POPs Persistent organic pollutants

Chemicals have become normal to modern man living, but the harm that they do is clearer and more evident than ever. Population alone equates more use of consumer products, to include plastic in so many formats, and chemicals in our food, cosmetics, drink, agriculture induced growing, and so many others as our smart phones and the radiation and chemical content near our bodies at all times, Thus learn about POP’s -the accumulation of all these laboratory experiments on man and our environment. (Wikapedia content edited)

Persistent organic pollutants (**POPs**), sometimes known as "**forever chemicals**" are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes.[1] Because of their persistence, POPs bioaccumulate with potential adverse impacts on human health and the environment. The effect of POPs on human and environmental health was discussed, with intention to eliminate or severely restrict their production, by the international community at the Stockholm Convention on Persistent Organic Pollutants in 2001.
Many POPs are currently or were in the past used as pesticides, solvents, pharmaceuticals, and industrial chemicals.[1] Although some POPs arise naturally, for example volcanoes and various biosynthetic pathways, most are man-made[2] via total synthesis.

POPs typically are halogenated organic compounds (see lists below) and as such exhibit high lipid solubility. For this reason, they bioaccumulate in fatty tissues. Halogenated compounds also exhibit great stability reflecting the nonreactivity of C-Cl bonds toward hydrolysis and photolytic degradation. The stability and lipophilicity of organic compounds often correlates with their halogen content, thus polyhalogenated organic compounds are of particular concern. They exert their negative effects on the environment through two processes, long range transport, which allows them to travel far from their source, and bioaccumulation, which reconcentrates these chemical compounds to potentially dangerous levels.[3] Compounds that make up POPs are also classed as PBTs (**P**ersistent, **B**ioaccumulative and **T**oxic) or TOMPs (**T**oxic **O**rganic **M**icro **P**ollutants).

Long-range transport[edit]

POPs enter the gas phase under certain environmental temperatures and volatize from soils, vegetation, and bodies of water into the atmosphere, resisting breakdown reactions in the air, to travel long distances before being re-deposited.[4] This results in accumulation of POPs in areas far from where they were used or emitted, specifically environments where POPs have never been introduced such as Antarctica, and the Arctic circle.[5] POPs can be present as vapors in the atmosphere or bound to the surface of solid particles. POPs have low solubility in water but are easily captured by solid particles, and are soluble in organic fluids (oils, fats, and liquid fuels). POPs are not easily degraded in the environment due to their stability and low decomposition rates. Due to this capacity for long-range transport, POP environmental contamination is extensive, even in areas where POPs have never been used, and will remain in these environments years after restrictions implemented due to their resistance to degradation.

Bioaccumulation of POPs is typically associated with the compounds high lipid solubility and ability to accumulate in the fatty tissues of living organisms for long periods of time.[6][8] Persistent chemicals tend to have higher concentrations and are eliminated more slowly.

Dietary accumulation or bioaccumulation is another hallmark characteristic of POPs, as POPs move up the food chain, they increase in concentration as they are processed and metabolized in certain tissues of organisms. The natural capacity for animals gastrointestinal tract concentrate ingested chemicals, along with poorly metabolized and hydrophobic nature of POPs makes such compounds highly susceptible to bioaccumulation.[9] Thus POPs not only persist in the environment, but also as they are taken in by animals they bioaccumulate, increasing their concentration and **toxicity** in the environment.[4][10]

Health effects

POP EXPOSURE MAY CAUSE DEVELOPMENTAL DEFECTS, CHRONIC ILLNESSES, AND DEATH. SOME ARE CARCINOGENS PER IARC, POSSIBLY INCLUDING BREAST CANCER.[1] MANY POPS ARE CAPABLE OF ENDOCRINE DISRUPTION WITHIN THE REPRODUCTIVE SYSTEM, THE CENTRAL NERVOUS SYSTEM, OR THE IMMUNE SYSTEM. People and animals are exposed to POPs mostly through their diet, occupationally, or while growing in the womb.[1] For humans not exposed to POPs through accidental or occupational means, over **90%** of exposure comes from animal product foods due to bioaccumulation in fat tissues and bioaccumulate through the food chain. In general, POP serum levels increase with age and tend to be higher in females than males.[8]

Studies have investigated the correlation between low level exposure of POPs and various diseases. In order to assess disease risk due to POPs in a particular location, government agencies may produce a human health risk assessment which takes into account the pollutants' bioavailability and their dose-response relationships.[17]

Endocrine disruption[edit]

The majority of POPs are known to disrupt normal functioning of the endocrine system. Low level exposure to POPs during critical developmental periods of fetus, newborn and child can have a lasting effect throughout their lifespan. A 2002 study[18] summarizes data on endocrine disruption and health complications from exposure to POPs during critical developmental stages in an organism’s lifespan. The study aimed to answer the question whether or not chronic, low level exposure to POPs can have a health impact on the endocrine system and development of organisms from different species. The study found that exposure of POPs during a critical developmental time frame can produce a permanent changes in the organisms path of development. Exposure of POPs during non-critical developmental time frames may not lead to detectable diseases and health complications later in their life. In wildlife, the critical development time frames are in utero, in ovo, and during reproductive periods. In humans, the critical development timeframe is during fetal development.[19]

Reproductive system[edit]

The same study in 2002[18] with evidence of a link from POPs to endocrine disruption also linked low dose exposure of POPs to reproductive health effects. The study stated that POP exposure can lead to negative health effects especially in the male reproductive system, such as decreased sperm quality and quantity, altered sex ratio and early puberty onset. For females exposed to POPs, altered reproductive tissues and pregnancy outcomes as well as endometriosis have been reported.[20]

Gestational weight gain and newborn head circumference[edit]

A Greek study from 2014 investigated the link between maternal weight gain during pregnancy, their PCB-exposure level and PCB level in their newborn infants, their birth weight, gestational age, and head circumference. The lower the birth weight and head circumference of the infants was, the higher POP levels during prenatal development had been, but only if mothers had either excessive or inadequate weight gain during pregnancy. No correlation between POP exposure and gestational age was found.[21] A 2013 case-control study conducted 2009 in Indian mothers and their offspring showed prenatal exposure of two types of organochlorine pesticides (HCH, DDT and DDE) impaired the growth of the fetus, reduced the birth weight, length, head circumference and chest circumference.[22][23]

Additive and synergistic effects[edit]

Evaluation of the effects of POPs on health is very challenging in the laboratory setting. For example, for organisms exposed to a mixture of POPs, the effects are assumed to be ***additive.[24] Mixtures of POPs can***

in principle produce synergistic effects. With synergistic effects, the toxicity of each compound is enhanced (or depressed) by the presence of other compounds in the mixture. When put together, the effects can far exceed the approximated additive effects of the POP compound mixture.[3]

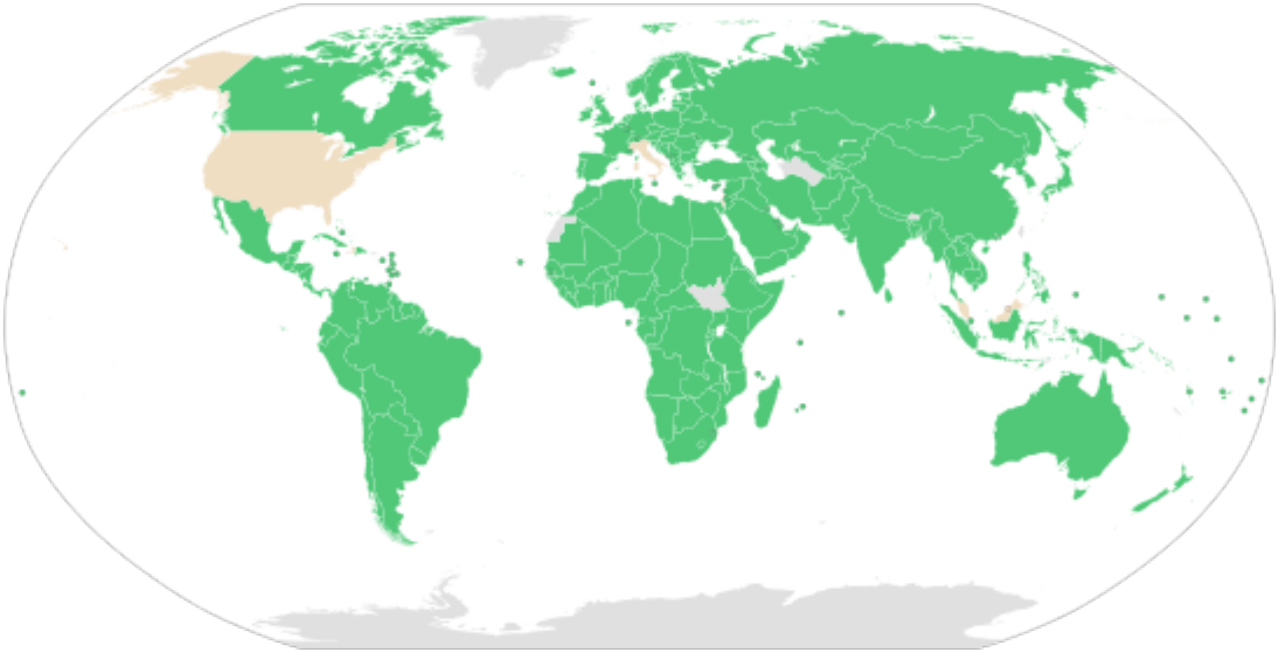
In urban areas and indoor environments[edit]

Traditionally it was thought that human exposure to POPs occurred primarily through food, however indoor pollution patterns that characterize certain POPs have challenged this notion. Recent studies of indoor dust and air have implicated indoor environments as a major sources for human exposure via **inhalation and ingestion.**[25] Furthermore, significant indoor POP pollution must be a major route of human POP exposure, considering the modern trend in spending larger proportions of life indoor. Several studies have shown that i**ndoor (air and dust) POP levels to exceed outdoor (air and soil) POP concentrations**.[24]

Control and removal in the environment[edit]

Current studies aimed at minimizing POPs in the environment are investigating their behavior in photo catalytic oxidation reactions. POPs that are found in humans and in aquatic environments the most are the main subjects of these experiments. Aromatic and aliphatic degradation products have been identified in these reactions. Photochemical degradation is negligible compared to photocatalytic degradation.[26] A method of removal of POPs from marine environments that has been explored is adsorption. It occurs when an absorbable solute comes into contact with a solid with a porous surface structure. This technique was investigated by Mohamed Nageeb Rashed of Aswan University, Egypt.[27] Current efforts are more focused on banning the use and production of POPs worldwide rather than removal of POPs.[28]

Stockholm Convention on Persistent Organic Pollutants[edit]



State parties to the Stockholm Convention on Persistent Organic Pollutants

Main article: Stockholm Convention on Persistent Organic Pollutants

The Stockholm Convention was adopted and put into practice by the United Nations Environment Programme (UNEP) on May 22, 2001. The UNEP decided that POP regulation needed to be addressed globally for the future. The purpose statement of the agreement is "to protect human health and the environment from persistent organic pollutants." As of 2014, there are 179 countries in compliance with the Stockholm convention. The convention and its participants have recognized the potential human and environmental toxicity of POPs. They recognize that POPs have the potential for **LONG RANGE TRANSPORT AND BIOACCUMULATION AND BIOMAGNIFICATION.** The convention seeks to study and then judge whether or not a number of chemicals that have been developed with advances in technology and science can be categorized as POPs or not. The initial meeting in 2001 made a preliminary list, termed the "dirty dozen," of chemicals that are classified as POPs. As of 2014, the United States of America has signed the Stockholm Convention but has not ratified it. There are a handful of other countries that have not ratified the convention but most countries in the world have ratified the convention.[11]

Compounds on the Stockholm Convention list[edit]

In May 1995, the United Nations Environment Programme Governing Council investigated POPs.[12] Initially the Convention recognized only twelve POPs for their adverse effects on human health and the environment, placing a global ban on these particularly harmful and toxic compounds and requiring its parties to take measures to eliminate or reduce the release of POPs in the environment. [2][13][14]

1. **Aldrin**, an insecticide used in soils to kill termites, grasshoppers, Western corn rootworm, and others, is also known to kill birds, fish, and humans. Humans are primarily exposed to aldrin through dairy products and animal meats.
2. **Chlordane**, an insecticide used to control termites and on a range of agricultural crops, is known to be lethal in various species of birds, including mallard ducks, bobwhite quail, and pink shrimp; it is a chemical that remains in the soil with a reported half-life of one year. Chlordane has been postulated to affect the human immune system and is classified as a possible human carcinogen. Chlordane air pollution is believed the primary route of humane exposure.
3. **Dieldrin**, a pesticide used to control termites, textile pests, insect-borne diseases and insects living in agricultural soils. In soil and insects, aldrin can be oxidized, resulting in rapid conversion to dieldrin. Dieldrin's half-life is approximately five years. Dieldrin is highly toxic to fish and other aquatic animals, particularly frogs, whose embryos can develop spinal deformities after exposure to low levels. Dieldrin has been linked to Parkinson's disease, breast cancer, and classified as immunotoxic, neurotoxic, with endocrine disrupting capacity. Dieldrin residues have been found in air, water, soil, fish, birds, and mammals. Human exposure to dieldrin primarily derives from food.
4. **Endrin**, an insecticide sprayed on the leaves of crops, and used to control rodents. Animals can metabolize endrin, so fatty tissue accumulation is not an issue, however the chemical has a long half-life in soil for up to 12 years. Endrin is highly toxic to aquatic animals and humans as a neurotoxin. Human exposure results primarily through food.
5. **Heptachlor**, a pesticide primarily used to kill soil insects and termites, along with cotton insects, grasshoppers, other crop pests, and malaria-carrying mosquitoes. Heptachlor, even at every low doses has been associated with the decline of several wild bird populations – Canada geese and American kestrels. In laboratory tests have shown high-dose heptachlor as lethal, with adverse behavioral changes and reduced reproductive success at low-doses, and is classified as a possible human carcinogen. Human exposure primarily results from food.
6. **Hexachlorobenzene (HCB**), was first introduced in 1945–59 to treat seeds because it can kill fungi on food crops. HCB-treated seed grain consumption is associated with photosensitive skin lesions, colic, debilitation, and a metabolic disorder called porphyria turcica, which can be lethal. Mothers who pass HCB to their infants through the

placenta and breast milk had limited reproductive success including infant death. Human exposure is primarily from food.

7. **Mirex**, an insecticide used against ants and termites or as a flame retardant in plastics, rubber, and electrical goods. Mirex is one of the most stable and persistent pesticides, with a half-life of up to 10 years. Mirex is toxic to several plant, fish and crustacean species, with suggested carcinogenic capacity in humans. Humans are exposed primarily through animal meat, fish, and wild game.
8. **Toxaphene**, an insecticide used on cotton, cereal, grain, fruits, nuts, and vegetables, as well as for tick and mite control in livestock. Widespread toxaphene use in the US and chemical persistence, with a half-life of up to 12 years in soil, results in residual toxaphene in the environment. Toxaphene is highly toxic to fish, inducing dramatic weight loss and reduced egg viability. Human exposure primarily results from food. While human toxicity to direct toxaphene exposure is low, the compound is classified as a possible human carcinogen.
9. **Polychlorinated biphenyls** (PCBs), used as heat exchange fluids, in electrical transformers, and capacitors, and as additives in paint, carbonless copy paper, and plastics. Persistence varies with degree of halogenation, an estimated half-life of 10 years. PCBs are toxic to fish at high doses, and associated with spawning failure at low doses. Human exposure occurs through food, and is associated with reproductive failure and immune suppression. Immediate effects of PCB exposure include pigmentation of nails and mucous membranes and swelling of the eyelids, along with fatigue, nausea, and vomiting. Effects are transgenerational, as the chemical can persist in a mother’s body for up to 7 years, resulting in developmental delays and behavioral problems in her children. Food contamination has led to large scale PCB exposure.
10. **Dichlorodiphenyltrichloroethane** (DDT) is probably the most infamous POP. It was widely used as insecticide during WWII to protect against malaria and typhus. After the war, DDT was used as an agricultural insecticide. In 1962, the American biologist Rachel Carson published Silent Spring, describing the impact of DDT spraying on the US environment and human health. DDT’s persistence in the soil for up to 10–15 years after application has resulted in widespread and persistent DDT residues throughout the world including the arctic, even though it has been banned or severely restricted in most of the world. DDT is toxic to many organisms including birds where it is detrimental to reproduction due to eggshell thinning. DDT can be detected in foods from all over the world and food-borne DDT remains the greatest source of human exposure. Short-term acute effects of DDT on humans

are limited, however long-term exposure has been associated with chronic health effects including increased risk of cancer and diabetes, reduced reproductive success, and neurological disease.

11. **Dioxins** are unintentional by-products of high-temperature processes, such as incomplete combustion and pesticide production. Dioxins are typically emitted from the burning of hospital waste, municipal waste, and hazardous waste, along with automobile emissions, peat, coal, and wood. Dioxins have been associated with several adverse effects in humans, including immune and enzyme disorders, chloracne, and are classified as a possible human carcinogen. In laboratory studies of dioxin effects an increase in birth defects and stillbirths, and lethal exposure have been associated with the substances. Food, particularly from animals, is the principal source of human exposure to dioxins.
12. **Polychlorinated dibenzofurans** are by-products of high-temperature processes, such as incomplete combustion after waste incineration or in automobiles, pesticide production, and polychlorinated biphenyl production. Structurally similar to dioxins, the two compounds share toxic effects. Furans persist in the environment and classified as possible human carcinogens. Human exposure to furans primarily results from food, particularly animal products.

New POPs on the Stockholm Convention list[edit]

Since 2001, this list has been expanded to include some polycyclic aromatic hydrocarbons (PAHs), brominated flame retardants, and other compounds. Additions to the initial 2001 Stockholm Convention list are as following POPs:[15][16]

- Chlordecone, a synthetic chlorinated organic compound, is primarily used as an agricultural pesticide, related to DDT and Mirex. Chlordecone is toxic to aquatic organisms, and classified as a possible human carcinogen. Many countries have banned chlordecone sale and use, or intend to phase out stockpiles and wastes.
- α-Hexachlorocyclohexane (α-HCH) and β-Hexachlorocyclohexane (β-HCH) are insecticides as well as by-products in the production of lindane. Large stockpiles of HCH isomers exist in the environment. α-HCH and β-HCH are highly persistent in the water of colder regions. α-HCH and β-HCH has been linked Parkinson's and Alzheimer's disease.[*citation needed*]
- Hexabromodiphenyl ether (hexaBDE) and heptabromodiphenyl ether (heptaBDE) are main components of commercial octabromodiphenyl ether (octaBDE). Commercial octaBDE is highly persistent in the environment, whose only degradation pathway is through debromination and the production of bromodiphenyl ethers, which can increase toxicity.

- Lindane (γ-hexachlorocyclohexane), a pesticide used as a broad spectrum insecticide for seed, soil, leaf, tree and wood treatment, and against ectoparasites in animals and humans (head lice and scabies). Lindane rapidly bioconcentrates. It is immunotoxic, neurotoxic, carcinogenic, linked to liver and kidney damage as well as adverse reproductive and developmental effects in laboratory animals and aquatic organisms. Production of lindane unintentionally produces two other POPs α-HCH and β-HCH.[*citation needed*]
- Pentachlorobenzene (PeCB), is a pesticide and unintentional byproduct. PeCB has also been used in PCB products, dyestuff carriers, as a fungicide, a flame retardant, and a chemical intermediate. PeCB is moderately toxic to humane, while highly toxic to aquatic organisms.
- Tetrabromodiphenyl ether (tetraBDE) and pentabromodiphenyl ether (pentaBDE) are industrial chemicals and the main components of commercial pentabromodiphenyl ether (pentaBDE). PentaBDE has been detected in humans in all regions of the world.
- Perfluorooctanesulfonic acid (PFOS) and its salts are used in the production of fluoropolymers. PFOS and related compounds are extremely persistent, bioaccumulating and biomagnifying. The negative effects of trace levels of PFOS have not been established.
- Endosulfans are insecticides to control pests on crops such coffee, cotton, rice and sorghum and soybeans, tsetse flies, ectoparasites of cattle. They are used as a wood preservative. Global use and manufacturing of endosulfan has been banned under the Stockholm convention in 2011, although many countries had previously banned or introduced phase-outs of the chemical when the ban was announced. Toxic to humans and aquatic and terrestrial organisms, linked to congenital physical disorders, mental retardation, and death. Endosulfans' negative health effects are primarily liked to its endocrine disrupting capacity acting as an antiandrogen.
- Hexabromocyclododecane (HBCD) is a brominated flame retardant primarily used in thermal insulation in the building industry. HBCD is persistent, toxic and ecotoxic, with bioaccumulative and long-range transport properties.

Conclusion research

Stopping the use of chemicals in our environment and removing the existing polluting chemicals from our bodies and environment is critical. Photocatalytic

Oxidation/ degradation of organic pollutants is a promising technology due to its advantage of degradation on pollutants instead of their transformation under ambient conditions. The process is capable of removing a wide range of organic pollutants such as pesticides, herbicides, and micropollutants such as endocrine disrupting compounds. TiO_2 photocatalysis is constrained by several factors such as wide band gap (3.2eV), lack and inability of efficient and cost-effective catalyst for high photon-efficiency to utilize wider solar spectra. used to optimize the process and design appropriate reactor for potential large scale applications. The use of solar radiation has to be improved by virtue of the design of the photoreactor in order to reduce the cost of treatment.

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NOTE on The **chemical industry** comprises the companies that produce industrial chemicals. Central to the modern world economy, it converts raw materials (oil, natural gas, air, water, metals, and minerals) into more than 70,000 different products. The plastics industry contains some overlap, as most chemical companies produce plastic as well as other chemicals.
As of 2018, the chemical industry comprises approximately 15% of the US manufacturing economic sector. Although chemicals were made and used throughout history, the birth of the heavy chemical industry (production of chemicals in large quantities for a variety of uses) coincided with the beginnings of the Industrial Revolution in general.

Charles Tennant's St. Rollox Chemical Works in 1831, then the biggest chemical enterprise in the world.

Products[edit]

"Polymers and plastics, especially polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, polystyrene and polycarbonate comprise about 80% of the industry's output worldwide".[11] These materials are often converted to fluoropolymer tubing products and used by the industry to transport highly corrosive materials.[12] Chemicals are used in a lot of different consumer goods, but they are also used in a lot of different other sectors; including agriculture manufacturing, construction, and service industries.[11] Major industrial customers include rubber and plastic products, textiles, apparel, petroleum refining, pulp and paper, and primary metals. Chemicals are nearly a $3 trillion global enterprise, and the EU and U.S. chemical companies are the world's largest producers.[citation needed]

Sales of the chemical business can be divided into a few broad categories, including basic chemicals (about 35 to 37 percent of the dollar output), life sciences (30 percent), specialty chemicals (20 to 25 percent) and consumer products (about 10 percent).[13]

New polypropylene plant PP3 in the Slovnaft oil refinery (Bratislava, Slovakia)

Basic chemicals, or "commodity chemicals" are a broad chemical category including polymers, bulk petrochemicals and intermediates, other derivatives and basic industrials, inorganic chemicals, and fertilizers. **Polymers**, the largest revenue segment at about 33 percent of the basic chemicals dollar value, includes all categories of plastics and man-made fibers.[citation needed] The major markets for plastics are packaging, followed by home construction, containers, appliances, pipe, transportation, toys, and games.

Other derivatives and basic industrials include synthetic rubber, surfactants, dyes and pigments, turpentine, resins, carbon black, explosives, and rubber products and contribute about 20 percent of the basic chemicals' external sales.

Inorganic chemicals (about 12 percent of the revenue output) make up the oldest of the chemical categories. Products include salt, chlorine, caustic soda, soda ash, acids (such as nitric acid, phosphoric acid, and sulfuric acid), titanium dioxide, and hydrogen peroxide.

Fertilizers are the smallest category (about 6 percent) and include phosphates, ammonia, and potash chemicals.

Life sciences[edit]

Life sciences (about 30 percent of the dollar output of the chemistry business) include differentiated chemical and biological substances, pharmaceuticals, diagnostics, animal health products, vitamins, and pesticides. While much smaller in volume than other chemical sectors, their products tend to have very high prices—over ten dollars per pound—growth rates of 1.5 to 6 times GDP, and research and development spending at 15 to 25 percent of sales. Pesticides, also called "crop protection chemicals", are about 10 percent of this category and include herbicides, insecticides, and fungicides.[citation needed]

Specialty chemicals[edit]

Specialty chemicals are a category of relatively high valued, rapidly growing chemicals with diverse end product markets.

Consumer products[edit]

Consumer products include direct product sale of chemicals such as soaps, detergents, and cosmetics. These speciality products are marketed by chemical companies to the downstream manufacturing industries as pesticides, speciality polymers, electronic chemicals, surfactants, construction chemicals, Industrial Cleaners, flavours and fragrances, speciality coatings, printing inks, water-soluble polymers, food additives, paper chemicals, oil field chemicals, plastic adhesives, adhesives and sealants, cosmetic chemicals, water management chemicals, catalysts, textile chemicals. Chemical companies rarely supply these products directly to the consumer.

Every year, the American Chemistry Council tabulates the U.S. production volume of the top 100 chemicals.[citation needed] In 2000, the aggregate production volume of the top 100 chemicals totalled 502 million tons, up from 397 million tons in 1990. Inorganic chemicals tend to be the largest volume, though much smaller in dollar revenue terms due to their low prices. The top 11 of the 100 chemicals in 2000 were sulfuric acid (44 million tons), nitrogen (34), ethylene (28), oxygen (27), lime (22), ammonia (17), propylene (16), polyethylene (15), chlorine (13), phosphoric acid (13) and diammonium phosphates (12).[citation needed]

From the perspective of chemical engineers, the chemical industry involves the use of chemical processes such as chemical reactions and refining methods to produce a wide variety of solid, liquid, and gaseous materials. Most of these products serve to manufacture other items, although a smaller number go directly to consumers. Solvents, pesticides, lye, washing soda, and portland cement provide a few examples of product used by consumers. The industry includes manufacturers of inorganic- and organic-industrial chemicals, ceramic products, petrochemicals, agrochemicals, polymers and rubber (elastomers), oleochemicals (oils, fats, and waxes), explosives, fragrances and flavors. Examples of these products are shown in the Table below.

Although the pharmaceutical industry is often considered[who?] a **chemical industry** , it has many different characteristics that puts it in a separate category. Other closely related industries include petroleum, glass, paint, ink, sealant, adhesive, and food processing manufacturers.

Chemical processes such as chemical reactions operate in chemical plants to form new substances in various types of reaction vessels. In many cases the reactions take place in special corrosion-resistant equipment at elevated temperatures and pressures with the use of catalysts. The products of these reactions are separated using a variety of techniques including distillation especially fractional distillation, precipitation, crystallization, adsorption, filtration, sublimation, and drying.

The processes and product or products are usually tested during and after manufacture by dedicated instruments and on-site quality control laboratories to ensure safe operation and to assure that the product will meet required specifications. More organizations within the industry are implementing chemical compliance software to maintain quality products and manufacturing standards.[17] The products are packaged and delivered by many methods, including pipelines, tank-cars, and tank-trucks (for both solids and liquids), cylinders, drums, bottles, and boxes. Chemical companies often have a research-and-development laboratory for developing and testing products and processes. These facilities may include pilot plants, and such research facilities may be located at a site separate from the production plant(s).

World Chemical Production[edit]

The scale of chemical manufacturing tends to be organized from largest in volume (petrochemicals and commodity chemicals), to specialty chemicals, and the smallest, fine chemicals.

The petrochemical and commodity chemical manufacturing units are on the whole single product continuous processing plants. Not all petrochemical or commodity chemical materials are made in one single location, but groups of related materials often are to induce industrial symbiosis as well as material, energy and utility efficiency and other economies of scale.

Those chemicals made on the largest of scales are made in a few manufacturing locations around the world, for example in Texas and Louisiana along the Gulf Coast of the United States, on Teesside in the Northeast of England in the United Kingdom, and in Rotterdam in the Netherlands. The large scale manufacturing locations often have clusters of manufacturing units that share utilities and large scale infrastructure such as power stations, port facilities, road and rail terminals. To demonstrate the clustering and integration mentioned above, some 50% of the United Kingdom's petrochemical and commodity chemicals are produced by the Northeast of England Process Industry Cluster on Teesside.

Specialty chemical and fine chemical manufacturing are mostly made in discrete batch processes. These manufacturers are often found in similar locations but in many cases they are to be found in multi sector business parks.

Continents and Countries[edit]

In the U.S. there are 170 major chemical companies.[18] They operate internationally with more than 2,800 facilities outside the U.S. and 1,700 foreign subsidiaries or affiliates operating. The U.S. chemical output is $750 billion a year. The U.S. industry records large trade surpluses and employs more than a million people in the United States alone. The chemical industry is also the second largest consumer of energy in manufacturing and spends over $5 billion annually on pollution abatement.

In Europe the chemical, plastics and rubber sectors are among the largest industrial sectors.[*citation needed*] Together they generate about 3.2 million jobs in more than 60,000 companies. Since 2000 the chemical sector alone has represented 2/3 of the entire manufacturing trade surplus of the EU.

in 2012 The chemical sector accounted for 12% of the EU manufacturing industry's added value. Europe remains world's biggest chemical trading region with 43% of the world's exports and 37%of the world's imports, although the latest data shows that Asia is catching up with 34% of the exports and 37% of imports.[19] Even so, Europe still has a trading surplus with all regions of the world except Japan and China where in 2011 there was a chemical trade balance. Europe's trade surplus with the rest of the world today amounts to 41.7 billion Euros.[20]

Over the 20 years between 1991 and 2011 the European Chemical industry saw its sales increase 295 billion Euros to 539 billion Euros, a picture of constant growth. Despite this the European industry's share of the world chemical market has fallen from 36% to 20%. This has resulted from the huge increase production and sales in the emerging markets like India and China.[21] The data suggest that 95% of this impact is from China alone. In 2012 the data from the European Chemical Industry Council shows that five European countries account for 71% of the EU's chemicals sales. These are Germany, France, United Kingdom, Italy and the Netherlands.[22]

The chemical industry has shown rapid growth for more than fifty years.[*citation needed*] The fastest-growing areas have involved the manufacture of synthetic organic polymers used as plastics, fibres and elastomers. Historically and presently the chemical industry has been concentrated in three areas of the world, Western Europe, North America and Japan (the Triad). The European Community remains the largest producer area followed by the US and Japan. The traditional dominance of chemical production by the Triad countries is being challenged by changes in feedstock availability and price, labour cost, energy cost, differential rates of economic growth and environmental

pressures. Instrumental in the changing structure of the global chemical industry has been the growth in China, India, Korea, the Middle East, South East Asia, Nigeria, and Brazil.
Just as companies emerge as the main producers of the chemical industry, we can also look on a more global scale to how industrialized countries rank, with regards to the billions of dollars worth of production a country or region could export. Though the business of chemistry is worldwide in scope, the bulk of the world's $3.7 trillion chemical output is accounted for by only a handful of industrialized nations. The United States alone produced $689 billion, 18.6 percent of the total world chemical output in 2008.[23]