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Emerging Contaminants in Environmental Pollution: Innovative Approaches to Monitoring and Mitigation Strategies

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Abstract: Emerging contaminants (ECs) present a growing environmental challenge due to their persistence, bioaccumulation, and toxic effects, yet there is still a significant knowledge gap regarding their sources, transport mechanisms, and long-term impacts on ecosystems and human health. This article reviews the origins, types, pathways, and effects of emerging pollutants, focusing on pharmaceuticals, personal care products, microplastics, pesticides, and industrial chemicals. Using a comprehensive literature review and case studies, the paper evaluates current monitoring techniques, such as advanced chemical analysis, biological indicators, and remote sensing, alongside innovative mitigation strategies including bioremediation, advanced oxidation processes, and green infrastructure. Findings reveal that although detection

methods have improved significantly, existing regulations and removal technologies remain insufficient to fully manage EC risks. Results emphasize the urgent need for integrated and sustainable monitoring frameworks and mitigation strategies. The study contributes to strengthening scientific understanding and policy development for the protection of environmental and human health from emerging contaminants.

Keywords: emerging contaminants, environmental pollution, monitoring techniques, mitigation strategies, ecosystem health, human health, bioremediation, advanced oxidation

1. Introduction to Emerging Contaminants

Environmentally harmful chemicals and materials are constantly entering the market, and industrial output continues to rise. The pollutants generated have entered all aspects of the environment, including water sources, soil, air, also other regions. Emerging pollutants are defined as substances newly discovered or previously considered harmless, substances presenting new concern, or those already found but recently discovered to be toxic [1]. Emerging pollutants, depending on their accumulation, bio-toxicity, persistence, transformation, etc., have raised widespread concern. The production, application, and environmental behaviors of these substances have not been effectively managed and understood, therefore study of the fate and movement of emerging pollutants in land, air, water, biopotential and other aspects becomes a research hotspot [2]. Already, several townspeople have passed on attempting the new-fangled make-up water likewise some decompositions have the capability to obtain LDHs or other matters, and some even possess the function of UV irradiation (removal of degradation). Upon moving Cannabis sativa L. making the most of irrigation water assimilated by LDH, the total Governing body (EC) plus delta P (DOC) amplification were soared throughout expansion, meanwhile, the novel and traditional affixation of growing factory that had the ability to be elevated were compared via ultrahigh-performance liquid chromatography-high resolution-mass spectrum sooner or later, thereby investigating the fate of 8 pesticides in soil, effluent and herb (the other hand). In Iran, after researchers found that heavy metals were higher than standard levels in some traditional reasoning, they opted to examine the concentrations of some of these heavy metals in herbs, irrigation water and soils, so as to get enough knowledge in order to reduce the perils of consuming medicinal herbs.

2. Types of Emerging Contaminants

There is no standard definition for the term "emerging contaminant." Emerging contaminants are defined as “a new contaminant that is being discovered in the environment and for which there is little or not enough information regarding its occurrence and toxicity.” Some other definitions

have adopted a time criterion so that emerging contaminants must have attracted wide notice during the last 10-15 years [2].

For monitoring and assessment purposes, environmental agencies and institutions currently use the definitions proposed by the European Commission's Joint Research Centre. A traditional or well-known group of chemicals might be considered as emerging contaminants when a certain threshold level in terms of presence in water or new evidence of toxic and adverse effects is exceeded. Meanwhile, 'true' or really new contaminants may be defined as chemicals that are widely regarded as pollutants for the first time, i.e. not simply at newly or much higher detected levels, but for which relatively little or no environmental monitoring, assessment and risk analysis is currently undertaken.

As emerging contaminants are regarded as particularly challenging, it is important to make a concise overview of what types of these are most pertinent from an environmental perspective. Based on a critical literature review, three categories at least can be identified. A diverse set of anthropogenic organic compounds have been labelled as emerging contaminants in water, including pesticides, pharmaceuticals, personal care products and fragrances, plasticizers, hormones, flame retardants, nanoparticles, perfluoroalkyl compounds, chlorinated paraffins, siloxanes; algal toxins; various trace elements including rare earths and radionuclides; and a host of other persistent, bio-accumulative and toxic substances. Furthermore, "emerging" could refer to specific concerns or problems about contaminants already known and well-studied: bioavailability and aquatic toxicity, the development and application of appropriate technologies for their removal and destruction, the fate of pollutants derived from the transformation of emerging contaminants, and so forth. Apart from the presence of emerging contaminants, their persistence, bio-accumulation, and other hazardous properties broaden the concept to "emerging" water pollution threats. [3][4]

2.1. Pharmaceuticals and Personal Care Products

2. ECOLOGICALLY PERSISTENT PHARMACEUTICALS

2.1. Pharmaceuticals and Personal Care Products Emerging chemicals of concern are pharmaceuticals and personal care products; drugs have garnered concern as more is learned about their biological activity at very low levels in the environment. Concern for exposure comes from finding pharmaceuticals, for which many classes have recognized specific pharmacological activity of concern that bioconcentrate in aquatic organisms, in both surface and groundwater sources ([5]). Pharmaceuticals account for a relatively small land burden of usage compared to the many industrial and agricultural chemicals currently manufactured, especially as trade restrictions have limited sales of pharmaceuticals based on the environmental risk of their exceedingly persistent chemical structures. Triclosan, in some toothpaste and personal care products such as deodorant, is acutely toxic to many aquatic organisms, but is not classified as a high priority chemical because its half-life in water is only on the scale of days. The field of pharmaceuticals and their effects of concern is still developing, in part because contaminants in the environment that have historically been considered are animal waste and landfill leachate. There is also concern for a variety of plasticizers and toxic byproducts of plastics manufacture, used as artificial sweeteners or fat substitutes, or as resins in food packaging. Hormones of concern are largely estrogen analogs: bisphenol A (BPA), DES, and a variety of phthalate diesters such as DEHP, with other classes being long-chain hydrophobic molecules in general and things that are antimicrobial or are converted to antimicrobial constituents in vivo. Non-covalent associated complexes are not considered biologically persistent but structure ensemble fulfillment is poorly understood in complex systems with mixtures in many physical forms, such as the complex structure of waste discharges treated through plants designed for simple organic pollutants that transform rather than adsorb a solubilized knowledge of them. Particles 500 nm and larger are among the most effective POC the majority of which in water bodies are flocculated organic matter complexes that are generally of natural origin.

2.2. Microplastics

Innovative new analytical technologies are emerging to trace potentially harmful organic and inorganic contaminants in various environmental samples at extremely low concentration. Recently, a new and handy device for extracting microplastic particles from soil and sediment matrix has been represented. The device consists of a pipette bulb machined from heat-resistant glass. Pipette bulb is open at the bottom and is equipped with a plastic stopcock on the top. A cap is screwed on the top to seal the device. The studies of the density materials show potential interest in sediment for the extraction and monitoring of the abundance of microplastic particles. The density of microplastic is always different from the nature of the sediment, thus the development of this device can help in the research of the impact of routinely monitoring microplastics on the pristine environment.

Various innovative extraction procedures for soil and sediment sample have been reviewed. There are new devices for separating embraced microplastics from marine and freshwater sediments. There are also newly developed techniques for the detection of microplastics in sediment and field-collected organisms. The extraction of obscured plastic particles from a complex matrix minimizes the sample pretreatment procedures and the introduction of contamination, it represents a critical aspect for the strategies aimed at the aggregation of the analytical determinations of the plastic particles. Particle size, appearance, and nature of the sediment were indicated as the key parameters influencing the extraction efficiency. A density-based device for the soil and sediment sample was developed, which mimics the density column used in water samples. Since the concerns for aquatic environments, many methods require the use of solutions combined with sodium iodide. These high-density solutions prevent heavy plastics and entrap microplastics to rise while separating; they raise to the bottom the sediment particles which eventually can settle down in the plastic-rich fraction. [6][7][8]

2.3. Pesticides and Herbicides

2.1.1. Backgrounds

The use of pesticides is restricted to original agricultural areas according to the recommended directions. Management of use is regulated to some extent, for example, application is forbidden a certain time before harvest time, no application in general river regions, and limitation in the use of allowed quantity for each type of pesticide. This system works as a kind of safety control so that points of application for pesticides become a non-point source of pollution to a variety of environments. Groundwater represents the most meaningful way through which most pollution by pesticides occurs, allowing them to spread well beyond the points of application [9]. Migration of pollutants caused by such an occurrence may be supported by surface erosion and adsorption/desorption capacities of pesticides. Off-target drift poses a similar danger by bringing them to non-agricultural zones where they can persist.

2.1.2. Recent Analyses and New Trends Recently, numerous environmental and ecological problems have occurred as a result of a variety of residues in environmental compartments, rendering soil and groundwater systems particularly vulnerable to the use of these pesticides. Accordingly, studies have been intensively conducted, and pesticides are now routinely monitored by state agencies, pesticide registrants, and research groups at numerous universities. Monitoring data indicate that the pesticides under surveillance often exceed threshold levels in a variety of locations, prompting discussions about public health standards. The development of such a complex multi-residue analysis system will permit improved and safe control of pesticide contamination. With the prospective enlargement in monitoring programs, this sort of sample preparation system would be anticipated to fulfill a large need for the monitoring of pesticide residues that affect human health in the food chain. Meanwhile new issues are arising about the side and unintended effects of pesticides in ecological systems. For instance, fipronil is one such associated herbicides, the eggs of which were found to contain heavy concentrations of the herbicide; subsequently, they were banned for sale in several nations. Similarly, the results of

recent research indicate that numerous grouped pesticides are accumulating in eggs due to a heavy contamination of crops, which in turn is caused by a soil contamination.

2.4. Industrial Chemicals

The unprecedented growth of the world's population and rapid industrialization in the recent past have been imposing a huge demand for water. Accumulation of industrial, agricultural, urban and domestic waste in the aquatic environment poses a serious threat to the human race's existence and is a source of numerous contaminants, which are directly and indirectly discharged into rivers, lakes and coastal water bodies. Eventually pollutants are transferred to ground soil and combine with ground water [5]. There are increasing concerns over excessive use of pharmaceutical products and personal care products, release of industrial chemicals, periodical treatment of drinking water with chlorine and public health; attention has been directed towards the emergence of various chemical compounds and microorganisms in the environment, that are not routinely monitored by standard control procedures.

The environmental impacts of the industrial activities could result in the generation of wastewater containing complex mixtures of various pollutants. Some of these pollutants can generate compounds that are more toxic than the original ones generated. There is an increasing demand on process technologies for the effective treatment of toxic wastewaters; biological and chemical treatment processes may be used in the treatment of the wastewaters. The presence of azo dyes and phenolic compounds has been reported in the effluent of different textile industry categories and also pulp and paper industry poses a serious pollution problem. However development of environmentally benign treatment methods and technologies as alternatives to the use of harmful ones, such as phytoremediation could be an attractive option, particularly from long-term and economic viewpoints and to develop an industrial process at pilot plant scale.

3. Sources of Emerging Contaminants

Introduction

More than a 140 years ago, in 1871, the first degree in chemistry at Queen's University in Ontario, Canada was conferred to Harriett Ann Innis, who was the first woman to graduate with a science degree in Canada. Today only 140 out of the 537 elements in the Periodic Table can be found in their original form in the environment. Heavy metals, typically referring to metallic elements with an atomic weight above 20 g mol-1, are both naturally occurring and anthropogenic in origin. In 2013, metal production in the world amounted to more than a million tons of gold, lead, manganese, nickel, zinc, and other metallic elements. Mining and smelting activities contribute to soil contamination by the introduction of trace metals in their metallic forms. A significant amount of other toxic metals can be introduced in the environment by means of indirect pathways such as sewage sludge and fertilization with chemical products like pesticides. Some metallic contaminants have the red list of priority pollutants for non-ferrous mining and metallurgical sectors. Discharge of waste rock and soil erosion at mine sites may contribute to the transport of metal contaminated particles to freshwater ecosystems by runoff and sedimentation. Long chemical industries have resided in abandoned sites where residual metal contamination has been observed. Water bodies naturally overflowing with toxic elements have been seriously affected by extraction processes, even more in the last years when new methods were developed to extract from areas that were not economically feasible in the past. The occurrence of soils with metal(loid) concentrations higher than maximum levels allowed has become an environmental issue [2].

3.1. Agricultural Runoff

Climate change, urbanization, and expansion and intensification of large-scale, high value agricultural operations, like concentrated animal feeding operations, contribute to emerging challenges associated with sources of agricultural run-off as a point and nonpoint source of emerging contaminants such as veterinary pharmaceuticals, their metabolites and transformation

products, personal care and pharmaceutical products, xenoestrogens and endocrine disruptors, steroidal growth promoters, feed additives, and metalloestrogens. Alternate and innovative approaches to monitoring and mitigation of these sources and types of agricultural run-off are needed. Agricultural run-off can impact different environmental compartments such as water and soil. Agriculture is diverse and can present as crop agriculture, animal agriculture, high value agriculture, or large contributing operations. Urbanization of rural settings, and subsequently the loss of productive agricultural land, has become an issue in the United States, and around the world, as population expanse requires additional housing, infrastructure, and commercial operation development, often taking the form of urban sprawl. The production and application of veterinary pharmaceuticals contributes to emerging contamination in the environment. Majority of the veterinary pharmaceutical application growth, and product development, is in high value animals. High value, concentrated, or large-scale, animal feeding operations can produce significant waste and excrement. Majority of veterinary pharmaceuticals are drugs that contribute to herd health through disease prevention and treatment. Common production classes such as antibiotics, steroids, and parasiticides, are used as growth promoters. Emerging contaminants from agriculture, and exposure can be excreted unmetabolized or in biotransformed form as metabolites, may eventually enter the environment. Injectable or implanted delivery can enhance biodegradability and potential for metabolite degradates. Dry compound administration in feed promotes passage in waste, hence land application on crops for bioavailability and disposal of digested compounds. Tagging compound enables time release profile for optimal dosing, but may persist in environment. Emerging contaminants such as pharmaceuticals in the terrestrial environment can pose a threat to human health via food chain, and pathogenic microbe drug resistance acceleration [10].

3.2. Wastewater Treatment Plants

Water is the unique substance on Earth that allows life. It is found in three states. The chemical components of pure water are two hydrogen atoms and one oxygen atom. Despite having a simple composition, water is a very complex dynamic system representing for mankind the vital fluid necessary for survival. To comply with widely accepted standards, water must be free of harmful impurities that can be a threat to human health or cause a reduction of aesthetic qualities. Human activities have sine very old time impacted the environment state by exploiting these resources and discarding large quantities of waste. Industrial and domestic effluents are discharged in water bodies. Theses discharges are made full of physical, chemicals and biological toxic waste [11]. Dye plants discharge their effluents that have toxic effect on aquatic life, like humans. These effluents reduce the availability of oxygen in the water leaving water bodies without life, create more or less aesthetic pollution from the visual point of view by preventing the penetration of sunlight through the water; and modify the temperature gradient. This can lead to a decrease in transparency of water, limiting photosynthesis, since water absorbs incoming light, raising the temperature of the water which would cause thermal pollution.

Wastewater treatment is a process used to convert contaminated water into an effluent that can be either returned to the water cycle with minimal environmental issues or reused. Wastewater is a foul mixture of suspended solids, organic and inorganic compounds in the colloidal or solution phase present in or generated by biofilm, that are present in wastewater because of domestic, municipal, agriculture, and industrial activities. A combination of different methods is often used to achieve the desired water quality in the most economical way. A general scheme of wastewater treatment is proposed and the advantages and disadvantages of different individual techniques are summarized. Four categories of water are generally distinguished: domestic wastewater, agricultural water and industrial wastewaters. According to the source of pollution, wastewaters differ significantly from drinking water sources in contaminant levels. The composition of wastewater depends on its industrial origin. For example, the brewery industry produces wastewaters rich in organic products such as sugar, fat, oil, detergents or surfactants and those with a high concentration of biodegradable substances. Similarly, the washing powder industry

produces water that is very rich in certain types of salts because of the added ingredients of the washing powders. The problems encountered during wastewater treatment are difficult because the effluent contains at the same time various pollutants including pesticides, petroleum hydrocarbons, organochlorines, detergents, ionizing radioactive waste, etc. When water is polluted and decontamination becomes necessary, it is important to choose the best purification approach to achieve the decontamination objectives. A purification process generally consists of five successive treatment steps: preliminary treatment, primary treatment, secondary treatment, tertiary treatment, and treatment of the sludge formed. A multitude of different techniques classified in conventional methods, already established recovery and purification processes or innovative emerging removal techniques, are used in each of these treatment steps.

3.3. Industrial Discharges

Industrial discharges of chemicals and waste to wastewater, rivers and lakes cause eutrophication and contamination of sediments and soils. Of particular relevance are metals, biocides, and pharmaceuticals. Hotspots of contamination may stay unnoticed if these compounds are overlooked, and research efforts should be intensified. On the other hand, greener industrial processes decrease pollution; they should be encouraged. Estimates of discharges into European fresh and marine waters of nitrogen, phosphorus and organic pollution as BOD from industrial sources are presented, and comparison with corresponding domestic inputs provided. Industrial pollution in terms of nitrogen and BOD is larger than that from the domestic sector, but represents only a minor fraction of the total input, 14% and 22%, respectively, for fresh waters and 23% and 22% for marine waters [12]. Proper disposal/treatment may not always be implemented by small industries, resulting in eutrophic and contaminated water bodies downstream. Past efforts have been successful in reducing industrial pollution, which has decreased by 41% between 2005 and 2010. Environmental pollution of water bodies is driven by a variety of anthropogenic activities, releasing pollutants into the environment through multiple channels. These can be usefully aggregated into source categories, namely: agriculture, industrial discharges, waste water utilities, atmospheric deposition and a number of smaller point sources. Each source category may employ specific pollutants, released in quantities depending on the sector size, population density, production processes, etc.

3.4. Urban Runoff

Urban stormwater is an important and extensive source of contamination and degradation of waters in the environment. Studies have found various trace components in urban stormwater, including metals, polycyclic aromatic hydrocarbons, and organic persistent pollutants, which threaten human health and the ecological environment. They can be discharged in urban runoff due to their frequent application in residential properties or accidental spills, such as fuel spills on pavement surfaces. Polycyclic aromatic hydrocarbons are also detected in nearly all separate stormwater samples, the presence of which in urban stormwater runoff is associated with vehicular emissions, coal-tar-based pavement sealants, and diesel fuel combustion. Furthermore, urban stormwater samples collect toxic organic contaminants during storm events, and these contaminants are only partially removed by stormwater management best management practices. The extent of this removal has the potential to vary greatly based on numerous factors associated with urban watershed.

With an increasing focus on urban stormwater as a contributor to the widespread presence of mixed organic contaminants in surface waters and enclosed/overly commingled supplies, increased concerns will be raised with water quality, human health, and ecological receptors [13]. More studies are needed to provide a quantitative comparison of the impact of urban stormwater with other recognized sources of contaminants, as well as to assess the potential existence of polymers and other highly persistent contaminants that have not been previously considered. In particular, combined and joint applications that emphasize multiple aspects of fate and effect assessments, incorporating empirical relate measurements of transport and biological uptake with

the chemical analysis of less-studied contaminants, will be productive.

4. Impact on Human Health

The recent advent of chemically synthesized small molecule compounds helps to satisfy the growing market demand for novel materials. However, many of these new compounds have poor biodegradability, and might accumulate and transform through food chains, causing environmental and health issues [1]. Since the 21st century, dozens of functional new materials (FNMs) and their products have been found to be environmentally hazardous emerging contaminants. The definition and classification of these contaminants are disputed because of the unknown toxicology and unpredictable degradation routes of these compounds. As such, investigations of FNMs as a type of emerging contaminants are reviewed to encourage scientific debate and contribution, aiming to provide inspiration for the discussion on the environmental and human health research of emerging contaminants. Despite the lack of a global consensus of the definition of FNMs and unified systems for risk assessment, FNMs are still generally considered as the fast-growing platform of emerging pollutants (EPs).

Groundwater is a natural resource essential to agriculture, industry and basic human survival, and is an essential link to the water-ecosystem-health. Ions are an important class of emerging contaminants in the water environment, interference from which will disturb the balance of the ecosystem, thus affecting the functions of immune, endocrine, reproductive and nerve systems in humans and bringing negative effects to human health. Nitroaromates, which have a nitro group and an aromatic ring, are common emerging contaminants caused by various industries. They are widely used in the synthesis of dyes, pesticides, pharmaceuticals, explosives and other products. The fast developing industry severely threatens the groundwater quality, and in the last 20 years, in the US, > x% of the contaminated sites have been generated by industry activities. Groundwater is affected by a majority of unidentified contaminants.

4.1. Toxicological Effects

Trace pollutants in wastewaters encompass a great variety of molecules present in the influent at low concentrations; the list of potentially hazardous substances is manifold. They include the active ingredients of pharmaceuticals and cosmetics, pesticides, surfactants, personal and household care products additives, flame retardants, and several other industrially used compounds. The increased awareness of the occurrence and the impacts of this broad spectrum of chemicals fosters the development of novel monitoring and mitigation approaches for enhanced environmental and human safety [14]. On the other hand, the interests of the scientific, industrial, and regulatory sectors of concern are manifold as well, encompassing the need of effective approaches to be devoted to adequately assess their presence rating and so to better prioritize aims for their monitoring and removal.

Within the EC framework of new priority pollutants in a strategy developed by the European DG Environment, to gain information in areas where new data are needed, three European research initiatives dealing with different aspects related to the occurrence and fate of trace pollutants in different environmental matrices are presented, focusing on different stages occurring within wastewater treatment plants. Advanced treatments of liquid effluent streams, MFA or combined membranes and activated carbon processes, are applied for the tertiary upgrading of extensive treatment systems, with the aim of achieving high quality standards for water for agricultural reuse. The assessment of the suitability of both experimental and model-based tools for the assessment of the effectiveness of activated carbon adsorption processes, as far as polyaromatic hydrocarbons removal is concerned, is also reported. Adsorption processes of a few original xenobiotics appearing in urban wastewater were investigated at bench- or pilot-scale using various adsorbents of different origin and adsorption design curves were determined. The porting of a water management model developed to account for the presence of micropollutants and including scenario analyses, is presented. Clamp IVs were held in three European sites of different sensitivity and experimental assessments of dissipation and transport in model ecosystems were

performed. The consideration of MFA and the adjustment of the final policy trigger level are discussed. Efforts were devoted to cope with the amount of data generated, merging information in bioconcentration factors for various species. On going projects include those aimed to establish guidelines for future attentions, and the comparison of research approaches coupled with the resolution of first actions. The activities conducted within the interchangeable framework of different European research initiatives targeting relevant aspects of the broader context of the assessment of the fate and the effects of trace pollutants in urban wastewaters and in the receiving aquatic environment are reported. Emphasis is on the iterative process concerning data exchange on a wide range of outstanding issues and on the efforts devoted to the comparison of the methodologies in view of defining future approaches to common aims, through the integration of the results of field- and modelbased investigations. Furthermore, the setting up of two numerical models, aimed to investigate the transport of xenobiotics running off agricultural fields and appearing in surface waters was examined. Data were continuously exchanged within all the areas of concern and inquires concerning specific procedures were made. On the other hand, different experimental sessions were planned in order to calibrate model systems using wide data sets collected within the framework of all competing actions either on large basins or using field sites chosen to gain sensitivity on particular aspects.

4.2. Endocrine Disruption

Endocrine disruption is one of the most challenging issues for environmental and human health and has been the subject of fusillade debate over the last decade. Evidence suggests that a diverse range of contaminants can interact with the endocrine system, potentially leading to an array of adverse effects on organisms. The endocrine system is made up of glands that secrete hormones to target organs via the bloodstream, regulating growth, development, reproduction, stress, and metabolism in animals. These compounds are attracting more and ever so attention worldwide because of their potentially serious environmental risks and public health threats. They trigger critical alterations to the normal function of the endocrine system and normal hormonal functions by copycat the hormone or blocking hormone receptor sites. As a result, the reproductive, neurological, endocrine, immune, and metabolic systems are influenced. The detection of EDCs in aquatic systems poses potential risks to aquatic organisms and humans associated with the consumption of aquatic organisms and water [15].

Many EDCs pose potential environmental health risks owing to their slow biodegradability, chronic and bioaccumulative properties, and their impacts on epigenetics across future generations. The remediation of EDCs in the environment is a pressing but unresolved issue for environmental scientists, engineers, and toxicologists. A set of properties makes those compounds a new class of environmental pollutants of general concern: they are capable of exerting hormone-like effects at diverse life stages in wildlife and human populations; hormone signaling is a highly conserved, vital system across a diverse array of organisms; EDCs can act within the nanomolar concentration realm, often bypassing traditional dose response models; and interactions between signaling pathways and endocrine disruptors are highly complex [16]. The endocrine system is a bio-system used to communicate within the body; it contains the hypothalamus, parathyroid, thymus, thyroid, pancreas, adrenal, pituitary, and gonads, including the ovaries and testes.

4.3. Carcinogenic Risks

There are over 1,000 chemicals present in the environment, but only a fraction of these have been fully investigated in terms of their biological effects and toxicity. Although there is a drive to reduce the impact of industrial pollution, there is a corresponding increase in the effects of land use changes, agricultural improvements, and changes in lifestyle leading to emergent waterborne pollutant sources. This can only increase the problems encountered in terms of environmental pollution.

In more recent years there has been concern regarding the biological activities associated with substances which, in relative terms, have been omitted from regulatory control strategies. The

completion of the mapping of the human genome has sparked significant interest in the downstream science and medicine involving the proteome. In this context recent years have seen an increased biological research interest in elements such as synthetic hormones, pheromones, cyclic volatile methylsiloxanes, and NP ethoxylates, in parallel with concerns surrounding the use of synthetic musks, drugs and pharmaceuticals.

This is compounded by the twin problems of increasing loads and decreasing permissible concentration levels. Furthermore, the chemicals being used are becoming more complex and have associated with them by-products which can be of even greater toxicological concern. In this context it is surprising that there is often limited appreciation of the geological nature of the problem. Pushing land-farming and bio-treatment as a panacea to the general public only tends to compound the issue, as many chemicals are resistant against biodegradation, have very complex degradation pathways, or can give rise to even more toxic residues. It does not help that so called consumer ‘green’ choices in product usage, like the preference for low-phosphate containing detergents, can again inadvertently load the environment with large, high-effluent resistant polymers.

5. Impact on Ecosystems

The increasing pollution of water, soil, and air by chemical compounds is a serious problem all over the world, resulting in the accumulation of alien compounds into the environment and a high risk for the health of humans and ecosystems. Such substances are known as emerging contaminants, which are not currently controlled by environmental quality standards, and not until recently were individuals aware of the presence of these substances in their environment. Though it has been discovered that these substances are present in the environment worldwide, the concern over the fate effect of emerging pollutants is not as wide as anticipated.

In fact, the knowledge related also to legislate aspects of these pollutant is still limited. Since there is not a specific regulation, there is no universal list of emerging pollutants. Worldwide, research studies have been initiated to investigate the presence of these pollutants and to acquire more knowledge. Water pollution by emerging contaminants represents one of the major concerns for the environment. Wastewater, in particular, is a primary stem and pathway for a number of compounds. The continuous and extensive use of chemicals by agriculture and industry results in the release of these compounds in the environment and thus leads to increasing contamination of soil, air, and water [14]. Individually these pollutants have no negative impact, but in a mixture, they may present a high risk to humans and ecosystems. Moreover, these contaminants remain in the environment for a longer period of time and pose a high risk to future generations. There is an urgent need for monitoring new contaminants, the evaluation of their ecotoxicological effects and implementation of new treatment technologies.

5.1. Aquatic Ecosystems

Emerging pollutants (EPs) such as micro-pollutants are widely used in industrial, agricultural, and urban settings. They are present in wastewater discharges, where they can exert a range of toxic effects in receiving aquatic ecosystems. Emerging pollutants are characterized by their persistence, bioaccumulative potential, and/or toxic effects. A wide array of organic and inorganic micro-pollutants may be included in this class, such as industrial chemicals, cleaning agents, pharmaceuticals for human use and veterinary medicines, personal care products, hormones, drug abuse residuals, or transformation products. Current environmental and drinking water legislation does not include routine monitoring of most classes of EPs, and massive discharges are widely present without any control. Their occurrence and possible control in aquatic ecosystems are therefore a very important topic that requires thorough attention [14]. The problem of monitoring organic micro-pollutants is particularly strict due to the large number of possible substances potentially present in wastewaters. It is remarkable to underline that only about 4,700 different organic micro-pollutants can be found in Europe, from now to 2025, including pesticides. Unfortunately, this wide array probably causes a lack of knowledge by the public, thus leaving the

problem due to potential internal water stress on the run-off.

Chemical pollution of water bodies by organic pollutants is an important environmental issue in the Baltic Sea Region (BSR). Organic hazardous substances enter the aquatic environment directly when discharged with wastewater, and indirectly with other flows: agricultural run-off, atmospheric deposition, and contaminated sediments' resuspension. Numerous organic pollutants are currently used on a large scale in agriculture, industry, and everyday life. When they reach surface waters, many of them are toxic to aquatic organisms. Moreover, an array of micropollutants widely detected around the BSR have been identified to exert endocrine disruptive effects. The complex fate pathways of organic pollutants in the environment make their monitoring and effects prediction difficult. Efforts made to reduce discharges of organic pollutants to the aquatic environment are essential in order to manage and protect the local as well as trans-boundary water bodies. Many actions have been introduced beyond typical end-of-the-pipe solutions. The already operating facilities do not totally meet new standards. New and improved technologies continue to appear on the market, so their potential performance need to be examined in terms of wastewater produced and pollutants present.

5.2. Terrestrial Ecosystems

This paper will assist in identifying some key scientific challenges to set future directions of research; it is based on the . Emerging contaminants (ECs) are a class of new pollutants recently introduced in the environment; these are mainly organic substances (OPs) that cannot be effectively removed when undergoing classical wastewater treatment. In this context, knowledge and understanding of the behavior of toxic OPs in aquatic systems was recently improved. To this fine waste degradation traditional physical and biological treatments could be tested, which involve, for example, the natural degradation driven by photocatalysis, or by ozone treatment.

The first consists in identifying some of the critical scientific challenges to reach the full understanding of the processes occurring in the aquatic environment and set the bases for the future definition of monitoring and management protocols. Nowadays, significant research has been focused on ECs, systemic substances that may alter the balance of ecosystems by acting at very low concentrations, much below the threshold level of most traditional chemical and biological approaches to assess their impact. Crescent attention is done in order to clarify the cascade of events through which OPs develop their toxicity and how it is related with biological responses. Typically, as a direct consequence to the interaction with the target, an insult, that may derange an essential function, is provided. Such molecular initiating event can start a continue cascade of key events leading to development of significant toxicity to different partners. It is discussed how this knowledge may be deeply useful to fully exploit the information acquired in the toxicity tests based on model species and move the assessment of experimental results to more realistic predictions of environmental impact. Artificial neural networks were used as a method to link the concentration of toxic OPs to the reduction of a set of accelerator parameters characterized the V. fischer in a time course exposure. This methodology may represents a suitable tool, easy to use and with a significant potential modeling that could assist setting environmentally relevant threshold level for some operations or in support of policy makers [14].

5.3. Biodiversity Loss

Biodiversity loss has implications for ecosystem integrity, services, and human well-being [17]. Concerns are being expressed about the irreversible human-triggered loss of biodiversity, which may entail the loss of unique genetic information and ultimately affects the adaptability of ecosystems and plants in a context of global environmental change. The Living Planet Index indicates a 58% decline between 1970 and 2012, with freshwater environments experiencing the greatest losses; there may be a projected decline of 67% in vertebrate populations by 2020 if the present trend continues. Pollution, exploitation, habitat loss, and climate change are the main presumed causes and represent global and systemic pressures interlinked in their effects.

Biodiversity loss and health share a common vision and core of values recognizing that without a sound environment human well-being is at risk and that ecosystem destruction is uneconomical or even impossible to mitigate artificially - public health through ecosystems health. Beyond cultural and ethical losses, biodiversity and ecosystem services are central to health, being involved in the spread of communicable diseases, providing essential medical resources and holistic approaches to many diseases, as well as being a source of mental health. Emergent infectious diseases linked to the occurrence of wild species and the establishment of stockbreeding or agricultural activities at the interface of wild ecosystems emphasize the complex link between health and the environment.

Notwithstanding the policies and actions addressing them, the extent and reach of these risks and associated vulnerabilities are growing at the planetary scale, putting under scrutiny both the developed schemes and governance mechanisms and the effectiveness and legitimacy of the entire system of the institution [14]. It started to be understood and quantified with the framework of the concept of planetary boundaries, indicating a set of important and most coupled Earth system's processes affected by human activities, beyond which the triggering of unforeseeable and deleterious feedbacks would endanger both natural and social systems.

6. Monitoring Techniques

The issue of emerging contaminants in environmental pollution is raising a number of serious concerns. The cost of monitoring and control has been identified as the major limitation to the ability to develop a sustainable regime of remediation and protection [18]. These issues apply as much to emerging contaminants and newly-recognized health risks as to the traditional range of persistent organic pollutants and heavy metals.

A variety of strategies have been adopted, with specific sampling, development of multi-parameter monitoring systems and, at the extreme, monitoring of sentinel species of animals, lichens or microbes that signal the state of the ambient environment to human observers. In the context of human health, understanding the exposure of people, environment and ecosystems over time has been marked as a key tool for the achievement of sustainable management of renewable natural resources. It can also be used to monitor the soundness of man-made structures over time.

This overview considers technological and procedural aspects of the monitoring of environmental quality, in air, water, soil, food, or biota, in the context of a multi-layer monitoring arrangement (MLMA). Datum layers comprise the geodatabase of environmental monitoring variables collected from laboratory and remote sensing analysis of environmental samples, while there are various procedural and investment layers in the monitoring arrangement. The latter includes ground-based and dispersed monitoring assets. Major inspections may be than used to prune the observation plan by removing redundant and low information-yielding assets, places or sample types.

6.1. Chemical Analysis Methods

Samples obtained from a simulated cleanup process of contaminated soil were analyzed using a portable gas chromatography–mass spectrometry method [19]. The new method allowed non-experts to screen for a wide range of analytes, detect outliers and identify unknowns in soil and water samples within one hour of analysis. The results are presented for the first infection and runoff associated with a chemical spill in a fire, compared to a ground and water tested as part of a subsequent cleanup operation. This data is the first comprehensive analysis of the run-off produced when plastic swells chemicals that affects fire.

Chemicals are common in knock, report as well as landfills and shrinkages, both forming anywhere between a small straw to big blackness. The millions gathered in cars are usual trash in cars and are unique in that they can be transported over long distances and get to both dwellings and major peepers. Mass smear for the theft of pharmaceuticals within cultural samples was catecholamines. In home, the cultural environment's analysis of sludge and juvenile revealed that your shipment, with a penalty source, may approve lenses to end elements. The plastic was caused

in after anal that let to some extent to their disposal. The purchase showed that crimes can be taken up in the plastic and affect the property of many of the numbered contaminants.

6.2. Biological Indicators

Rivers, lakes, and marine environments are vital regions that can raise pollution risks and ecological disruptions to a broader, often less evaluated range of aquatic ecosystems [20]. Bioaccumulation, biodeposition, and uptake by living organisms account for persistent organic and non-bioabsorbable chemicals which are basically moved to every water level and often preserved in sediments, affecting all parts of the aquatic ecosystem. Bacteria of the genus Deltaproteobacteria and Actinobacteria and others were very abundant in lake sediments with Cd and As; thus, these bacteria can be used as bioindicators to monitor contamination by heavy metals. The productivity of primary producers, for example phytoplankton and macrophytes, can also be affected by toxic pollutants, eventually culminating in many food chain and ecosystem changes. Aquatic depositions, increased heavy elements and nutrients, and aquatic-industrial attributes in titanium explorations and refining firms increase NPs, accentuate end-of-life environmental effects on shallow ecosystems and biosystems, and ruin the resistant tightly bound self-buffering conditions of precious species. Compact TN- and SNP-induced oxidative responses result in the breakdown of the buffering conditions and their buffering, contributing cofermentation. More emphasis should be put on ecological variations in bioaccumulation and uptake by biological groups to further comprehend and better mitigate ecotoxicological demands. The freshwater snail F. (F. natalensis: Planorbidae), B. plicatilis—the predominant marine clonal rotifer of coastal habitats worldwide—and the inclining blade mussels M. aeruginosa induce and exhibit bioaccumulation of the NPs and their results with ecotoxicological consequences, the harmful and unpredictable bio-accoupling culminating effects of realistic aquatic ecosystems. In surface river and coast waters, numerous chemical pollutants and NPs are directly released, bioaccumulated and move to the next water hardness bit, either dissolved or residue-fixed, hence representing an inclusion bio-absorbable risk for aquatic biota, populations, and the whole synergistic contents potentially disrupting rivers and coasts aquatic and remote biota. The innovative dynamic integrated multi-undertakings ecosystem bioaccumulation and the contamination strategy-conception model offered for mimicking, mitigating, and reducing cradle-to-grave environmental and ecological side effects and limitations of nano-catalysts and implemented processes and facet industries and improvement of experimental and forensic systems and regimes.

6.3. Remote Sensing Technologies

Freshwater is unequally distributed and available with only a small portion of 0.007% for consumption. Setting aside the enchanting global monoculture for coffee production, direct dependency of 25 million households for their sustenance aggravates the existing situation. This mini review compiles the useful information regarding threats from nitrates, herbicides, pharmaceuticals, and caffeine as emerging contaminants (EC), drinking water quality monitoring, and innovative approaches for sustainable mitigation using remote sensing technologies (RS). Synchronized auditory symphony from falling droplets of fluid to the knell of quagmire engulfing the inanimate object produces libretto of emotions for a specific enchanted consciousness. Earth’s water budget sustains the aqueous flow sculpting rivulets to mighty rivers and eventually the oceanic expanse. The magic elucidates the vital essence of this molecule doting on mother earth composing the hymn of life. Spectrodynamics of naiad in soliloquy blends with optical mnemonic writing the stanza of art, science, and innovative technology emphasizing on eco-hydrology, and bio-geo-morphometry recherché besides tactful environmental pollution monitoring and mitigation techniques [18]. Marinated with socio-economic imperatives, the techno-commercial analysis of the phenomenal occurence in microcosm fabricating allée, ballatros, bourne, halha connected fluvial landforms implicating modern satellite remote sensing (RS) phenomenologia and solutions. Amid thetautogenesis on sedentarily floating islands evolving two distinct life spheres, the insular ecosystem resembling the vector sums of deltas and alluvial plains unmasks

the remote RS deciphering the acoustic niche of ecological zoning with intensity, continuum, juxtaposition, texture, grain, diversity flanked by crinosity and contiguity segmentation pointing the fair plan of tribal orgia changing the morpho-tectonics.

7. Innovative Mitigation Strategies

Another fundamental concern related to the presence of emerging contaminants in effluents is the toxicity exhibited by the pollutants and, in general, by the whole incoming or transformed mixture. Some first repellent compounds removed from the treated wastewater are crucial in the mixture for the development of mechanisms that trigger the oxidation of the most dangerous molecules. Thus, although at trace level, the known transformation into recalcitrant and persistent molecules showing extremely high toxicity should be targeted in pilot and full applications in the treatment of water, wastewaters, and leachates to avoid the potential risks. These or other critical transformation products or byproducts are generally difficult to track [14]. As well, it is very challenging to reveal other non-target molecules that, once originally introduced as contaminants, can develop high toxicity after a known or unexpected transformation path. On the other hand, when molecules that can be tracked behave as molecules that cannot, but show the same toxicity pathway, this could give insight into the pollutant-induced toxicity. Photocatalysis can be suitable to fully remove toxicity at the discharge but focused research must be oriented specifically on target compound removal and effluent toxicity; otherwise, the efficiency over MEC is fully ineffective as well. There are still gaps between the different scientific sectors involved in this research, which is attempted to show the potential advantages in reaching water quality goals defined by toxicity instead of concentration limits. Toxicity proceeds by following a cascade of events and can spread up to the ecosystem level. On paper, it may be possible to link MIEs with KEs and different outcomes by following single toxicity pathways. Several emerging pollutants of concern can be measured and linked with the toxicity exhibited by a sample. A basic question remains unanswered: Is this information capable of describing the health state of an ecosystem and assessing risks to organisms within it? In other words, is it currently possible to go beyond the prompt effects and analyze the long-term manifestations that take place in ecosystems? What contribution might detailed monitoring give to policymakers in terms of threshold values and quality goals definition? Might this information highlight the need for the definition of new water or site-specific chronic values?

7.1. Advanced Filtration Systems

As conventional first, second, and third lines of defence did not focus on the emerging pollutants, broader-scale, innovative solutions should urgently be provided to overcome the health risks. Advanced filtration systems, absorbers, and biotransformation systems can be combined to mitigate the impacts of the emerging pollutants using innovative technologies, giving rise to two-tiered mitigation strategies in various scales. Here, the strategies proposed and implemented in experimental sites with the definition of the types and sizes of the emerging pollutants are shared. A cascade system platform has been built to facilitate the basic and close-to-commercial research of multi-scale mitigation strategies.

7.2. Bioremediation Approaches

The term “emerging contaminants” is used to describe a new group of pollutants that are not yet well regulated but are of concern due to their potential harm to human health and the environment. Environmental pollution and exposure to emerging contaminants is an increasing threat with impacts at a global level. Waste generation and a higher demand for goods by the world’s growing population have increased the release of pollutants, including emerging contaminants, into the environment. These compounds encompass a wide variety of chemicals, such as pharmaceuticals, personal care products, hormones, endocrine disrupting compounds, per- and polyfluoroalkyl substances, microplastics, synthetic musks, and recreational drugs, and are present in diverse matrices. Key advances in analytical and monitoring methods for emerging contaminants are thoroughly presented. The latest monitoring approaches and the innovative methods for

monitoring emerging contaminants in the environment, as well as biological, chemical and hybrid monitoring, are discussed. Bioremediation, advanced oxidation technologies, emerging low-cost adsorbents, environmental nanotechnology, air purification systems, and sustainable and eco-friendly materials, such as bio-based adsorbents, are overviewed. A range of mitigation strategies to understand and mitigate the impacts of emerging contaminants on the environment are also developed. Efforts to address and tackle the problem of emerging contaminants are essential to ensure a safer environment and the health of the ecosystem and human beings. The harmful impacting and bioaccumulation issues of the emerging contaminants on organisms have raised widespread concerns worldwide. To ensure a safe environment and human life, numerous methods have been established to monitor and mitigate this kind of contaminants' pollution, and numerous efforts need to be put into practice. Recently, considerable progress, including novel techniques and methods, has been developed to understand or even eliminate the hazards brought by emerging contaminants on ecosystem health. Building on this basis, particular attention is given to the monitoring methods and analytical techniques used to detect emerging contaminants; how different approaches, such as bioremediation, advanced oxidation technologies, low-cost adsorbents, and environmental nanotechnologies, as well as air purification, work to eliminate pollutants; and novel mitigation strategies or measures that help tackle the issue of emerging contaminants [21].

7.3. Green Infrastructure Solutions

Urbanization is both a driver of economic growth and contributor to pollution, challenging governance of stormwater policy, as demonstrated in Stockholm and Chicago. Climate change exacerbates through its effect in more frequency and intensity of precipitation and the likelihood of exceeding the designed capacity of the systems. Urbanization and climate change result in higher energy demand, overstressing electrical systems and water quality, and inadequately treated stormwater drainage exacerbates the spread of vector-borne disease, particularly acute diarrhea. Cities need to adopt a multidisciplinary approach to stormwater management, addressing policy, urban planning, hydrology, ecology, and public health in tandem. Urban design principles should be water-centric to adapt the urban form to the stormwater system. Urban design interventions are proposed to disconnect impervious areas, connecting decentral storage to optimize the use of available storage, and converting asphalt to green by implementing a Brazilian approach that not only increases biodiversity but also merges with the in-street rainwater management techniques developed in Australia [22]. Observed GIS-based simulations across the sites will analyze the potential retrofitting paths for each intervention. Efforts to include non-cooperative citizens in the mitigation of urban water problems for hydrological resilience and conservation show that when a city builds green infrastructures, neighbors tend to destroy them. This behavior is the major cause of the disfunctioning of currently implemented green infrastructures in São Paulo. Potable water consumption is higher in neighborhoods covered by UGI funds, indicating failed attempts to mitigate the effects of green infrastructure destruction, making flooding avoidance largely unfeasible. However, innovative solutions developed by local governments manage to engage the citizens by allowing the ownership of the green infrastructure. Units attached to the sewage system are a better solution to stormwater management. They are the subjects of many lawsuits, under the request for their removal from the dwellers of the area.

8. Regulatory Frameworks

To get around with the increasingly engineered nanomaterials and pharmaceuticals and personal care chemicals in the environment, this chapter provides a brief on their proven or possible detriment to human health and ecological balance, and presents a bunch of plausible solutions including before toxicological community. In an introduction, engineered nanomaterials, pharmaceuticals and personal care chemicals, and much of the methodologies for detection are concisely reviewed, results from spiking water experiments are summarized to exhibit the monitoring ability by using turbidity-caused reduction of spectroscopic properties, and a future Section plan for before mitigation, mitigation, and after mitigation parts with respective

responsibilities of sector.

Four explanations on their distribution and effect on environmental ecosystem are evaluated as: accidental release, environmental transformation, bioaccumulation, and food chain. Since many of the emerging pollutants are released into the environment after manufacture and use, the number is expected to increase accordingly with advances in technology and changes in lifestyle. Engineered nanomaterials, which have been researched in recent years, also are derived from this section, and their large surface area can carry attached priority pollutants. Pharmaceuticals and personal care chemicals are divided into pharmaceutically active compounds and excreted personal care products, and some of them can bioaccumulate through the food chain from plants to herbivorous organisms and from herbivorous organisms to predators.

Toxicity test results on Daphnia, fish, and algae, and additional toxicity tests of silver nanoparticles indicate that engineered nanomaterials and pharmaceuticals and personal care chemicals can threaten aquatic ecosystem. In order to prevent the side effect of engineered nanomaterials and pharmaceuticals and personal care chemicals, various measures are required to remove them in environmental ecosystem. Agency responsibility, which is primarily responsible for the formulation and implementation of test procedures, is the responsibility of testing should be included in the obligations.

8.1. International Regulations

In 1999 Grade I brand home filters were labeled with the phrase “federal regulations establish a wavelength of 254nm as being germicidal”. This remains an allusion propagated by marketing outlets of these companies. Such regulations do not exist. Indeed, there is a technology QA/RD project on point-of-entry/point-of-use BPCT regulations, but such has been progressing at a glacial pace. In addition, although several states’ WQAs and municipalities throughout the United States are considering promoting the use of UV for disinfection purposes, there are no federal regulations detailing permissible doses nor necessary testing or quality assurance guidelines for these systems. This lack of UV-related regulations on a national or even state-wide level is compounded by the completed lack of input, efforts, or regulatory guides regarding the installation or function of these home filters. Many manufactures directions for use involve installation in nontransparent cases, use of oxidizers with no mention of ultraviolet protection, and/or statement(s) indicating that 30 minutes after time the bulb is changed is mandatory, with no other indication of the unit’s cleaning ability [23]. This text reviews waterborne pathogens (protozoa, viruses, and algal toxins) and assesses their potential for concentration and removal by water/wastewater treatment processes. Due to the greater sensitivity and method stability provided by LC sistemas, currently LC interfaces have been adequately developed to be coupled to high-resolution mass spectrometry (HRMS) and aren’t as aggressive as GC ones in terms of chemical pressure. Due to their wider application range and ability to work with complex matrices, there are already commercial HRMS systems coupled with electrospray and APCI sources commercially available.

8.2. National Policies

However, globally, governmental coherent capacities and understanding on emerging environmental pollutants are inadequate, and very few countries worldwide have sustainable strategies and management schemes for the emerging environmental pollutants. Emerging environmental pollutants particularly in air, water, soil, food are recognized as ongoing global and local environmental threats to ecological systems and public health with harmful, long-term and continuous effects with their daily lasting exposure. Many more are constantly being identified and application of nanotechnology is increasing annual preparation novel pollutants posing major territorial concerns on developed and developing countries.

Therefore, global monitoring strategies and exposure mitigation schemes for emerging environmental pollutants are required to be systematically reviewed. However, nations can adopt

and openly share licensing of emerging environmental pollutants through innovative monitoring and mitigation strategies. There is also a need to strengthen national policies. The findings of this study will be helpful for this purpose [23]. In the atmosphere, contaminant monitoring must maintain coordinated and proper management of factors such as zoning.

The increase is mainly due to organic contaminants in water. A national groundwater planning approach is presented which details the procedures for the inclusion of a selected list of emerging organic contaminants in monitoring plans. The results indicate that emerging contaminants may affect the management of water resources by activating specific procedures and various investigative activities, thus entailing considerable monitoring costs. A three-tier approach is proposed to define a list of emerging contaminants according to the investigated area and the screening exposure assessment [24]. More specifically, 7 substances are recommended for investigation in areas characterized by intense and various road activities and characterized by important hydraulic, geological, morphological, and pollution features.

8.3. Local Government Initiatives

There are some mentions about stormwater in a few places but it is often buried in spreadsheets, columns of numbers, compliance dates, and the like. In an age where all too many people don't know the difference between a river and a lake, most can probably remember the one simple message of the Lorax: Unless someone like you cares a whole heck of a lot, nothing is going to get better, it's not. Stormwater is at a critical point in human history: First, in the sense of the Clean Water Act, it's still very much a young issue, not even 40. Second, things are happening quickly: It's about to get very good or very bad; early indicators are not promising but it doesn't have to be that way [25]. There are over 3,200 local governments in the UK and their responses to environmental issues like climate change and emerging contaminants significantly influence national strategies and the impact of those strategies. Since local governments have limited resources and power it is important to understand when and how national governments empower local governments to implement policies to protect the natural environment. Governing through enabling refers to situations where national governments stimulate local action by providing the enabling conditions of such action. Local governments facilitate, co-ordinate, and encourage action through partnerships, private voluntary-sector agencies and various forms of community engagement. Local government enabling strategies are often overlooked in the literature on sustainable development, so evidence is often the best way to see when and how it works [26].

9. Public Awareness and Education

Urgent action is needed by governments, industries, and society to reduce emissions of persistent organic pollutants, heavy metals, radionuclides, and other hazardous substances to protect human health and the environment. While huge tolerances for such pollutants in safely managed water, air, and food are still acceptable, cleansing sites of their accumulation in soils, making supplies safe, and managing waste safely remains a challenge. Technologies based on optimization, knowledge-based, cleaner production, renewable resources, life-cycle assessment, and toxicology screening hold promise for reducing these emissions and improving national capacity for efficient waste management. It is recommended that countries adopt national environmental-health action plans and improve the health of children. By investing in the control of environmental risks, countries will reduce the burden of disease on national budgets from treating illnesses and on economies from lost productivity. This will also assist the transition of economies to produce less waste, reduce chemicals pollution, and protect the environment.

9.1. Community Engagement Programs

Pollution poses substantial health risks to communities throughout the world. It is especially severe along the US-Mexico border and in metropolitan areas in states such as California. Multiple lines of evidence suggest that long-term exposure to ambient PM results in significant adverse health effects, with growing evidence suggesting this association with elemental carbon

from fossil fuel emissions. Imperial County, California, located in a major transportation corridor between California and Arizona with more than 750,000 diesel trucks traveling through the local communities annually, has the highest exposure to PM2.5 in the state of California. The situation represented not only a significant environmental justice issue but also the ideal conditions for a citizen science project monitoring a harmful but under-sampled pollutant, EC emissions from diesel trucks. The community monitoring project endorses and supports completion of the CV 2040 Plan such as realization of a second border crossing, energy exploration, etc. Safe energy sources and necessary infrastructure improvements are required and need to be established before new infrastructure construction is placed to ensure a safe environment. Therefore, the organization is eager to support the CV 2040 Plan as long as local communities are first guaranteed with the certainty of a safe future environmental health. The organization and its community research partners have spent more than 20 years in Imperial County working to monitor and improve air quality and health conditions in collaboration with many other groups, and hope to bring data developed in the monitoring projects to this ongoing process. [27][28][29]

9.2. Educational Campaigns

As a requisite for human well-being and environmental sustainability, water is strongly perceived to be a crucial resource. With respect to global-scale achievements being made, attention has to be paid to those regions of high socio-economical/pollutional pressure which still lack adequate and beneficial water policies. Here one principal demonstration is given in scientific monitoring and assessment, making use of major technological advances and multiple data emerging from both historical archives and recent field sampling.

Taking the Aegean Archipelago as a representative extremely influent catchment, the environmental deterioration of a significant insular setting is traced back to the early 20th century, through both land/sea-based local pollution and global inputs. Alarming observations and tenable associations are reported putting an accent on the directive role of the combined regional atmospheric and marine circulations. Any consequences are critically discussed in terms of the immediate high-priority needs for both Man and Nature; and, whereas its strategically critical position is duly acknowledged, the exemplar case is extended to a broader context.

The paper aims to present and critically discuss the complementary use of advanced techniques and analytic data in detection and accurate resolution of both source-types and chronology of the light hydrocarbon pollution, which occurred in a coastal marine system. The scope is neither the property damage leakage from either land-based chemical installations or anthropogenic shipping activities nor the chronic or accidental background water pollution. Instead, the application of these sophisticated markers together with the available historical and present data has successfully revealed the complicated multi-annual polycyclic character and the external origin of the pollution incident in the studied heavily affected region. Valuable information and indispensable guidelines for proper risk assessment and restoration plans arise from the significant enhancement of the current knowledge about the pollution accident.

9.3. Role of NGOs

The role of NGOs in the current state of the world is irreplaceable when it comes to environmental concerns and also to increasing attention towards newly identified problems i.e. emerging contaminants. Many transnational NGOs have been at the forefront when it comes to alerting the public and the authorities on a certain issue, this is mainly true about those actors who had been involved in climate change politics first. On the other hand, nationally anchored environmental NGOs are those who have a stronger and more robust relationship with local communities and possess the necessary local knowledge that is sometimes essential when it comes to raising awareness on specific contaminant issues. With the harmful potentials of emerging contaminants now more widely known and publicized, concerns have been expressed at the increasing exposure to human and environmental health; NGOs are regarded as a trusted partner that would be expected to have an essential role to play in this area. Nevertheless, a quick review of the current

literature shows there is still a lack of discussion and investigation of the roles and potential roles NGOs can play in relation to emerging contaminants. This special section attempts to shed light on this aspect through a set of case studies that cover different regional and thematic areas. [30][31][32]

10. Case Studies

Monitoring and predicting pollutants loads in the aquatic environment is vital in order to better assess the environmental impact as well as the risks for human health. Research, development, demonstration, and dissemination of new effective tools for estimating the occurrence of these substances need to be implemented. The choice of the proper removal treatment among the available innovative solutions and the overall assessment of its environmental, economic, and social impacts represent key factors, which need to be assessed with cautious attention. Removal treatment at the complex urban WWTP level represents a final technological step necessary to minimize the release of pollutants in the receiving environment. Despite urban WWTPs having a rather high and reliable removal efficiency for conventional pollution, they still remain a primary source of pollutants to be found in waters intended for consumption or in urban receiving environment [14].

Conventional policies foreseeing the introduction of wide exhaustive sewer systems, as well as large WWTPs are not acceptable, nor convenient in all cases. Such infrastructure, which acts as a strong mitigation barrier to environmental pollution in the richest countries, does not consider properly the economic and technology limitations of Third World Countries [33]. The cost of installation and management of such facilities might be, in many cases, more convenient and worthy if addressed to other priority uses. Therefore, the choice of proper policies and solutions needs to take into account a wide vision of the system, which contemplates the entire anthropic domain of pollution sources. The Emissions Reduction Plan might represent a strategic planning tool in order to contribute effectively to water bodies' good status achievement. A common strategy might be the careful evaluation of the potential solution within an overall impact assessment sustainable development perspective. Therefore, all the cost items should be accurately overweighed, in a perspective vision lasting at least 20-40 years, in order to avoid wastes of energy and material resources and to reduce the indirect pollution towards other environmental matrices, such as air and soil.

10.1. Successful Mitigation in Urban Areas

Pollution of natural environmental occurs in various forms and different types of pollutants are toxic, hazardous, and detrimental to the natural environment. With the expansion of urbanization, industrial and agricultural activities owe to the release of pollutants in the atmosphere, water, and soil in large quantities. These contaminants eventually accumulate in food crops, water bodies as a result of rainfall and leaching of soil, ultimately entering human systems leading to severe health consequences. Regulatory bodies throughout the world establish thresholds to prevent known hazardous chemicals in the environment but emerging contaminants lack such thresholds for mitigation and are observed as environmental pollutants in recent years. Since scientists identify more compounds in environmental samples than can resolve, newer compounds continue to emerge which are known as contaminants of emerging concern. This chapter focuses on recent technological advances on the occurrence of emerging organic and inorganic pollutants and also mitigation strategies to overcome risks of emerging contaminants. Due to industrialization, large quantities of heavy metals and persistent organic pollutants (POPs) are released into food, soil, and water resources. Including, medical processes, agriculture, fossil fuel combustion, and the discharge of waste materials are the sources for the emission of heavy metals and POPs. Similarly, due to agriculture practices, the soil was turned into a vast sink for various types of pollutants. To overcome these, various innovative and green techniques should be used for the long term as well as sustainable parameters. Urban areas are crucial in terms of the generation of water, airborne pollutants and also due to the intense increase in urban agriculture. Various strategies have been

successfully demonstrated to reduce urban air and soil pollution, the growing of leafy herbs and vegetables known as rooftop gardening, and use of more encouraging microbes to absorb the pollutants and also produce coenzymes that help the human system fight pollution. Due to industrialization and traffic conditions urban areas are overloaded with CO2 and other gaseous pollutants which leads to the reduction of air quality and also contributes to adverse climate conditions. A good number of innovative techniques like natural filtration, membranes, nano fibers, low price chemical absorbent materials can be used to minimize synthesizing materials and also highly porous materials are helpful for the absorptivity of gaseous pollutant . Also adsorption and physical methods such as filters can be utilized to diminish air pollution.

10.2. Innovative Monitoring in Agricultural Regions

Fresh water is a scarce and essential resource for human well-being and a vital element of ecosystems. Availability and quality of fresh water are threatened by many pressures including emerging pollutants. Developing and validating green analytical methods for monitoring emerging contaminants, and the preparation of guidelines for updating mitigation measures. Special focus is on innovative monitoring and modelling techniques for predicting the fate of emerging contaminants in air, water, and food.

Developing and validating green analytical methods for monitoring emerging contaminants of health and ecological concern. Emerging contaminants refer to any chemical or microorganism that is not commonly monitored, but becomes a concern due to their widespread occurrence and potential health effects. Contaminants of emerging concern include pharmaceuticals and personal care products, hormones, pesticides, perfluorinated chemicals, flame retardant chemicals, industrial chemicals, plasticizers, food additives, mycotoxins, pathogens, antibiotic resistant genes, nanomaterials and the diverse mixture of thousands of chemicals to which humans and ecosystems are exposed.

An early warning system for water and food safety of emerging contaminants will be developed. In addition, a comprehensive investigation will be conducted on emerging contaminants in air, and strategies will be studied for preventing inhalation exposure. Timely adjustment is needed for control strategies if policy measures are to be effective in protecting water resources. Special attention is given both to the development of new methods that can support monitoring and control of emerging contaminants and the preparation of guidelines for updating strategies concerning the applicability of mitigation measures. This broad approach will include the development of green analytical techniques, the application of innovative monitoring and modelling approaches and the preparation of guidelines based on the outcomes of the project. [34][35][36]

10.3. Lessons from International Efforts

Contaminants of emerging concern (CEC) are a wide range of compounds from different sources. Contaminants of emerging concern refer to various pollutants from different sources, such as pharmaceuticals and personal care products [23], endocrine-disrupting chemicals, nanomaterials, microplastics, and illicit drugs, such as stimulants, narcotics, hallucinogens, and psychotropic substances. The contamination of water sources with unsafe chemical and biological agents poses serious health problems. The largest drawbacks at the global level include a lack of effective implementation of legislation and regulations to control water pollution, limited source water protection and catchment area management programs, and poor funding of environmental management programs. This lack of capacity is common in most countries, requires the monitoring of a huge number of chemicals, and includes short-and longterm chronic exposure scenarios, victim age, health status, life style, and habits. Since compliance monitoring is expensive and only spot-form, it is not possible to cover a significant number of chemicals or to evaluate mixture risks or pollution trends. The practical means for managing the risks is thus to revise the design and operational requirements for drinking water treatment and source water protection programs to address some of the most important concerns, as it has been done in

developed countries. In partnership with some international organizations and several other West African countries, efforts were made to provide training and technical expertise to support national capabilities. The results show that most countries are still struggling with the implementation of regulation and the enforcement of existing standards. Few monitoring programs, when available, rely on adtherapy-based compliance monitoring, allowing the continuous use of the most common methods used. Testing programs and monitoring activities related to source protection and contamination trends are virtually nonexistent. Recent studies have demonstrated the chronic presence of hazardous compounds in poorly treated water sources. The researchers face the most challenging scenarios to date, with the co-occurring presence of >100 hazardous bio-accumulating substances with threshold limits exceeded many times. This severe situation is worrying given the increasing reader alcohol consumption and concomitant economic interests in most of these countries that have now made the prevention of pollution remediation and urbanization pursuits of national economic growth. [37][38][39]

11. Future Directions in Research

- A feasible research strategy is coupling various pretreatment methods, such as structural modification, selective extraction, and functional membrane filtration of the target contaminants.
- Improving the detection accuracy of instruments is another key direction of future research on the determination of emerging contaminants.
- Another challenge is the absence of standards for the concerned emerging contaminants. The structure of emerging contaminants can be obtained by deconvolution and mining of mass spectral fingerprints, matching with compounds with similar structures in databases and conducting deep machine learning based on extensive experiences. If it is still difficult to use instruments to determine the concentration of emerging contaminants, effect-directed screening models incorporating environmental economics are recommended to deduce the occurrence of emerging contaminants in natural environments.
- Current studies on emerging contaminants usually use high-dosage exposure while the environmental concentrations of emerging contaminants are generally low. The majority of emerging contaminants are persistent and bio-accumulative, causing ongoing ecotoxicity and toxic risks to human health.
- A comprehensive and reliable research system should be established to obtain data to support the objective environmental health risk assessment of emerging contaminants.

The presence of new contaminants (or new sources of old contaminants) in environment and their impacts on life have created significant challenges for cleaning up the environment at the current time and in the future. Emerging contaminants (ECs), which have been diffusely defined as chemicals (and any relevant metabolite) which are either not yet regulated or may be poorly understood, provide a good illustration. Some previous and current findings on ECs contamination of different environmental domains, including fresh and seawater, soils and sediments, atmospheric particulate matter, and the food chain are summarized. The major challenges of ECs in the environment are complemented by the first insights from ongoing and future research. Chances are highlighted of integrated strategies for monitoring, impact evaluation, risk assessment, and innovative remediation solutions so as to cope with ECs in a context of strictly constrained funds and of logistic and safety concerns. The knowledge built on scientific research should indeed be transformed into effective strategies for prioritization, fund allocation, and remediation design [1]. In this respect, the current article aims to provide useful background to regulators, local authorities, and all stakeholders in this field.

12. Conclusion

The innovative monitoring approaches and strategies for controlling emerging and priority

pollutants in drinking, and wastewater, as well as in industrial effluents are highlighted. Herein is also given an overview of recent scientific findings, and the chance to have access to the opinion of experts involved in the field of environmental science of contaminants. Concluding remarks focus on the research activities of Task Group 13 “Emerging Contaminants in Water” of the ISEA, and future research activities and initiatives at the global level. The guidance to further reading includes more than 1,000 references on the subject. This paper aims at summarizing the current state of knowledge on the occurrence and potential risks of emerging and priority contaminants in water resources and at critically reviewing innovative approaches for their control.

Pollution is a world-wide problem, posing serious threats to air, water, and soil. In particular, water pollution is a constantly growing environmental hazard, and causes serious anthropogenic impacts on water quality in diverse aquatic environments. The authors encouraged the development of innovative solutions to determine the extent of environmental contamination, to assess the associated risks, and to identify possible mitigation actions.

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