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BOOK CHAPTERS

EARTH
AND
ENVIRONMENT

Editor

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Chapter 1

Electronic Waste and Its Management

The fastest-growing waste stream in industrialised nations is electronic waste (Toxics Links, 2004). Electronics are transforming every aspect of human life, including how we do business, raise our children, stay in touch with one another, and enjoy our own personal pleasure. Unsurprisingly, the manufacturing sector with the fastest growth rate is the electronics sector. Customers are attracted to the newest cell phones, computers, air conditioners, and consumer electronics. These devices' obsolescence has created a distinct mentality among consumers, who would prefer to replace them over repair and reuse. The rapid obsolescence is also a result of the quick development of technology, but on the other hand, it is obvious that corporations profit financially from the throw-away philosophy. This throwaway principle will undoubtedly lower the standard of living for us and future generations in the aftermath of the transformation of the twenty-first century. Global effort is necessary to address the issue of electronic trash, or e-waste (Balde et al., 2015).

Concept of E waste

Waste electrical and electronic equipment (WEEE), often known as electronic waste or e-waste, refers to abandoned electrical or electronic gadgets. The term "electronic waste" may also refer to outdated computers, office equipment, entertainment devices, mobile phones, television sets, and freezers that are constructed from complex composites of metals, polymers, and other materials. This definition covers used electronics that are intended for recycling, disposal, salvage, and resale. Waste Electrical and Electronic Equipment is the name given to this new waste stream by the European Union (EU).

The WEEE is simply referred to as "E-waste" in India's environmental rules because there is no definition for it there. WEEE is diverse and complex in terms of materials and components as well as the production process, according to Gui et al. The characterization of this waste stream is crucial for creating a recycling system that is both economical and environmentally responsible. The Government of India classifies e-waste as falling under the general category of hazardous waste. Large and small household appliances, electrical and electronic toys and sporting goods, tools, computers and related equipment, among other categories, are included in e-waste. These items contain both metallic and non-metallic elements, alloys, and compounds, including Copper, Aluminium, Gold, Silver, Palladium, Platinum, Nickel, Tin, Lead, Iron, Sulphur, and Phosphorous. The fraction includes over 60% of metals, while plastics account for about 30% and the hazardous pollutants comprise only about 2.70%.

E-Waste- Indian Scenario

India is the third-highest producer of e-waste among Asian nations. In terms of absolute amounts, the nation produced 1.7 Mt in 2014 (Blade et al., 2015). More than 60% of the country's total e-waste is produced in 65 cities. 70% of all e-waste is produced by ten states. On the list of states that generate the most e-waste, Maharashtra comes in first, followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh, and Punjab. Mumbai is the top-ranking city among the top ten cities that produce electronic garbage, followed by Delhi, Bangalore, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat, and Nagpur. In Chennai and Bangalore, there are two little facilities for e-waste destruction. In India, there are no significant organised e-waste recycling facilities, and all recycling is done in the unorganised sector. The various State Pollution Control Boards have started the effort to collect data on e-waste generation since there is a shortage of reliable and complete information about the availability of e-waste for household generating.

E waste issues

An evaluation of the current practise in e-waste management was developed based on the findings of the research conducted and the consensus reached at the National Workshop on electronic waste management held in March 2004 and June 2005 and organised by CPCB and the Ministry of Environment & Forests. The evaluation revealed the following issues.

A. Increasing amount of E- Waste

Because of the rapid pace of invention and the dynamism of product manufacturing and marketing, many computer products have short lifespans (less than two years), which has accelerated the rate of product obsolescence. Over the next five to six years, the amount of e-waste will double due to short product lifespans combined with exponential growth at an average rate of 15% each year.

B. Toxic components

E-waste must be handled carefully because it is known to include dangerous materials like lead, cadmium, mercury, polychlorinated biphenyls (PCBs), etching compounds, and brominated flame retardants. Inadequate handling of these materials led to the uncontrolled release of harmful compounds into the environment as a result of irregular recycling practises in the informal sectors.

C. Lack of environmentally sound recycling infrastructure

It has been proven that when e-waste isn't properly disposed of, it ends up with scrap dealers who then push it further into the supply chain of dismantlers. The currently in place ecologically friendly recycling infrastructure is not able to handle the rising levels of e-waste. The majority of the demolition work is being done in a risky manner in the informal/unorganized sector. Numerous recyclers worldwide have expressed interest in opening recycling facilities in India due to the potential for growing e-waste output and the lack of suitable recycling infrastructure.

D. Impacts on environment

Heavy metals, persistent organic pollutants, flame retardants, and other potentially dangerous compounds are all included in e-waste. If these pollutants are not effectively controlled, there may be threats to the environment. Three main kinds of compounds are discharged into the environment during recycling and material recovery, and because they are highly harmful, they require immediate treatment. The first group consists of the original components of the equipment, such as lead and mercury. The second group, which includes cyanide, is added during some recovery procedures, and the third group, which includes dioxins and furans, is created during recycling processes. Such compounds may pose serious dangers to human and environmental health if they are not handled properly (Joseph, 2007). The presence of harmful materials in the treatment and management of e-waste is demonstrated by the following forms of emissions or outputs.

Leachates from disposal activities, coarse and fine particulate matter from demolition, bottom and fly ashes from burning operations, fumes from mercury amalgamate, desoldering, and other burning operations, wastewater from demolition and shredding facilities, and effluents from cyanide leaching and other leaching operations all pollute soil and water resources (Lundgren, 2012). The emission of mercury, cadmium, and beryllium, which are very harmful to human health, may result from improperly breaking or burning printed circuit boards (PCBs) and switches (Handout 10, 2012). Recycling hazardous materials like flame retardants made of halogenated chlorides and bromides, which burn at low temperatures and produce persistent dioxins and furans, is another risky procedure. An investigation on the burning of printed circuit boards in India revealed disturbing levels of dioxins around open burning areas that were 30 times the Swiss advisory level. Electronic waste is the source of around 70% of the heavy metals, primarily mercury and cadmium, found in landfills. An estimated 40% of the lead in landfills is a result of consumer electronics. (WHO, 2010) These chemicals have been linked to cancer, allergic responses, and brain impairment. The highly dispersed recycling facilities throughout India cause issues like air emissions of dioxins and heavy metals like lead, cadmium, and mercury, indiscriminate soil contamination from spent fluids and chemicals, groundwater contamination from leachate, land filling of non-recyclables, and BFR release (Sharma et al., 2012).

E. Occupational health impacts of e-waste

To protect the health of individuals who handle e-waste, there is little regulation in the unorganised sector. Workers are not adequately protected in a setting where lead and mercury toxins are released into the air during the open burning of e-waste from PC displays, PCBs, CDs, motherboards, cables, and toner cartridges. Numerous of these workers report experiencing chronic headaches, respiratory issues, and eye irritation (Li et al., 2011). Lack of clean drinking water and toilets, cramped seating on the ground for long periods of time, toxic fume inhalation, poor lighting and ventilation, straining the eyes, and exposure to fire, acid, and other chemicals are some serious occupational health concerns. The best example is the town of Guiyu in south-east China. Since 1995, the traditionally rice-growing community of Guiyu has turned into an intensive informal ewaste recycling centre, probably the largest in the world. Researchers observed many health effects in relation to the rudimentary recycling techniques (Lundgren, 2012).

F. Regulatory regime for e-waste

There are special environmental regulations or guidelines for e-waste that exist in India. Since May 2012, the E-waste (Management and Handling) Rule, 2011, has been in effect. The various international measures to control the flow of e-waste are described below.

1) The Hazardous Wastes (Management and Handling) Rules, 2003: The Hazardous Waste (Management and handling) Rule, 2003, defines "hazardous waste" as any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or likely to cause danger to health or environment, whether alone or when on contact with other wastes or substances, and shall include Waste substances that are generated in the 36 processes indicated in column 2 of Schedule I and consist of wholly or partly of the waste substances referred to in column 3 of same schedule.

Waste substances that consist wholly or partly of substances indicated in five risks class (A,B,C,D,E) mentioned in Schedule 2, unless the concentration of substances is less than the limit indicated in the same Schedule. Waste substances that are indicated in Lists A and B of Schedule 3 (Part A) applicable only in cases of import and export of hazardous wastes in accordance with rules 12, 13 and 14 if they possess any of the hazardous characteristics listed in Part B of schedule 3.

2) Basel Convention: Basel Convention covers all discarded/disposed materials that possess hazardous characteristics as well as all wastes considered hazardous on a national basis. Annex VIII, refers to E-waste, which is considered hazardous under Art. 1, par. 1(a) of the Convention: A1180 Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-rat tubes and other activated glass and PCB capacitors, or contaminated with Annex I constituents (e.g., cadmium, mercury, lead, olychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III. Annex IX, contains the mirror entry, B1110 Electrical and Electronic assemblies given below.

• Electronic assemblies consisting only of metals or alloys

• Waste electrical and electronic assemblies or scrap (including printed circuit boards) not containing components such as accumulators and other batteries included on List A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or not contaminated with Annex 1.

Management of e-waste

In this context, it is important to evaluate the current e-waste recycling situation in India, where recycling of e-waste is done in order to recover things with economic worth. According to an analysis of the Indian e-waste recycling market, the trade in e-waste originates in the legitimate dismantling market before moving to the unregulated market for recycling. Trade drives the flow of e-waste from the formal economy to the unorganised sector, and the trade value chain can be followed. The material movement from the formal to the informal sectors can be used to map the value chain for the trade of electronic waste. This chain was discovered using a bottom-up methodology and a three-level hierarchy of e-waste creation. The three e-waste generating hierarchy levels result in the three different categories of e-waste trade stakeholders that are explained below.

- *1st Level – Preliminary e-waste Generators.*
- *2nd Level – Secondary e-waste Generators.*
- *3rd Level – Tertiary e-waste Generators.*

The following are the steps involved in an e-waste management facility. In a formal sector the e-waste is segregated into different streams depending on their material composition and recycling potential. After which the hazardous nature is checked to understand its reuse or disposal options.

A. Composition and recycle potential

The composition of e-waste and its recyclable potential is specific for each appliance. In order to handle this complexity, the parts or materials found in e-waste may be divided broadly into six categories as follows: • Iron and steel, used for casings and frames • Non-ferrous metals, especially copper used in cables, and aluminum • Glass used for screens, windows • Plastic used as casing, in cables and for circuit boards • Electronic components • Others (rubber, wood, ceramic etc.).

B. Methodologies

The approach and methodology to determine the hazardousness has been described in following steps .This approach follows the basis used by "Department for Environment, Food and Natural Affairs", Government of United Kingdom to classify E-waste. However, it has been customized as per Indian situation.

• Step 1: Identification of E-waste category

• Step 2: Identification of E-waste composition or determine it

• Step 3: Identification of possible hazardous content • Step 4: Identifying whether the E-waste component is hazardous or the entire E-waste item is hazardous.

C. Recycling, Reuse and Recovery

E-waste is made up of a variety of materials, including glass, plastic, electronic components, ferrous and non-ferrous metals, and other materials. It has also been shown that e-waste contains hazardous substances. Therefore, reducing the concentration of these dangerous chemicals and components through recycling and recovery is the primary method of treating e-waste. Some e-waste fractions serve as secondary raw materials in the recycling or recovery process so that valuable goods can be recovered. The following unit operations are a part of recycling and recovery.

1) Dismantling: Removal of parts with hazardous materials (CFCs, Hg switches, PCB); removal of parts with valuable materials that are simple to access (cable with copper, steel, iron, and parts with precious metals, such as contacts).

2) Segregation of ferrous metal, non-ferrous metal and plastic: This separation is normally done in a shredder process.

3) Refurbishment and reuse: Those used electrical and electronic devices that can be easily repaired and put back to their original function are candidates for refurbishment and reuse of e-waste.

4) Recycling/recovery of valuable materials: Ferrous metals are used in electrical furnaces, non-ferrous metals are used in smelting facilities, and precious metals are used in separation processes.

5) Treatment/disposal of dangerous materials and waste: Shredder light fraction is dumped in landfills or occasionally burned (expensive), CFCs are thermally treated, PCB is burned or dumped in underground storage facilities, and Hg is frequently recycled or dumped in subterranean landfills. If the right technologies are applied, recovery from the elements would have a considerably higher value.

D. Treatment & disposal

Due to landfilling and incineration, the presence of hazardous materials in e-waste has the possibility of intensifying their environmental discharge. Depending on the composition, the following treatment and disposal options are

1) Land filling:

The degradation processes of e-waste in landfills are very complicated and run over a wide time span. At present it is not possible to quantify environmental impacts from E-waste in landfills for the following reasons:

1) Landfills contain mixtures of various waste streams;

2) Emission of pollutants from landfills can be delayed for many years;

3) Data on the concentration of chemicals in leachate and landfill gas from municipal waste disposal sites vary by a factor of 2-3 depending on climatic conditions and landfill technologies (such as leachate collection and treatment, impermeable bottom layers, and gas collection).

The conditions on a landfill site are different from a native soil, notably in terms of the leaching behaviour of metals, according to one study on landfills, therefore the environmental risks from land filling of e-waste cannot be ignored. Additionally, it is known that mercury and cadmium are released either diffusely or through a landfill gas combustion facility. Landfilling does not seem to be an environmentally sound treatment method for substances that are volatile and not biologically degradable (Cd, Hg, CFC), persistent (PCB), or with unknown behaviour in a landfill site (brominated flame retardants), even though the risks cannot be quantified and linked to ewaste. Due to the complex material composition of e-waste, even in secured land filling, environmental (long-term) concerns cannot be completely eliminated.

2) Incineration:

The decrease of trash volume and use of combustible materials' energy content are benefits of burning of e-waste. For recycling, certain factories extract the iron from the slag. Some organic materials that are harmful to the environment are transformed into less dangerous molecules through incineration. The air emissions from materials escaping flue gas cleaning as well as the substantial amounts of residue from gas cleaning and burning are drawbacks of incineration. There is no existing research study or comparable data that shows how e-waste emissions affect municipal waste incineration plants' overall performance. Waste incineration facilities provide a sizable contribution to the cadmium and mercury emissions each year. In addition, heavy metals not emitted into the atmosphere are transferred to slag and exhaust gas residues and can reenter the environment on disposal. Therefore, e-waste incineration will increase these emissions, so reduction measures like removal of heavy metals are necessary.

The scenario of the generation of e-waste in India and other nations is summarised in the current article. To comprehend the dangerous nature of e-waste in the form of heavy metals and halogenated compounds, definition, material composition, current disposal techniques, and hazardous nature of e-waste are also provided. The environment and human health may be at danger from improper handling and management of these wastes during recycling and other end-of-life treatment alternatives. The issue is made worse in India by the lack of public understanding on the proper way to dispose of electronic items and the inadequate policies in place to address these issues. In India, the majority of recycling takes place in the unorganised sector because there are no large-scale organised E-waste recycling facilities. Additionally, there are numerous health and environmental problems with the management practises, which are frequently poorly constructed. A thorough analysis of the present and future situation, including quantification, characterisation, current disposal procedures, environmental implications, and occupational health risks, is urgently required. For the environmentally appropriate management of e-wastes, national and/or regional e-waste collection, transportation, treatment, storage, recovery, and disposal needs to be developed.

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Chapter 2

Solid Waste- Its Health Effects and Management

Here, the term "solid waste" refers to all non-liquid wastes. However, infrequently, diapers and young children's faeces may be mixed with solid waste. Excreta are often omitted from this. If solid waste is not properly and safely disposed of, it can cause major health problems and create a very unpleasant living environment. If trash is not disposed of properly, rodents (rats), pests, snakes, and insect-vectors may breed there, increasing the risk of disease transmission. It might also contaminate the surroundings and water supplies.

Definition

All non-liquid wastes are referred to as solid waste here. Excreta are generally excluded from this, but occasionally diapers and young children's faeces may be combined with solid waste. If solid trash is not disposed of properly and safely, it can lead to serious health issues as well as a highly unpleasant living environment. If garbage is not properly disposed of, it may serve as a breeding ground for vermin (rats), pests, snakes, and insect-vectors that raise the risk of disease transmission. It might potentially contaminate the environment and water supplies.

Associated risks

Disease transmission

Animals, vermin, and insects are attracted to decomposing organic waste. Particularly if home trash contains faeces (typically those of children), flies may play a significant role in the transmission of faecal-oral illnesses. Rodents can enhance the spread of illnesses like salmonella and leptospirosis and draw snakes to waste piles. Mozzies may find breeding grounds in solid waste. The Aedes genus of mosquitoes, which cause dengue and yellow fever, lay their eggs in water kept in abandoned objects like tins and drums. Such conditions may also attract mosquitoes of the *Anopheles* genus, which transmit malaria. Mosquitoes of the *Culex* genus breed in stagnant water with high organic content and transmit microfilariases (Médecins Sans Frontières, 1994), appropriate conditions are likely to arise where leachate from waste enters pooling water.

In times of famine or food scarcity, members of the affected population may be attracted to waste heaps to scavenge for food; this is likely to increase the risk of gastro-enteritis, dysentery and other illnesses.

Pollution

Leachate pollution of surface water or groundwater may result from improper collection and disposal of solid waste. If the garbage contains harmful materials or if local water sources are used for water supply, this could result in serious issues. Large quantities of dry garbage may pose a fire risk when kept in warm climates. Smoke pollution and the potential of fire to both persons and structures are other dangers..

Effect on morale

Living in an unclean and disorganised environment can have the impact of making people feel demoralised and less motivated to make their surroundings better. garbage attracts more garbage and promotes generally less sanitary behaviour.

Sources and types of solid waste

Sources of solid waste

In most emergency situations the main sources of solid waste are:

- Medical centres
- Food stores
- Feeding centres
- Food distribution points
- Slaughter areas
- Warehouses
- Agency premises
- Markets
- Domestic areas

Type and quantity of waste

The type and quantity of waste generated in emergency situations varies greatly. The main factors affecting these are:

- the geographical region (developed or less-developed country or region);
- socio-cultural practices and material levels among affected population;
- seasonal variations (affecting types of food available);
- the stage of emergency (volume and composition of waste may change over time); and
- the packaging of food rations.

In general, where the population is rural in origin and the food rations provided are unpackaged dry goods, the level of trash generated is likely to be limited and generally biodegradable. Urban populations that have been displaced are more prone to produce higher amounts of non-biodegradable garbage, particularly in situations when packaged food rations are offered. According to recommended values, each person is expected to create 0.5–1.0 litres of waste per day with a 25–35% organic content and 10–60% moisture content. Estimates should be made locally because this is likely to vary substantially.

Different categories of solid waste include:

Organic waste:	Waste from preparation of food, market places, etc.
Combustibles:	Paper, wood, dried leaves, or relief items, etc.
Non-combustibles:	Metal, tin cans, bottles, stones, etc.
Ashes/dust:	Residue from fires used for cooking
Bulky waste:	Tree branches, tyres, etc.
Dead animals:	Carcasses of domestic animals and livestock
Hazardous waste:	Oil, battery acid, medical waste
Construction waste:	Roofing, rubble, broken concrete, etc.

Initial steps

In order to establish effective solid waste management in the affected area the following process should be used:

Key components of solid waste management

Solid waste management can be divided into five key components:

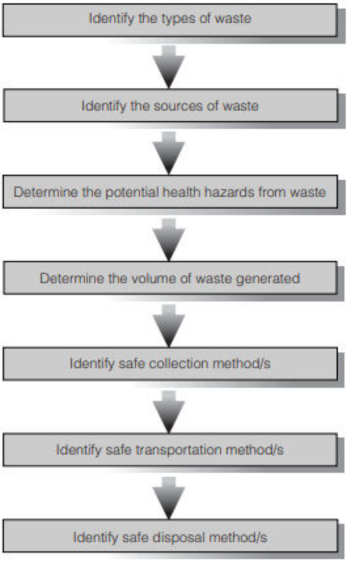
- Generation
- Storage
- Collection
- Transportation
- Disposal

1. Generation

Generation of solid waste is the stage at which materials become valueless to the owner and since they have no use for them and require them no longer, they wish to get rid of them. Items which may be valueless to one individual may not necessarily be valueless to another. For example, waste items such as tins and cans may be highly sought after by young children.

2. Storage

Storage is a system for keeping materials after they have been discarded and prior to collection and final disposal. Where on-site disposal systems are implemented, such as where people discard items directly into family pits, storage may not be necessary. In emergency situations, especially in the early stages, it is likely that the affected population will discard domestic waste in poorly defined heaps close to dwelling areas. If this is the case, improved disposal or storage facilities should be provided fairly quickly and these should be located where people are able to use them easily. Improved storage facilities include:



- Small containers: household containers, plastic bins, etc.
- Large containers: communal bins, oil drums, etc.
- Shallow pits
- Communal depots: walled or fenced-in areas

In determining the size, quantity and distribution of storage facilities the number of users, type of waste and maximum walking distance must be considered. The frequency of emptying must also be determined, and it should be ensured that all facilities are reasonably safe from theft or vandalism.

3. Collection

Collection simply refers to how waste is collected for transportation to the final disposal site. Any collection system should be carefully planned to ensure that storage facilities do not become overloaded. Collection intervals and volumes of collected waste must be estimated carefully.

4. Transportation

This is the stage when solid waste is transported to the final disposal. There are various modes of transport which may be adopted and the chosen method depends upon local availability and the volume of waste to be transported. Types of transportation can be divided into three categories:

- Human-powered:open hand-cart, hand-cart with bins, wheelbarrow, tricycle
- Animal-powered:donkey-drawn cart
- Motorised:tractor and trailer, standard truck, tipper-truck.

a. Human-powered

Wheelbarrows are perfect for moving rubbish around compact areas like markets, but they are rarely appropriate when moving waste long distances off-site. For longer distances, handcarts offer a better alternative because they can push more people and carry a lot more rubbish. Open carts and carts with multiple bins or containers are both options.

b. Animal-powered

Animal-powered transportation means such as a horse or donkey with cart are likely to be appropriate where they are commonly used locally. This may be ideal for transportation to middle distance sites

c. Motorised

The usage of a motorised vehicle could be the only practical solution when travelling a long distance or when there is a lot of rubbish to transfer. Tractor and trailer, a regular truck, or a tipper-truck are available options; the ultimate decision will largely depend on the ease and speed of procurement. Sometimes a two-stage transportation system involving a transfer station may be necessary for big amounts of waste. As an illustration, waste is moved with a handcart to a transfer station and then loaded onto a truck and driven several miles to an off-site disposal facility.

5. Disposal

The final stage of solid waste management is safe disposal where associated risks are minimised. There are four main methods for the disposal of solid waste:

- Land application: burial or landfilling
- Composting
- Burning or incineration
- Recycling (resource recovery)

The most common of these is undoubtedly land application, although all four are commonly applied in emergency situations.

A. On-sitedisposaloptions

The technology choices outlined below are general guidelines for disposal and storage of waste on-site, these may be adapted for the particular site and situation in question.

a. Communal pit disposal

Direct waste disposal into a public pit is arguably the simplest solid waste management solution. The number of individuals it serves will determine the size of this hole. Six cubic metres per fifty individuals is the recommended long-term goal. The pit should normally be no farther than 100 metres from the residences to be served and should be enclosed by fencing to prevent little children from falling in. To reduce flies and other pests, garbage should ideally be covered with a thin layer of dirt at least once every week.

Advantages: It is rapid to implement; and requires little operation and maintenance.
Constraints: The distance to communal pit may cause indiscriminate disposal; and waste workers required to manage pits.

b. Family pit disposal

Where there is enough room, family pits might be a better long-term solution. Families should be urged to frequently cover waste with soil from sweeping or ash from cooking fires. These should be somewhat shallow (up to 1 m deep). Families with vast lots and areas where organic food waste makes up the majority of household waste are the ideal candidates for this strategy.

Advantages: Families are responsible for managing their own waste; no external waste workers are required; and community mobilisation can be incorporated into hygiene promotion programme.
Constraints: Involves considerable community mobilisation for construction, operation and maintenance of pits; and considerable space is needed.

c. Communal bins

Communal bins or containers are designed to collect waste where it will not be dispersed by wind or animals, and where it can easily be removed for transportation and disposal. Plastic containers are generally inappropriate since these may be blown over by the wind, can easily be removed and may be desirable for alternative uses. A popular solution is to provide oil drums cut in half . The bases of these should be perforated to allow liquid to pass out and to prevent their use for other purposes. A lid and handles can be provided if necessary.

In general, a single 100-litre bin should be provided for every fifty people in domestic areas, every one hundred people at feeding centres and every ten market stalls. In general, bins should be emptied daily.

Advantages: Bins are potentially a highly hygienic and sanitary management method; and final disposal of waste well away from dwelling areas.
Constraints: Significant collection, transportation and human resources are required; sys- tem takes time to implement; and efficient management is essential.

d. Family bins

Family bins are rarely utilised in emergency situations since they necessitate a complex collecting and transportation system and a significant number of containers or bins. Community members can be urged to create their own trash baskets or pots and to assume responsibility for emptying them at shared pits or depots in the later phases of an emergency, though.

Advantages: Families are responsible for maintaining collection containers; and potentially a highly sanitary management method.
Constraints: In general, the number of bins required is too large; significant collection, transportation and human resources are required; takes time to implement; and efficient management essential.

e. Communal disposal without bins

Solid waste management systems without dumpsters can be established for some public institutions, such as marketplaces or distribution depots, allowing customers to dump rubbish directly into the ground. Cleaning staff must be hired to periodically sweep around market stalls, collect rubbish, and transfer it to a designated off-site disposal facility for this to be effective. Vegetable trash can probably be disposed of in this way, but abattoir waste needs to be buried separately in liquid-tight containers.

Advantages: System rapid to implement; there is minimal reliance on actions of users; and it may be in line with traditional/usual practice.
Constraints: Requires efficient and effective management; and full-time waste workers must be employed.

B. Off-site disposal options

The technology choices outlined below are general options for the final disposal of waste off- site.

a. Landfilling

Once solid garbage has been removed from the site, it is often dumped there. Here, the trash is dumped into a sizable ground excavation (pit or trench), which is daily backfilled with dug soil. At the conclusion of each day, the deposited trash should ideally be covered by 0.5m of soil to prevent animals from digging it up and flies from reproducing. The choice of dump locations should be made after collaboration with the local government and the affected community. Sites should ideally be walled and located at least a km away from the nearest habitations.

Advantages: A sanitary disposal method if managed effectively.
Constraints: A reasonably large area is required.

b. Incineration

Combustible waste is sometimes disposed of by burning or incineration, but this should typically only occur off-site or well away from residences. Burning trash inside of a building poses a risk of fire or smoke, especially if numerous flames are ignited at once. When there is not enough room for burial or disposal, burning may be utilised to minimise the amount of waste. In the same way that waste is dumped, it should be burned in pits and then covered with soil. Here too, the same restrictions that apply to landfill site siting should be used.

Advantages: Burning reduces volume of combustible waste considerably; and it is appropriate in off-site pits to reduce scavenging.
Constraints: There can be smoke or fire hazards.

c. Composting

Many circumstances can benefit from the straightforward composting of vegetables and other organic waste. To add humus and fibre to the soil when people have their own gardens or vegetable plots, organic waste can be buried. This both helps the growth process and renders the waste completely harmless. Everywhere possible, especially in the later stages of an emergency project, this should be promoted. Properly managed composting requires careful monitoring of decomposing waste to control moisture and chemical levels and promote microbial activity. This is designed to produce compost which is safe to handle and which acts as a good fertiliser. Such systems require considerable knowledge and experience and are best managed centrally. In general, they are unlikely to be appropriate in emergencies.

Advantages: Composting is environmentally friendly; and beneficial for crops.
Constraints: Intensive management and experienced personnel are required for large-scale operations.

d. Recycling

The recycling of some waste materials may occasionally be viable, although complex recycling systems are unlikely to be acceptable. Since plastic bags, containers, tins, and glass are likely to be in short supply in many circumstances, recycling is frequently done automatically for these items. There is a strong recycling culture in the majority of developing country environments, which results in lower trash volumes than in many more industrialised countries.

Advantages: Recycling is environmentally friendly.
Constraints: There is limited potential in most emergency situations; and it is expensive to set up.

Siting of disposal sites

All disposal sites should be located after consulting with important parties, such as regional government officials, local and displaced population representatives, and other organisations active in the area. The consequences of scent, smoking, water pollution, insect vectors, and animals should be minimised by appropriate location. Since there is no need for transportation and minimal staffing requirements, on-site disposal is typically favoured. This is appropriate when there is lots of room, little waste volume, and mostly recyclable or organic waste. f the volumes of waste generated are large, or space within the site is severely limited, it may be necessary to dispose of waste off-site. Where off-site disposal is to be used the following measures should be taken in selecting and developing an appropriate site:

- Locate sites at least 500m (ideally 1 kilometre) downwind of nearest settlement.
- Locate sites downhill from groundwater sources.
- Locate sites at least 50m from surface water sources.
- Provide a drainage ditch downhill of landfill site on sloping land.
- Fence and secure access to site.

It should be carefully assessed to find out who owns the prospective site and to make sure that any places that appear to be unoccupied are not actually someone's farm or backyard.

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Chapter 3

The Impact of Covid-19 on E-Learning

Numerous businesses worldwide have been forced to completely utilise a number of developing internet communication platform technologies as a result of the Covid-19 pandemic. In order to continue a continuous instructional process, educational institutions are among the organisations that have urged students and educators to communicate using a range of online communication platforms. When adopting these developing technology, the Covid-19 epidemic has posed problems for the global education system. Numerous recent research have emphasised the difficulties.

Nowadays, e-learning is the standard in higher education. Even though the norm is observed, it has presented a number of difficulties for educators and students, particularly those who study English. Lack of technological expertise (Erlangga, 2022), student engagement (Igai & Yunus, 2022), internet connectivity (Razkane et al., 2021), and conducting online evaluations (Hijazi & AlNatour, 2021) are some of the difficulties encountered. To further emphasise the point, Bernama (2022) noted that little to no experience with online teaching results in difficulties, frustrations, and interminable flaws, mental exhaustion for both English teachers and students, a lack of motivation, challenges with communication when teaching grammar, and a lack of technical support.

The Impact of Covid-19 on the Education System

Due to lockdown and social segregation measures implemented in response to the Covid-19 outbreak, the majority of countries have had to close schools, training centres, and higher education institutions (Preeti, 2020). Tadesse & Muluve (2020) claim that "Education in Emergency" has been adopted by the instructional machine and educators through special online platforms. But the challenges that teachers and newcomers face, such as online learning, distant training, and persisting training, have evolved into a remedy for this massive global epidemic (Adams et al., 2018). For newcomers and educators, transferring from traditional face-to-face training to online training is exceptional given the lack of options. They are being forced to transform into a machine.

The Impact on the Education Environment

Due to the Covid-19 outbreak, schools have been closed across the globe, which has had an unexpected ripple effect on students, parents, and educators. In these trying times, educational institutions seek to preserve a high standard of education for everyone while governments, frontline staff, and health authorities battle to prevent the spread (Krishnan et al., 2020). They continued by saying that many pupils had gone through psychological and emotional turmoil and were unable to communicate effectively at home or in a communal setting. Many families and concerned authorities chose various approaches to provide their children with a better experience during this difficult period.

However, using technology for education became the new standard, which prompted various changes in the way that education was delivered. There have been several systemic changes brought about by the closing of educational institutions, most notably in teaching and learning. According to Preeti (2020), it had an impact on teaching and evaluation methods as well as learning and education frameworks. She also mentioned how learners' learning has been impacted by institution closures. To sustain continuity in institutions and universities, one urgent action is required. One such step was the adoption of digital learning tools and platforms by numerous educational institutions. Colleges and colleges started embracing open-source as a digital learning solution to run online classrooms while continuing to provide instruction through learning management systems.

The Impact on Educators and Learners

Movement restrictions not only impacted the learning of learners, but also affected the measurement of their learning. The lockdown brought changes to the lesson delivery mechanism as well as assessment and evaluation. Numerous examinations and evaluations have been canceled or postponed due to educational institution closures (Mohammad Izzamil et al., 2021).

Movement constraints had an effect on both how students learned and how their learning was measured. The method of delivering lessons, as well as assessment and evaluation, changed as a result of the lockdown. Due to educational institution closures, several tests and assessments have been postponed or cancelled (Mohammad Izzamil et al., 2021). By adopting online assessment tools, many colleges and institutions have made the transition from traditional classrooms to online classes and from offline to online examinations (Chung et al., 2020). Online assessment tools can, however, have downsides. Online evaluation technologies have a number of measurement mistakes compared to traditional measurement (Bibi Noraini & Jihan, 2020). However, evaluation and assessment are crucial since they are a crucial component of education that gauges the success of learning. Additionally, it provides accurate information for workers to compare prospects when hiring graduates. Burgess and Sievertsen (2020) demonstrated how employers evaluate candidates using educational credentials like grade point averages and degree categories. Thus, the lockdown had an impact on how recent grads were hired.

As candidate outcome disturbances rise, the effectiveness of new graduates' matching (the matching of new graduates with the target market of job specifications) is deteriorating, leading to higher employment separation rates and slower wage development. Preeti (2020) says that this is costly for both the individual and the community. Additionally, it is challenging to monitor how students complete online courses and make sure they are not plagiarising on exams (Basilaia & Kvavadze, 2020). To further emphasise the issue, online performance testing, practical tests, and laboratory exams are not practical. Tests and evaluations may be challenging for students without internet access (Sahu, 2020). Osman (2020) asserts that measuring and assessing learners' success in online learning is difficult for both educators and learners, particularly when teaching practical skills and technological competence. Online assessments are used to evaluate students, and this causes confusion, trial-and-error, and misunderstanding for parents, educators, and students. Depending on the ease and expertise of the instructor and the compatibility of the learners, doing evaluations online can take many different forms. Tadesse and Muluve (2020) claim that because of the big student population, many schools and institutions have yet to create efficient strategies to avoid plagiarism.

E-Learning

Technology like artificial intelligence has changed traditional education into current learning, claim Shahzad et al. (2021). Therefore, the term "e-learning" refers to a wider range of technology-based learning methods, including websites, learning portals, video conferencing, YouTube, mobile applications, and a myriad of other free blended learning websites. Any information system's effectiveness, though, depends on its users (Almaiah et al., 2020). E-learning is currently improving academic staff, professional and industrial people's abilities, as well as students' knowledge via the internet (Adams et al., 2018). As a result, in the context of an E-learning system, student acceptance of E-learning is seen as a key success component. Through two (2) sub-sections, titled "E-learning" and "Learning Resources," this part will be broadened.

E-Learning in Higher Education

Though virtual education is a common topic of discussion, users' use and acceptance of E-learning is a challenge for every educational institution, established or developing, in any country. According to Almaiah et al. (2020), developed nations are likely to have less anxiety about their learners' desire to embrace and utilise the E-learning system since necessary progressive steps have already been achieved as stated by Almaiah et al. (2020). The problems associated with implementing E-learning systems in underdeveloped nations remain a reality owing to the developing countries' digital divide (Almaiah et al., 2020).

The Benefits and Challenges of E-Learning to Educators and Learners

E-learning enables educators to achieve a greater degree of coverage to properly transmit their message to their target listeners (Ab Wahab & Mohamad, 2022). This guarantees that all learners get the same kind of instruction while using this form of instruction. However, E-learning has not yet gained equal status in different regions, mainly due to challenges in its practical usage. Despite the popularity of online education, many population segments deliberately avoid it, mainly because of a misleading image (Doucet et al., 2020). According to Krishnan et al. (2020), despite the growing popularity of online courses, most students choose conventional classroom instruction.

Physical classroom instruction is more natural than online learning, and students get the ability to debate, reflect, and discuss with their professors and classmates. As a result of their findings, they came to the conclusion that in-person education is essential for practical learning because e-learning may at any time run into unforeseen technology issues. Additionally, a strong internet connection with a high bandwidth connection is required for E-learning at all times. Due to a significant lack of connections and energy, it is not always successful. Due to a lack of the necessary infrastructure, students cannot attend virtual classrooms in rural areas, where e-learning is less developed than in urban areas (Mohammad Izzamil et al., 2021). However, E-learning is more pronounced these days due to the pandemic and many countries are trying out to adopt it to ensure continuity of learning.

When universities and schools were shut down due to the pandemic, e-learning systems let schools and colleges continue to provide instruction to students (Subedi et al., 2020). It's important to evaluate and support staff and student readiness as they adjust to new developments. Learners who have a fixed perspective find it challenging to adapt and make adjustments, whereas those who have a growth mindset are more open to changing their learning environment. Due of the wide range of subjects and the demands they place on learners, there is no one-size-fits-all model for online learning. Different approaches to online education are required for many disciplines and age groups (Doucet et al., 2020). Additionally, online education allows students with physical disabilities to study more independently in a virtual environment that necessitates less movement (Basilaia & Kvavadze, 2020).

Challenges in E-Learning

1) Lack of ICT Infrastructure and Support

A research discovered that system features, internet experience, and computer self-efficacy are the primary impediments to effective E-learning system adoption in Pakistan (Kanwal and Rehman, 2017). In similar research done in Kenya, three significant barriers to E-learning were identified: insufficient ICT infrastructure, a lack of technical skills, and budgetary restrictions (Tadesse & Muluye, 2020). According to research conducted by Rahim & Chandran (2021), the key challenges impeding the effective implementation of current E-learning programs include poor interface design, insufficient technical assistance, and a lack of IT skills.

2) Lack of Budget and Funding in some Higher Institutions
While economically disadvantaged students in many developing nations cannot afford online learning gadgets, online education exposes the learner to increasing screen time (Hove & Dube, 2021). As a result, offline activities and self-exploratory learning have become critical for pupils. They added that lack of parental direction, particularly for young learners, is another issue, primarily when both parents work. There are practical concerns with physical workplaces favorable to various learning modes as they may have difficulties integrating online learning tools (Bibi Noraini & Jihan, 2020). Institutions will need to budget for both per-learner and overall expenditures associated with online learning versus more conventional modes of instruction. Cost may become more bearable if courses can be leveraged over a larger learner (Ab Wahab & Mohamad, 2022).

Challenges among Educators

Due to a dearth of computers, internet access, mobile network access, and ICT-trained teachers in developing nations, educators and students may face a number of difficulties, including familiarity with online tools, the ability to maximise the benefits of the medium, teachers' availability during times of need, and the ability to provide feedback and prompt responses from students (Morgan, 2022).

As teachers, they encounter a number of difficulties with e-learning, such as limited experience with platform setup (for example, Zoom Meetings, Google Hangout Meet, Telegram, and Google Classroom), worries about student participation, a lack of assessment techniques for determining course learning outcomes, and a lack of experience creating e-content (Zhu et al., 2018; Bozkurt et al., 2020).

This is also previously stated by Ab Wahab & Mohamad (2022) who discussed the absence of engagement from the teacher’s standpoint. They claimed that when educators are unable to see their learners’ faces, they cannot detect symptoms of attentiveness or inattention and hence are unable to intervene swiftly.

Challenges among Learners

Many previous researches have examined a variety of difficulties encountered by both learners and educators. Learners encountered numerous obstacles, including administrative concerns, social interaction, academic and technical abilities, motivation, time constraints, restricted access to resources, and technological difficulties (Barrot et al., 2021).

The lack of online student discipline, faculty reluctance, and the high costs associated with online production and distribution were among the challenges that students faced when pursuing education online (Shahzad et al., 2021). These issues are similar to those found in earlier studies, such as unclear roles and responsibilities, a delay in obtaining feedback from teachers, a lack of technical support, a reliance on technology to an excessive degree, and low student performance and satisfaction (Chung et al., 2020). Additionally, difficulties might occur due to a lack of desire and a feeling of alienation and isolation, as learners see themselves as an online component (Sahu, 2020). Learners perceived it to be less appealing than other modes of instruction, unfriendly to learners, and insufficiently participatory to foster a sense of connection with educators and peers through social media platforms such as Facebook, WhatsApp, WeChat, and email (Haleem et al., 2020). Meanwhile, various issues have been identified, including learners' attitudes, personnel resources, time limits, lecturer self-efficacy, and technological difficulties (Zhu et al., 2018).

According to Abdul Rahman et al. (2021), who performed an exploratory sequential sentimental analysis during MCO in Malaysia, students in rural locations had difficulty enrolling in their online classes and occasionally were unable to do so due to a lack of internet connectivity. Additionally, they noted the lack of student engagement, the lack of knowledge of self-directed learning, and the fact that some students were unsure on how to handle their assignments and projects. Another study that looked at how Covid-19 affected university students' learning during the first pandemic peak in Malaysia found that personal health, work and information overload from instructors, and inability to adapt to the new online learning environment were all factors.

The learner's anxiety towards ODL exercises must be assessed. Before planning ODL activities, teachers must assess students' computer and Internet access, which may raise concerns (Bozkurt et al., 2020), particularly in rural and sub-rural locations. Will students be motivated to finish their studies when faced with interruptions and issues at home? Will students be able to accomplish the tasks described in ODL activities independently, without physical interaction with peers or lecturers? The aforementioned elements appear to have a substantial impact on students' academic progress and readiness for online learning (Shahzad et al., 2021).

Implication and Conclusion

Globally, the Covid-19 epidemic has had an impact on the education sector, and many institutions now confront difficulties as a result of this unexpected outbreak that established a new standard of almost complete integration of technology into daily life, notably in educational institutions. On the plus side, this epidemic has given everyone the chance to investigate and push the limits of educational institutions all over the world to improve their teaching methods and infrastructure. In this study, the researchers focused on how Covid-19 affected the educational system from the perspectives of the learning environment and relationships between teachers and students. In addition, there are other obstacles educators and students encounter when teaching and studying online, such as a lack of facilities, a lack of resources, and other factors.

The abrupt virus outbreak had a profound effect on the educational system as well as the environment as a whole. To summarise the paper's conclusions, it was discovered that numerous earlier research had emphasised the effect of COVID-19 on the educational system, which had led to issues that led to difficulties with online learning. Movement constraints had an effect on both how students learned and how their learning was measured. Due to the restrictions, traditional learning has to make way for online learning as the new standard for instructors and students. The use of technology and digital solutions by more families to keep kids entertained, interested in learning, and connected to the outside world was one of the topics highlighted . E-learning does not seem to always be fond of the winning side. Even though E-learning enables educators to achieve their objectives in teaching and assist schools and colleges in facilitating students' learning, it has always been reliant on a stable internet connection with a high-bandwidth connection, and the rural lack of infrastructure required for online courses resulted in learners being unable to attend virtual classrooms. Online laboratory examinations, practical exams, and performance testing are not feasible as the focus goes down to the assessment. Learners who do not have access to the internet may have difficulties with tests and evaluations. The challenges in E-learning are a lack of ICT infrastructure and support among educators and learners and insufficient funding among educational institutions. The challenges between the educators and learners are interconnected to each other such as a limited number of computers, internet access, mobile network access, and a shortage of ICT-trained teachers.

It is crucial that the conclusions of this study can inform key authorities, including administrators of educational institutions, employees of the Ministry of Higher Education, and decision-makers. To ensure the success of online teaching and learning, they must create a solid plan and implement strategies to deal with the difficulties. In order to encourage students to embrace online learning, universities and educators must develop programmes that inform them of the difficulties they will face and how to overcome them. For lecturers to become familiar with the E-learning systems and improve their understanding of developing and delivering digital content, university administrators should include in their plans to upgrade their existing online platforms to better ones. They should also give training opportunities for this purpose.

These measures are crucial in preparing the stakeholders of the education field for E-learning and to be prepared for any plans of education in an emergency in the future.

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Chapter 4

Particulate Matter and Human Health

What is PM, and how does it get into the air?

The term *aerosol* commonly refers to the particulate/air mixture, as opposed to the particulate matter alone. Sources of particulate matter can be natural or anthropogenic. They have impacts on climate and precipitation that adversely affect human health, in ways additional to direct inhalation.

Types of atmospheric particles include suspended particulate matter; thoracic and respirable particles; inhalable coarse particles, designated PM_{10}, which are coarse particles with a diameter of 10 micrometers (μm) or less; fine particles, designated $\mathbf{PM_{2.5}}$, with a diameter of 2.5 μm or less; ultrafine particles, with a diameter of 100 nm or less; and soot.

The IARC and WHO designate airborne particulates as a Group 1 carcinogen. Particulates are the most harmful form (other than ultra-fines) of air pollution due to their ability to penetrate deep into the lungs and brain from blood streams, causing health problems such as heart disease, lung disease, and premature death. In 2013, a study involving 312,944 people in nine European countries revealed that there was no safe level of particulates and that for every increase of 10 $\mu g/m^3$ in PM_{10}, the lung cancer rate rose 22% (95% CI [1.03–1.45]). The smaller $PM_{2.5}$, which can penetrate deeper into the lungs, were associated with an 18% increase in lung cancer per 5 $\mu g/m^3$; however, this study did not show statistical significance for this association (95% CI [0.96–1.46]).

Worldwide, exposure to $PM_{2.5}$ contributed to 4.1 million deaths from heart disease, stroke, lung cancer, chronic lung disease, and respiratory infections in 2016. Overall, ambient particulate matter ranks as the sixth leading risk factor for premature death globally.

PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.

Particle pollution includes:

- **PM_{10}** : inhalable particles, with diameters that are generally 10 micrometers and smaller; and
- **$PM_{2.5}$** : fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.
  - How small is 2.5 micrometers? Think about a single hair from your head. The average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle.

Sources of PM

These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

Atmospheric sources

Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation and sea spray. Human activities also generate significant amounts of particulates. For example,

- Burning of fossil fuels (e.g., aircraft), joss paper, waste, firecrackersand biomass including wood and stubble.
- Construction (activities of building refurbishment or demolition, roadworks, diesel exhausts of the heavy equipments used, emission from the production of building materials, etc).
- Dusty materials that are not properly covered (e.g., in construction sites, landfills and ceramics production facilities).
- Metalworking (e.g., welding).
- Woodworking.
- Glass reprocessing.
- Agricultural activities (e.g., ploughing and soil tilling).
- Power plants.
- Waste incineration.
- Road dust from tyre and road wear and road dust from unpaved road.[38]
- Wet cooling towers in cooling systems.
- Various industrial processes such as mining, smelting and oil refining.
- Disasters (both natural or caused by humans, e.g, wildfires, earthquakes, wars, and September 11 attacks, etc).
- Microplastics (gaining attention as a type of airborne PM).

Domestic combustion and wood smoke

In the United Kingdom domestic combustion is the largest single source of PM 2.5 and PM10 annually, with domestic wood burning in both closed stoves and open fires responsible for 38% of PM2.5 in 2019. To tackle the problem some new laws were introduced since 2021.

In some towns and cities wood smoke may be responsible for 60% of fine particle air pollution in the winter. There are a few ways to reduce wood smoke, e.g, buying the right wood heater and maintaining it well choosing the right firewood and burning it the right way. There are also regulations in some countries where people can report smoke pollution to the local council. The composition and toxicity of aerosols, including particles, depends on their source and atmospheric chemistry and varies widely. Wind-blown mineral dust tends to be made of mineral oxides and other material blown from the Earth's crust; this particulate is light-absorbing. Sea salt is considered the second-largest contributor in the global aerosol budget, and consists mainly of sodium chloride originated from sea spray; other constituents of atmospheric sea salt reflect the composition of sea water, and thus include magnesium, sulfate, calcium, potassium, and others. In addition, sea spray aerosols may contain organic compounds like fatty acids and sugars, which influence their chemistry.

Some secondary particles derive from the oxidation of primary gases such as sulfur and nitrogen oxides into sulfuric acid (liquid) and nitric acid (gaseous) or from biogenic emissions. The precursors for these aerosols—i.e. the gases from which they originate—may have an anthropogenic origin (from biomass and fossil fuel combustion) as well as a natural biogenic origin. In the presence of ammonia, secondary aerosols often take the form of ammonium salts; i.e. ammonium sulfate and ammonium nitrate (both can be dry or in aqueous solution); in the absence of ammonia, secondary compounds take an acidic form as sulfuric acid (liquid aerosol droplets) and nitric acid (atmospheric gas), all of which probably contribute to the health effects of particulates.

Secondary sulfate and nitrate aerosols are strong light-scatterers. This is mainly because the presence of sulfate and nitrate causes the aerosols to increase to a size that scatters light effectively. Organic matter (OM) found in aerosols can be either primary or secondary, the latter part deriving from the oxidation of volatile organic compounds (VOCs); organic material in the atmosphere may either be biogenic or anthropogenic. Organic matter influences the atmospheric radiation field by both scattering and absorption. Some aerosols are predicted to include strongly light-absorbing material and are thought to yield large positive radiative forcing. Some secondary organic aerosols (SOAs) resulting from combustion products of internal combustion engines, have been identified as a danger to health.[65] Particulate toxicity has been found to vary by region and source contribution which affects the particles chemical composition.

The chemical composition of the aerosol directly affects how it interacts with solar radiation. The chemical constituents within the aerosol change the overall refractive index. The refractive index will determine how much light is scattered and absorbed.
The composition of particulate matter that generally causes visual effects, haze, consists of sulfur dioxide, nitrogen oxides, carbon monoxide, mineral dust, and organic matter. The particles are hygroscopic due to the presence of sulfur, and SO_2 is converted to sulfate when high humidity and low temperatures are present. This causes reduced visibility and yellow color

Size distribution

Human-produced aerosols such as particle pollution tend to have a smaller radius than aerosol particles of natural origin (such as windblown dust). The false-color maps in the map of distribution of aerosol particles on the right show where there are natural aerosols, human pollution, or a mixture of both, monthly. Among the most obvious patterns that the size distribution time series shows is that in the planet's most southerly latitudes, nearly all the aerosols are large, but in the high northern latitudes, smaller aerosols are very abundant. Most of the Southern Hemisphere is covered by the ocean, where the largest source of aerosols is natural sea salt from dried sea spray. Because the land is concentrated in the Northern Hemisphere, the amount of small aerosols from fires and human activities is greater there than in the Southern Hemisphere. Overland, patches of large-radius aerosols appear over deserts and arid regions, most prominently, the Sahara Desert in North Africa and the Arabian Peninsula, where dust storms are common. Places where human-triggered or natural fire activity is common (land-clearing fires in the Amazon from August–October, for example, or lightning-triggered fires in the forests of northern Canada in Northern Hemisphere summer) are dominated by smaller aerosols. Human-produced (fossil fuel) pollution is largely responsible for the areas of small aerosols over developed areas such as the eastern United States and Europe, especially in their summer.

Satellite measurements of aerosols, called aerosol optical thickness, are based on the fact that the particles change the way the atmosphere reflects and absorbs visible and infrared light. As shown in this page, an optical thickness of less than 0.1 (palest yellow) indicates a crystal clear sky with maximum visibility, whereas a value of 1 (reddish-brown) indicates very hazy conditions. In general, the smaller and lighter a particle is, the longer it will stay in the air. Larger particles (greater than 10 micrometers in diameter) tend to settle to the ground by gravity in a matter of hours whereas the smallest particles (less than 1 micrometer) can stay in the atmosphere for weeks and are mostly removed by precipitation. There are also evidence that it is not uncommon for aerosols to "travel across the ocean". For example, in September 2017 wildfires burning across the western United States and Canada, and the smoke was found to have arrived over the United Kingdom and northern France in three days, as shown by satellite images. Diesel particulate matter is highest near the source of emission. Any information regarding DPM and the atmosphere, flora, height, and distance from major sources is useful to determine health effects.

Controlling technologies and measures

Particulate matter emissions are highly regulated in most industrialized countries. Due to environmental concerns, most industries are required to operate some kind of dust collection system. These systems include inertial collectors (cyclonic separators), fabric filter collectors (baghouses), electrostatic filters used in facemasks, wet scrubbers, and electrostatic precipitators.

Cyclonic separators are useful for removing large, coarse particles and are often employed as a first step or "pre-cleaner" to other more efficient collectors. Well-designed cyclonic separators can be very efficient in removing even fine particulates, and may be operated continuously without requiring frequent shutdowns for maintenance.

Fabric filters or baghouses are the most commonly employed in general industry. They work by forcing dust-laden air through a bag-shaped fabric filter leaving the particulate to collect on the outer surface of the bag and allowing the now clean air to pass through to either be exhausted into the atmosphere or in some cases recirculated into the facility. Common fabrics include polyester and fiberglass and common fabric coatings include PTFE (commonly known as Teflon). The excess dust buildup is then cleaned from the bags and removed from the collector.

Measurement

Particulates have been measured in increasingly sophisticated ways since air pollution was first systematically studied in the early 20th century. The earliest methods included relatively crude Ringelmann charts, which were grey-shaded cards against which emissions from smokestacks could be visually compared, and deposit gauges, which collected the soot deposited in a particular location so it could be weighed. Automated, modern methods of measuring particulates include optical photodetectors, tapered element oscillating microbalances, and Aethalometers. Besides measuring the total mass of particles per unit volume of air (particle mass concentration), sometimes it is more useful to measure the total number of particles per unit volume of air (particle number concentration). This can be done by using a condensation particle counter (CPC).

To measure the atomic composition of particulate samples, techniques such as X-ray spectrometry can be used.

Climate effects

Atmospheric aerosols affect the climate of the earth by changing the amount of incoming solar radiation and outgoing terrestrial longwave radiation retained in the earth's system. This occurs through several distinct mechanisms which are split into direct, indirect and semi-direct aerosol effects. The aerosol climate effects are the biggest source of uncertainty in future climate predictions. The Intergovernmental Panel on Climate Change (IPCC), Third Assessment Report, says:

While the radiative forcing due to greenhouse gases may be determined to a reasonably high degree of accuracy... the uncertainties relating to aerosol radiative forcings remain large, and rely to a large extent on the estimates from global modeling studies that are difficult to verify at the present time.

Aerosol radiative

Global aerosol optical thickness. The aerosol scale (yellow to dark reddish-brown) indicates the relative amount of particles that absorb sunlight.These maps show average monthly aerosol amounts around the world based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite.

Direct

The direct aerosol effect consists of any direct interaction of radiation with atmospheric aerosols, such as absorption or scattering. It affects both short and longwave radiation to produce a net negative radiative forcing. The magnitude of the resultant radiative forcing due to the direct effect of an aerosol is dependent on the albedo of the underlying surface, as this affects the net amount of radiation absorbed or scattered to space. For example, if a highly scattering aerosol is above a surface of low albedo it has a greater radiative forcing than if it was above a surface of high albedo. The converse is true of absorbing aerosol, with the greatest radiative forcing arising from a highly absorbing aerosol over a surface of high albedo. The direct aerosol effect is a first-order effect and is therefore classified as a radiative forcing by the IPCC. The interaction of an aerosol with radiation is quantified by the single-scattering albedo (SSA), the ratio of scattering alone to scattering plus absorption (*extinction*) of radiation by a particle. The SSA tends to unity if scattering dominates, with relatively little absorption, and decreases as absorption increases, becoming zero for infinite absorption. For example, the sea-salt aerosol has an SSA of 1, as a sea-salt particle only scatters, whereas soot has an SSA of 0.23, showing that it is a major atmospheric aerosol absorber.

Indirect

The Indirect aerosol effect consists of any change to the earth's radiative budget due to the modification of clouds by atmospheric aerosols and consists of several distinct effects. Cloud droplets form onto pre-existing aerosol particles, known as cloud condensation nuclei (CCN). Droplets condensing around human-produced aerosols such as found in particulate pollution tend to be smaller and more numerous than those forming around aerosol particles of natural origin (such as windblown dust).

Health effects

Size

Particle size is the main determinant of where in the respiratory tract it will come to rest when inhaled. Larger particles are generally filtered in the nose and throat via cilia and mucus, but particulate matter smaller than about 10 micrometers can settle in the bronchi and lungs and cause health problems. The 10-micrometer size does not represent a strict boundary between respirable and non-respirable particles but has been agreed upon for monitoring of airborne PM by most regulatory agencies. Because of their small size, particles on the order of 10 micrometers or less (coarse particulate matter, PM_{10}) can penetrate the deepest part of the lungs such as the bronchioles or alveoli. When asthmatics are exposed to these conditions it can trigger bronchoconstriction.

Similarly, fine particulate matter ($PM_{2.5}$) tends to penetrate into the gas exchange regions of the lung (alveoli), and very small particles (ultrafine particulate matter $PM_{0.1}$) may pass through the lungs to affect other organs. Penetration of particles is not wholly dependent on their size; shape and chemical composition also play a part. To avoid this complication, simple nomenclature is used to indicate the different degrees of relative penetration of a PM particle into the cardiovascular system. *Inhalable particles* penetrate no further than the bronchi as they are filtered out by the cilia. *Thoracic particles* can penetrate right into terminal bronchioles whereas $PM_{0.1}$, which can penetrate to alveoli, the gas exchange area, and hence the circulatory system, are termed *respirable particles*.

In analogy, the inhalable dust fraction is the fraction of dust entering the nose and mouth which may be deposited anywhere in the respiratory tract. The thoracic fraction is the fraction that enters the thorax and is deposited within the lung's airways. The respirable fraction is what is deposited in the gas exchange regions (alveoli). The smallest particles, nanoparticles, which are less than 180 nanometers in size, may be even more damaging to the cardiovascular system.

Particulate mass is not a proper measure of the health hazard. A particle of 10 μm diameter has approximately the same mass as 1 million particles of 100 nm diameter, but is much less hazardous, as it is unlikely to enter the alveoli. Legislative limits for engine emissions based on mass are therefore not protective. Proposals for new regulations exist in some countries, with suggestions to limit the particle *surface* *area* or the *particle count* (numerical quantity) / particle number concentration (PNC) instead.

Solubility

The site and extent of absorption of inhaled gases and vapors are determined by their solubility in water. Absorption is also dependent upon air flow rates and the partial pressure of the gases in the inspired air. The fate of a specific contaminant is dependent upon the form in which it exists (aerosol or particulate). Inhalation also depends upon the breathing rate of the subject.

Shape

Another complexity not entirely documented is how the shape of PM can affect health, except for the needle-like shape of asbestos fibres which can lodge in the lungs. Geometrically angular shapes have more surface area than rounder shapes, which in turn affects the binding capacity of the particle to other, possibly more dangerous substances. The table below lists the colours and shapes of some common atmospheric particulates:

Regulation

Most governments have created regulations both for the emissions allowed from certain types of pollution sources (motor vehicles, industrial emissions etc.) and for the ambient concentration of particulates. The IARC and WHO designate particulates a Group 1 carcinogen. Particulates are the deadliest form of air pollution due to their ability to penetrate deep into the lungs and blood streams unfiltered, causing respiratory diseases, heart attacks, and premature death. In 2013, the ESCAPE study involving 312,944 people in nine European countries revealed that there was no safe level of particulates and that for every increase of 10 $\mu g/m^3$ in PM_{10}, the lung cancer rate rose 22%. For $PM_{2.5}$ there was a 36% increase in lung cancer per 10 $\mu g/m^3$. In a 2014 meta-analysis of 18 studies globally including the ESCAPE data, for every increase of 10 $\mu g/m^3$ in $PM_{2.5}$, the lung cancer rate rose 9%.

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