern both as explosion hazards and as sources of adverse respiratory-health effects among exposed workers. Events such as the 2008 explosion of airborne and deposited sugar dust at the Imperial Sugar refinery in Port Wentworth, Ga., which killed 16 people and injured 42, are tragic, and conditions leading to this type of explosion are a legitimate cause for alarm. However, sometimes overlooked are the adverse health effects from long-term exposure to airborne contaminant. While the number of early deaths from chronic dust exposures has steadily decreased from a high of nearly 5,500 per year in the early 1970s, airborne dusts still contribute to the illness and early deaths of over 2,000 U.S. workers each year.

Unfortunately, this is not a simple proposition. Barriers remain in determining accurate aerosol concentrations, controlling airborne and fugitive dusts, and knowing what regulations apply to the various sectors of the CPI. This article provides information on how sampling of airborne dust is conducted, how personnel exposures are calculated and how to deal with the uncertainty in those measurements, relative to compliance with governmental regulations.

PERSONAL EXPOSURE

Exposure to airborne dust contaminants is determined in nearly every case by measuring the time-weighted average of exposure over the period of a single work shift in the breathing zone of the potentially affected worker. This is referred to as personal sampling for air contaminants. Compliance with legal limits is then determined by comparing the exposure value with the legal permissible exposure limit in a ratio called severity.

Once Y is determined, the resulting ratio is adjusted by the sampling and analytical error and then compared with compliance criteria according to upper and lower 95% confidence limits. SAE is determined from statistical errors of the analytical method(s) used in the laboratory and is combined with the errors resulting from sampling and later handling. Combining errors in this way may result in large SAE.

UCL is the upper confidence limit and *LCL* is the lower confidence limit. Compliance with Occupational Safety and Health Administration (OSHA; Washington, D.C.; www.osha.gov) legal limits is established when the $UCL_{95\%}$ is less than one. Non-compliance, along with a possible

OSHA citation, is concluded when $LCL_{95\%}$ is greater than one. In the condition where *LCL* is less than one and *UCL* is greater than one, a possible overexposure is concluded.

For exposure concentrations close to the permissible exposure limit, the value of the SAE determines whether an overexposure (or possible overexposure) has occurred. As noted earlier, SAE values can be large, thus interpretation of how errors contribute to the SAE could mean a facility is in non-compliance with federal regulations even though the personal sample is less than the legal limit.

Interpretation is not just limited to personal dust exposures. It is the root of the issue for combustible dust safety, as well. LePree outlines the U.S. Federal government's response to combustible-dust explosions by broadly applying the OSHA General Duty Clause in cases where standards, such as a combustible-dust standard, have yet to be written.

This can be confusing for business managers. The presence of clearly written standards or the intentional absence of them allows employers to confidently do business knowing they are in compliance with federal and state regulations. In situations where the law is ambiguous and where there is room for broad interpretation, it is arguably "safer" for processors to collect accurate measurements of workplace airborne concentrations using reliable tools and subsequently to control exposures to levels well below the regulatory limits than it is for them to risk being cited for non-compliance and allow unsafe, unhealthy conditions that could lead to explosion or illness.

Protecting workers' health and safety is of paramount importance, but can we go too far in creating overly protective workplaces? In the imaginary world of unlimited resources, the answer would be no. We don't live in an imaginary world. Resources are indeed limited. Chemical processors feel constant pressure to deliver the highest-quality products, maximize throughput, keep inventories low, protect the health and safety of the entire community, and to have minimal impact on the environment. And these goals are sought within an environment of legal and statistical ambiguity. It is an unenviable position to be in. So what can be done?

There are two approaches that can be used to address this challenge. The first is statistical in nature and has immediate application, but it is also overly protective and likely very expensive. The other, engineering design of aerosol samplers, is a longer-term approach but would serve to allow for better characterization of variability so sampling and analytical error of dust exposures would be more tightly controlled. Both approaches are described in the following sections.

Aerosol Sampling Statistics

Correct and accurate measurement of aerosols in the workplace is dependent on the nature of the material being sampled. Currently, OSHA regulates approximately 500 air contaminants, of which around 10% are aerosols. Respiratory exposure to these materials, and many more that are not regulated, can result in severe adverse health effects or even death. In addition to the health hazard, many of these dusts are known combustion hazards. Table Z-1 of the Toxic and Hazardous Substances, (found in OSHA 29 CFR 1910.1000) is a complete list of federally regulated airborne contaminants and contains legal permissible exposure limits (PEL) for peak, short-term and eight-hour work-shift exposures. The table lists exposure concentrations in parts per million (ppm) and mass per volume (mg/m^3). Generally, gas exposure levels have units in volume-based concentration as ppm, while dust exposures are mass-based concentrations in mg/m^3.

A number of recognizable materials are found in OSHA's Table Z-1 including aluminum, malathion, tin and many others. Malathion and tin have PELs for total dust. Aluminum has PELs for total dust and respirable dust. The distinctions between total and respirable dust are important to note because they reflect the location within the lung where disease would be present if exposure were to occur over long periods of time. Total dust refers to exposures that may affect the entire airway, from the nose and mouth down to the alveoli in the gas-exchange region of the lungs.

Total dust samplers collect all dust sizes that penetrate past the nose and mouth, which is about 100 micrometers (µm) and smaller. Respirable dust refers to the particulate matter that is of most concern when it penetrates past the upper and middle parts of the airway and then is transported into the gas-exchange region. These dusts are typically less than 10µm in diameter and most are less than 5µm. Conducting personal breathing zone (PBZ) sampling to generate a valid exposure measure requires that the correct sampling protocols be used. For malathion or tin, this would mean sampling for total dust. For aluminum, this could mean sampling for both total and respirable dust concentrations.

Instructions for conducting personal sampling are available in the OSHA Technical Manual. Specific sampling protocols for hundreds of materials can be found in the NIOSH Manual of Analytical Methods [4]. Sampling undertaken "in-house" should receive oversight by an industrial hygienist who is certified by the American Board of Industrial Hygiene (ABIH; Lansing, Mich.; www.abih.org). Those who have earned this designation are referred to as Certified Industrial Hygienists (CIHs) and many processors have one or more employed as key members of their environment, safety and health departments.

Example Exposure

Suppose the plant safety and health team, in concert with a CIH, has collected full-shift personal breathing-zone samples for two workers over the course of five work shifts. The safety and health (S&H) team thus has five total dust-aluminum measurements to use as indications of each worker's overall exposure. This is useful for understanding the extent of the exposure experienced by the worker, as well as for predicting what possible exposures may occur in the future. This strategy also allows for the development of a long-term exposure-control strategy and the mitigation of combustible-dust hazards, if present.

The example fictitious exposure data collected by the S&H team can be seen in Table 1 for workers with confidential identifiers 094 and 0152. These IDs would be known only to members of the S&H team and possibly to members of company management or human resources dept. In real air-sampling campaigns, the use of identifiers is common and identities are kept in confidence. Note that a large amount of data is collected when conducting air sampling campaigns, some of which is personal, and thus must be protected. Table 1 would represent a small subset of the entire data record.

TABLE 1. TWO WORKERS' FICTITIOUS EXPOSURES TO ALUMINUM TOTAL DUST (PEL 15 mg/m³)

Worker ID	Location	Date	Exposure (mg/m³)
094	Mixing	2014/09/06	4
0152	Intake	2014/09/06	1
094	Mixing	2014/09/07	6
094	Mixing	2014/09/08	6
0152	Intake	2014/09/07	3
094	Mixing	2014/09/09	5
0152	Intake	2014/09/08	5
094	Mixing	2014/09/08	4
0152	Intake	2014/09/07	13

1 Worker ID 094 GM = 4.919019 mg/m³
2 Worker ID 094 GSD = 1.2249965
3 Worker ID 0152 GM = 3.73687570 mg/m³
4 Worker ID 0152 GSD = 2.91100820
5 Worker ID 094 95th percentile statistic = 6.8684746 mg/m³
6 Worker ID 0152 95th percentile statistic = 21.670059 mg/m³

In this case, we treat the personal samples as being lognormally distributed and then calculate the geometric mean (GM), geometric standard deviation (GSD) and percentile decision statistics according to Equations as follows.

The GM and GSD can be easily calculated by hand. However, Data software can also be used to quickly calculate these values. For the data in Table 1, worker ID 094 has a GM of 4.9 mg/m^3 and a GSD of 1.2. Worker ID 0152 has a GM of 3.7 mg/m^3 and a GSD of 2.9. Because the collected air samples are part of the lognormal distribution, with GMs of 4.9 and 3.7, respectively, they accurately represent the data from within those distributions. Note the difference in GSDs between these two groups; one is relatively small, at 1.2, and the other is rather large, at 2.9. A quick look at the raw values for each worker reveals that one is tight (4, 6, 6, 5, 4), while the other has a broader range (1, 6, 5, 13). The tight grouping allows for confident prediction that the next sample taken for worker 094 will likely be close to these values. However, the broader range of the exposure groupings for the second worker opens the door to the possibility that the next value could be very high. This is problematic, as we will soon see.

Interpreting Exposure Data

Now that both the GM and GSD for the two workers are known, we can find any value from within the respective distribution by calculating a percentile statistic according to the following:

$$\hat{X}_{0.95} = GM \times GSD^{1.645}$$

The product of the geometric mean and geometric standard deviation raised to the power of the z-score for the desired percentile will result in a comparison statistic that can be used to assess risk [5]. We look in the standard normal z-table and see that the 95th percentile corresponds to a z-score of 1.645. Plugging in the GM, GSD and z-score for the grouping of samples for worker 094 gives a value for the 95th percentile statistic of 6.9 mg/m^3. We do the same for worker 0152 and get a 95th-percentile statistic of 21. These two values are compared to the Exposure Categorization Scheme proposed by the American Industrial Hygiene Association

(AIHA) and further developed by Hewett [*5*] (Table 2).

For the current example, we are interested in the PEL for aluminum total dust, which is 15 mg/m^3. Applying this value to the recommended statistical interpretation column gives us Table 3.

TABLE 2. SIMPLIFIED VIEW OF AIHA EXPOSURE CATEGORIZATION SCHEME [5]

Exposure category	Rule-of-thumb description	Recommended interpretation
0	Trivial, non-existent exposures	$X_{0.95} \leq 0.01 \times OEL^*$
1	Highly controlled, limited exposure	$0.01 \times OEL \leq X_{0.95} \leq 0.1 \times OEL$
2	Well controlled, few exposures at low concentrations	$0.1 \times OEL \leq X_{0.95} \leq 0.5 \times OEL$
3	Controlled, frequent exposures at low concentrations	$0.5 \times OEL \leq X_{0.95} < OEL$
4	Poorly controlled, frequent exposures often at high concentrations	$X_{0.95} > OEL$

*OEL is occupational exposure limit, which includes legal permissible exposure limits (PEL)

TABLE 3. RECOMMENDED STATISTICAL INTERPRETATIONS FOR EXPOSURE TO ALUMINUM TOTAL DUST

Recommended interpretation	Aluminum total dust PEL = 15 mg/m^3	Exposure cat.
$X_{0.95} \leq 0.01 \times PEL$	$X_{0.95} \leq 0.15$	0
$0.01 \times PEL \leq X_{0.95} \leq 0.1 \times PEL$	$0.15 \leq X_{0.95} \leq 1.5$	1
$0.1 \times PEL \leq X_{0.95} \leq 0.5 \times PEL$	$1.5 \leq X_{0.95} \leq 7.5$	2
$0.5 \times PEL \leq X_{0.95} < PEL$	$7.5 \leq X_{0.95} < 15$	3
$X_{0.95} > PEL$	$X_{0.95} > 15$	4

Exposures seen by worker 094 are relatively low and close together, resulting in the 95th percentile decision statistic of 6.9 and thus the exposure category of 2, "well controlled, few exposures at low concentrations," provides adequate qualification. Those of worker 0152 are low and close together, with one significant exception (at 13). This single high value causes a much higher 95th percentile decision statistic of 21.7 for these lognormally distributed data. This value is well above the PEL of 15, and thus we could say the exposure is "poorly controlled."

It is notable that the lower mean exposure seen by worker 0152 (GM = 3.7) has the higher GSD (2.9), and thus has a much higher 95th percentile statistic. This is because it is associated with the broader range of values. The highest of these, 13 mg/m^3, may look like an outlier in comparison with the others in this exposure group. Instead, this value is a true measure of the worker's exposure to aluminum dust on the day it was collected and serves as an indicator that concentrations of this magnitude do exist. The wide variability of the exposure group sampling measurements for worker 0152 indicate that dust for the associated process is not being controlled. That is, the next sample taken could indicate that the worker is exposed to a concentration of aluminum dust well above 13 mg/m^3. We've already seen that an SAE of 20% would push this particular sampling result into a legal noncompliance category, indicating that overexposure has occurred. Moving toward the upper end of the distribution of measurements, we would see higher and higher concentrations, all of which would be above the legal limit. The worker could be at risk for adverse health effects and the plant operators would be held responsible for putting the worker in that position.

From here, additional exposure categorization work would be valuable, and is recommended. For example, this could include a re-calculation of 95% upper and lower confidence limits, evaluation of the possible use of respiratory protection, adjustments to the ventilation (or other dust-control) systems, collection of additional sampling measurements, and subsequent reassessment of the exposures using a Bayesian approach. As before, such steps should be taken under the watchful guidance of a CIH.

Returning to the discussion of the samples in the second worker's exposure group, the wider variability reveals the presence of uncertainty in the system. The findings do provide enough information to begin taking steps to reduce the exposure concentrations to lower and more consistent values. Most likely this will begin by checking the performance of the ventilation and dust-control systems and then be followed by further investigations, if necessary. In addition to these, there could be other sources of variability and each must be characterized in order to make the system more reliable and predictable. One important source is the fundamental design and performance of aerosol samplers used to collect exposure samples. This aspect of uncertainty determination is taken up in the next section.

Aerosol Sampler Performance

Multiple samples within an exposure group will each contain multiple sources of variability, which is compounded when we look at the samples over time and space, and from sampler to sampler. Sources of variability buried within the exposure measurement include work rate, work behavior, process being sampled, environmental conditions, pump performance and sampler performance, among others.

Aerosol samplers used for sampling the size fraction listed in OSHA Table Z-1, known as total dust, include the 37-mm closed-face sampling cassette, the Institute for Occupational Medicine (IOM) Inhalable Sampler, and the SKC Button sampler. Of these, the first was not designed specifically as an aerosol sampler; rather, it was adapted from the field of water sampling. The latter two were designed in wind tunnels to meet the performance of the inhalability criterion that was established to mimic the concentration by particle size inhaled by a human. Subsequent studies have shown that the 37-mm cassette performs like a designed inhalable sampler (like the IOM and SKC button) when wall losses are incorporated into the sample analysis. The inhalable fraction expression is given as the following:

Where *SI(d)* is the sampling efficiency for the inhalable fraction and d is the particle diameter. This expression is intended to describe the percentage of particles in the air at specified diameters between 1 and 100µm that will penetrate into the human airway.

Adoption of the inhalability criterion has now gone international after early calls to do so. This also includes sampling efficiency prediction for thoracic (50% sampling efficiency cut-set at 10µm) and respirable size fractions (50% cut-set at 4µm), although this article is limited to discussion of the inhalable fraction. These performance metrics for aerosol samplers are now referred to as the CEN/ISO/ACGIH Inhalable Criteria. The criteria were developed in moving air conditions. However, there have been recent calls and studies regarding a calm-air sampling criteria. This makes sense considering that much of the air inhaled by workers really is calm, rather than constantly moving.

The CEN/ISO/ACGIH sampling criteria are ideal and protective. These criteria essentially represent the expected average inhalability for humans over the range of particle sizes from 1 to 100µm. The criteria are applicable only to inhalation. That is, when a worker inhales particles and then exhales, the fraction considered for potential illness comes from only the inhalation portion of total respiration. Physiologically, we know that many inhaled particles will be exhaled; however, the current convention is used because aerosol samplers are intended to be operated for continuous inflow, which in turn is a protective approach for assessment of potential illness due to occupational exposure. After all, every human has a different response to exposures and it would be nearly impossible, and certainly financially prohibitive, to continuously monitor every worker, all the time, for any signs or symptoms of illness. Instead, we control exposures to levels well below the PELs and consider any particles that penetrate into the human airway as potential risk candidates for onset of illness.

Aerosol samplers, therefore, should collect the size fractions that penetrate into the human airway. Designs of new samplers and redesigns of existing samplers should be based on optimization of performance according to the CEN/ISO/ACGIH Inhalable Criteria for moving air, as well as optimized for a calm-air performance standard. Aerosol samplers have been studied in numerous wind-tunnel and calm-air chamber experiments, but few have been intentionally optimized for agreement with human inhalability. Samplers designed in this way would allow for better characterization of sampling variability and thus reduction in uncertainty when assessing occupational exposures.

Manan Jain (Final year)

Removal of heavy metals from water by organic adsorbents

Innovative processes for treating industrial wastewater containing heavy metals often involve technologies for reduction of toxicity in order to meet technology-based treatment standards. This article reviews the recent developments and technical applicability of various treatments for the removal of heavy metals from industrial wastewater. A particular focus is given to innovative physico-chemical removal processes such as; adsorption on new adsorbents, membrane filtration, electrodialysis, and photocatalysis. Their advantages and limitations in application are evaluated.

It is evident from survey that new adsorbents and membrane filtration are the most frequently studied and widely applied for the treatment of metal-contaminated wastewater. However, in the near future, the most promising methods to treat such complex systems will be the highly efficient organic adsorbents which are comparatively much cheaper than the current in-use processes. On the other hand, from the conventional processes, lime precipitation has been found as one of the most effective means to treat inorganic effluent with a metal concentration of >1000 mg/L. It is important to note that the overall treatment cost of metal-contaminated water varies, depending on the process employed and the local conditions. In general, the technical applicability, plant simplicity and cost-effectiveness are the key factors in selecting the most suitable treatment for inorganic effluent.

Pratik Solanki (Final Year)

Unit Operations

A structure of logic used for synthesizing and analyzing processing schemes in the chemical and allied industries, in which the basic underlying concept is that all processing schemes can be composed from and decomposed into a series of individual, or unit, steps. If a step involves a chemical change, it is called a unit process; if physical change, a unit operation. These unit operations cut across widely different processing applications, including the manufacture of chemicals, fuels, pharmaceuticals, pulp and paper, processed foods, and primary metals. The unit operations approach serves as a very powerful form of morphological analysis, which systematizes process design, and greatly reduces both the number of concepts that must be taught and the number of possibilities that should be considered in synthesizing a particular process.

Most unit operations are based mechanistically upon the fundamental transport processes of mass transfer, heat transfer, and fluid flow (momentum transfer). Unit operations based on fluid mechanics include fluid transport (such as pumping), mixing/ agitation, filtration, clarification, thickening or sedimentation, classification, and centrifugation. Operations based on heat transfer include heat exchange, condensation, evaporation, furnaces or kilns, drying, cooling towers, and freezing or thawing. Operations that are based on mass transfer include distillation, solvent extraction, leaching, and absorption or desorption, adsorption, ion exchange, humidification or dehumidification, gaseous diffusion, crystallization, and thermal diffusion. Operations that are based on mechanical principles include screening, solids handling, size reduction, flotation, magnetic separation, and electrostatic precipitation. The study of transport phenomena provides a unifying and powerful basis for an understanding of the different unit operations.

Vivek Karma (Final Year)

Introduction to Catalysis

Catalysis in Industry

Catalysts are the workhorses of chemical transformations in the industry.Approximately 85–90% of the products of chemical industry are made in catalyticprocesses. Catalysts are indispensable in

- Production of transportation fuels in one of the approximately 440 oil refineriesall over the world.
- Production of bulk and fine chemicals in all branches of chemical industry.
- Prevention of pollution by avoiding formation of waste (unwanted byproducts).
- Abatement of pollution in end-of-pipe solutions (automotive and industrial exhaust).

A catalyst offers an alternative, energetically favorable mechanism to the noncatalytic reaction, thus enabling processes to be carried out under industrially feasible conditions of pressure and temperature.

What is Catalysis?

A catalyst accelerates a chemical reaction. It does so by forming bonds with thereacting molecules, and by allowing these to react to a product, which detaches fromthe catalyst, and leaves it unaltered such that it is available for the next reaction. Infact, we can describe the catalytic reaction as a cyclic event in which the catalystparticipates and is recovered in its original form at the end of the cycle.Let us consider the catalytic reaction between two molecules A and B to give aproduct P, The cycle starts with the bonding of molecules A and B tothe catalyst. A and B then react within this complex to give a product P, which isalso bound to the catalyst. In the final step, P separates from the catalyst, thus leavingthe reaction cycle in its original state.

Ayush Pandey (Third year)

FAQ's in Chemical Engineering Interviews

This article will give you the list of subject specific questions frequently asked during interview. Chemical engineering implies to the study of chemical and biological processes and design of industrial scale equipments for a cost-, time -efficient and safe production. It is also known as process engineering. Since chemical engineering involves the fields of sciences like physics, chemistry, biology and fields of engineering like equipment design, cost and time optimization, chemical engineers are subjected to a wide variety of questions.

Explain the third law of thermodynamics. The third law states that 'As a system approaches absolute zero, the entropy of the system approaches a minimum value'.

What is entropy?

Entropy is a measure of disorderliness. It explains the system's closeness to equilibrium.

What is Gibbs free energy?

It is the available energy or the greatest amount of mechanical work done by a system at constant temperature and pressure.

At what temperature does water have maximum density?

At 4 deg C the density of water is 1000 kg/m^3.

What is an isochoric process? It is a thermodynamic process at constant volume. Also called isovolumetric process

What is a CSTR and what are its basic assumptions?
Continuous Stirred tank Reactor. Assumptions are steady state, constant density, constant temperature, one irreversible first-order reaction.

List the advantages and disadvantages of a PFR.
Advantages: Continuous operation, high conversion rate, less cost for operation. Disadvantages: temperature gradients, high maintenance cost.

Explain global warming from a common man's and an engineer's perspective.

In a common man's perspective, the increase in world temperatures is global warming. In an engineer's perspective, it is the average temperature increase in the surface temperature of the earth, mainly due to increased concentration of greenhouse gases. The greenhouse gases capture the heat radiated by the earth, inside the atmosphere, enabling the increase in temperature.

What is carbon sequestration?

A technique for capturing carbon dioxide for a long term in order to reduce its effects on global warming.

What are the greenhouse gases in earth's atmosphere?

Water vapor, carbon dioxide, ozone, methane, nitrous oxide and CFC.

Define octane number.

It is the resistance to detonation of a fuel in a spark ignition engine compared to the isooctane-n-heptane mixture.

Explain the working of a spray condenser. A spray condenser is used for the condensation of humid water vapor by direct contact with water. The inlet water is at a temperature less than the dew point of air in the chamber.

How does a cyclone separator work? It works as gas-solid separation equipment using vortex formation.

Define viscosity.

Viscosity is a measure of a fluid's resistance to shear stress.

What is critical radius of insulation? The critical radius of insulation is the thickness of an insulation that does not affect the convection resistance. It is the ratio of the thermalconductivity of the insulator to the convection heat transfer coefficient.

What is a black body?

An ideal object that absorbs all electromagnetic radiations.

Vikram Choudhary (Third year)

Production of Bio Alcohol from Organic Municipal Solid Waste

Introduction

In the current scenario, every country, every state, each and every city is facing a major problem of solid waste management. Excluding plastics which can be recycled, the remaining organic waste needs a proper way to be recycled or disposed.

When this organic waste contains energy, then why shouldn't we apply the "Law of conservation of energy". Stopping its disposal and land filling, its need of the hour to transform this energy into usable form.

Process

The process for deriving the energy from this MSW, is to convert the organics to energy containing liquids, in our case "ethanol" we name it Bio-ethanol. The basic process is to degrade the cellulose content to sugar alcohols and then to ethanol by biochemical means.

Products outcomes of the Process

The main product of the process will be bio-alcohol (ethanol/butanol).
This alcohol can be purified to higher levels of purity (98-99%) which can be used as a solvent in Pharmaceutical industries and blending with fuels (E85).
Alongside the bio-alcohol, the residual organic waste slurry will be sent for making vermi compost which can be used as manure in agriculture.

Project Beneficiary

This project of production of bio-alcohol from MSW, directly or indirectly benefits to all the peoples. It benefits the common people by reducing the emissions and other harmful effects of burying or burning.It benefits the industries, as easy availability of solvent.
It is beneficial for the governing bodies in two ways, by providing a way of waste management, and by increasing the exports of solvent which empowers the economy.
Also by converting the waste to alcohol, the environment is protected thereby making it more sustainable.

Manan Jain, Rashmi Naktode,
Akshay Yadav (Final year)

Homi Jehangir Bhabha-Father of Nuclear Power

Bhabha belonged to a wealthy Parsi family that was very influential in the west of India. He got a doctorate degree from the University of Cambridge in 1934 after he had completed his studies from the Elphinstone College and graduated from the Royal Institute of Science that resided in Bombay. All this time he worked along with Neil Bohr that led them to discover the quantum theory. Bhabha also did some work with Walter Heitler and they made a breakthrough in the cosmic radiation's understanding by working on cascade theory of electron showers. In 1941, Bhabha got elected for his work in the Royal Society.

Contributions and Achievements:

Bhabha went back to India in 1940 and started his research in Banglore at an institute in India named The Indian Institute of Science about the cosmic rays. He was given a position as a director at an institute in Bombay known as Tata Institute of Fundamental Research. He was a skillful manager and it was due to his prominence, devotion, wealth and comradeship with Jawaharlal Nehru, PM of India that he was able to gain a leading position for allocating the scientific resources of India.

Bhabha was the first one to become the chairperson of India's Atomic Energy Commission in the year 1948. It was under his direction that the scientists of India made their way into making an atomic bomb ant the first atomic reactant was operated in Bombay in the year 1956. Bhabha also led the first UN Conference held for the purpose of Peaceful Uses of Atomic Energy in Geneva, 1955. It was then predicted by him that a limitless power of industries would be found through nuclear fusion's control. He promoted nuclear energy control and also prohibition of atomic bombs worldwide. He was absolutely against India manufacturing atomic bombs even if the country had enough resources to do so. Instead he suggested that the production of an atomic reactor should be used to lessen India's misery and poverty. A post in Indian

Cabinet was rejected by him but he served as a scientific advisor to PM Nehru and LalBahadurShastri.

Bhabha got many rewards and award from Indian as well as foreign universities and he was an associate of various societies of science including a famous one in the US known as National Academy of Sciences. Bhabha was killed in an air crash accident on January 24, 1966 in Switzerland.

Shreya Lal (Final year)