

# Water Quality Degradation

Subjects: Water Resources

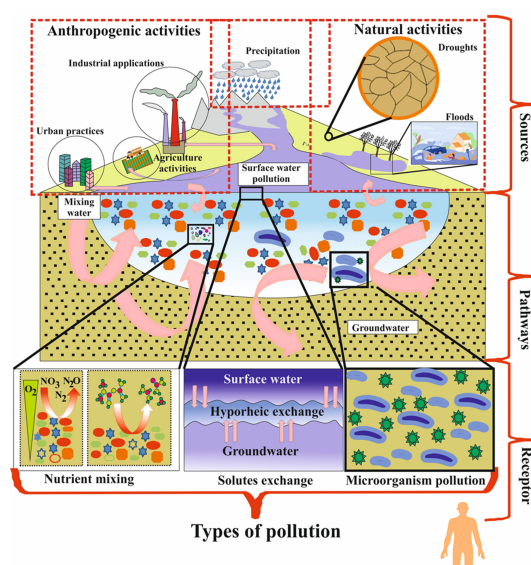
Contributor: Naseem Akhtar

Water quality degradation is happened through the natural processes that influence the surface water and groundwater quality by various sources such as climate changes, natural disasters, geological factors, soil-matrix, and hyporheic exchange. Water could also be contaminated by anthropogenic factors. Anthropogenic pollutants are substances caused by human actions, mostly resulting from land-use practices.

Keywords: water quality degradation ; natural processes ; contamination sources ; pathways ; anthropogenic activities

## 1. Introduction

Water resources are essential for life as we know it, in cultivated farmland, sustainability, human consumption, economic development, and environmental systems [1]. Globally, over five billion inhabitants are dependent on groundwater and surface water systems since people use these resources in numerous ways such as potable water, housing, crop production, and manufacturing applications [2][3]. The degradation of water resources is a much-studied phenomenon and can be caused by natural processes (climate change, water-rock interactions, and geological factors) and human activity (agriculture practices and urban waste), as well as the presence of considerable chemical compounds since the industrial revolution [4]. Despite this, the management of surface water and groundwater as resources remains complicated in many circumstances and relevant information remains unknown [5]. Apart from anthropogenic activities, natural heterogeneities of rock/soil interact with water, influencing natural water cycles and affecting water quality across all domains [6]. Such modifications can have severe repercussions for the functioning of human health and the living organism [7]. In addition, the physicochemical and biological characteristics, as well as quality, quantity and availability of water resources, fluctuate because of the impact of natural and human activities [2]. The pollutant types, pathways, and sources, as well as how they influence the surface water and groundwater systems based on natural sources and anthropogenic activities, are shown in **Figure 1**.



**Figure 1.** Schematic diagram illustrates water contamination due to natural sources (droughts and floods) and anthropogenic sources (industrial, agriculture, and urban activities), their pathways, receptors, and other types of pollution.

Surface water contaminations (specifically in rivers and streams) are mainly due to urbanization, agriculture, and manufacturing discharge [8]. In addition, environmental physical factors can also cause contamination, whereas the temperature of an aquatic environment can fluctuate with heated water discharged from power plants [9]. Moreover, hydro-heated water or water containing certain contaminants may not become an issue at any time of the year if it is

immediately diluted by combining with surface water <sup>[10]</sup>. Further, pollutants released by agriculture activities include metals, pesticides, pathogens, nutrients, and salts that influence surface water <sup>[11][12]</sup>. Moreover, untreated and partially treated sewage, construction waste, and solid/liquid waste factors contain hazardous substances emitted into the river water by urban activities <sup>[13]</sup>.

Some inorganic substances, such as zinc, iron, copper, nickel, etc., are necessary for the development of animals and plants, but these substances are harmful for animals or plants when the concentrations go above the acceptable limitations <sup>[14]</sup>. In addition, certain heavy metals such as lead, mercury, cadmium, and arsenic are no longer essential for the growth of plants and animals <sup>[15]</sup>. These toxic metals are mainly attributed to wastewater effluent in surface water due to conventional wastewater treatment, municipal waste based on activated sludge activities, and household waste <sup>[16]</sup>. Such pollutants are found widely at low concentrations from nanograms/liter (ng/L) to micrograms/litre (µg/L) <sup>[17]</sup>. Consequently, these toxic pollutants are released into river water either directly or indirectly, mainly by industrial waste, municipal and urban factors, as well as contaminated surface water discharge into the groundwater aquifer system by infiltration through soils and land-use practices <sup>[18]</sup>.

Groundwater aquifer vulnerability and its pollution risk in the anthropogenic environment increases from the complicated interactions of the natural mechanisms of the hydrological system with the physical changes to the land surface, discharge waste from human factors, and water resource exploitation <sup>[19]</sup>. Further, physical landscape alterations cause an increase in the vulnerability of groundwater systems through topography changes, artificial water bodies, construction, river channeling, surface sealing, and changes in surface ruggedness <sup>[20]</sup>. In addition to the change in land use and land cover, the widespread utilization of synthetic and natural chemical compounds (pesticides and fertilizers) is also part of anthropogenic activity <sup>[21]</sup>. Utilization of these compounds generates agricultural productivity and can be beneficial for animal and human health, sufficient energy, functional infrastructure, and production of materials <sup>[22][23]</sup>. Nevertheless, numerous compounds used extensively today have been revealed to be persistent, mobile and soluble in aquifer systems, which is harmful to human health and environment systems <sup>[24]</sup>. Several other substances are still unknown threats, and thus far, the risk that chronic product exposure to a combination of substances has been difficult to quantify in many environmental areas.

When groundwater is polluted with toxic chemical compounds through human activities it can become unsuitable for several years <sup>[25]</sup>. The residence time of chemical pollutants can be retained in the groundwater system for weeks to months, years, and decades <sup>[26]</sup>. It depends upon the properties of the physicochemical compounds and environmental scenarios, and further lack of water supplies does not remove the effects of the groundwater pollution. Previous studies have identified the flow of groundwater through the hydrological cycle of pollutants from waste sewage or spill areas to surrounding rivers, channels, and lakes <sup>[27]</sup>. In the scientific community, problems in the context of groundwater pollution are widely known. Regulatory bodies have determined the high level of numerous toxic compounds in potable water systems at many places of the world. For instance, nitrate and fertilizer compounds have been recorded at high concentrations in groundwater systems <sup>[28]</sup>. Therefore, the contamination resulting directly from agriculture and industrial activities is a persistent and growing problem. According to recent estimates, 80% of the world's population in 25 countries suffer the horrible death of infectious diseases caused by groundwater contamination <sup>[29]</sup>. The current expansion of human practices is often contrasted directly with what is required to safeguard groundwater supplies for future consumption <sup>[30][31]</sup>.

This review discusses several major contaminants of water resources degraded by natural and human factors, as well as several critical inorganic pollutant classifications released from anthropogenic activities. Furthermore, this study highlights several case studies in the literature investigating historical and emerging issues in polluted water resources and the diversity of issues in various areas of the globe. The impacts of these activities are described to emphasize the multiple issues arising if anthropogenic regulations are present on top of natural controls <sup>[32]</sup>. Scientific and government regulations have highlighted the critical need for better comprehension of pollutant processes in water resources and the environment <sup>[33]</sup>. The complicated interactions between types, sources, and transport pathways of water resource pollutants in various settings have been addressed in this study. Consequently, sustainable water quality should be secured rapidly, and transdisciplinary and transboundary activity is required, especially as humans go towards 2025 <sup>[23]</sup> <sup>[34]</sup>.

## **2. Major Pollutants of Water Resources**

An important problem for environmental researchers and decision-makers remains the improvement of understanding the extent and behavior of polluting chemicals on the surface and subsurface as well as the combined impact of a combination of substances <sup>[35][36][37]</sup>. Some countries have been performed and created a standard with limitations based

on information on current regulations for water resource concentration, especially drinking water [38][39][40]. These are critical factors that must be recognized, regardless of the complexity of solvent movement, reaction, and surface activity, whether compound control, mitigation, or water system rehabilitation is to effectively protect or enhance water quality. In this section, the characteristics of several prominent inorganic water pollutants are discussed (nitrate, fluoride, and heavy metal concentration).

## 2.1. Inorganic Substances

Non-carbon-based materials are referred to as inorganic pollutants. The most significant inorganic substances are naturally found in the environment system, such as nitrogen, fluoride, and heavy metals [14]. Furthermore, arsenic, fluoride, and iron pollutants are geogenic, while nitrates and some other heavy metals are mainly caused by anthropogenic behavior such as weak wastewater systems, poor agricultural practices, and industrial discharges [41]. In groundwater, in many regions of the world, including India, high levels of metals (mainly heavy metals) and other toxicants, such as fluoride and nitrate, have been found beyond the threshold limit, rendering them unfit for drinking. The most studied heavy metals produced by different wastewater factories are arsenic, copper, chromium, mercury, nickel, and zinc [42]. The impact of inorganic contaminants and their organic forms on flora and fauna of the Earth's environment is devastating (atmosphere, lithosphere, and hydrosphere), as they cause many health-related issues (abnormal growth, high risk of breast cancer, diabetes, obesity, etc.).

This results in oxygen depletion as the phase of decomposition occurs. These components overgrow and use a lot of oxygen during their development. The dissolved oxygen may be used more than can be filled during the decomposition process, contributing to the shortage of oxygen and having severe implications for the biota stream [43]. Failure to provide oxygen may destroy aquatic species. When marine species die, the components break down and cause more oxygen depletion. A type of organic pollution can occur when aquatic environments accumulate inorganic contaminants such as nitrogen and phosphates [2]. Inorganic contaminants such as nitrogen and fluoride are illustrated in **Table 1**.

**Table 1.** Water pollution due to fluorides and nitrates in numerous countries across the world.

Heavy Metals	Source	Pollution Type	Regions/Countries	GW Maximum Concentration	References
Fluoride	Industrial	Wastewater	Roopnagar, Delhi, India	7.4 mg/L	[44]
	Agriculture fertilizers	Infiltration	Pampa, Argentina	21.1 mg/L	[45]
	Municipal	Waste material	Taiwan	1.81 mg/L	[46]
	Power plant	Thermal Water	China	50 mg/L	[47]
Nitrate	Agriculture fertilizers	Infiltration	Jharkhand, India	319.1 mg/L	[48]
	Livestock farms and landfill	Wastematerial	Beijing, China	1736 mg/L	[49]
	Industrial hazardous	Wastematerial	Liaoh River, China	175 mg/L	[50]
	Anthropogenic activities	Chemical fertilizer	Sicily, Italy	225 mg/L	[51]

## 2.2. Sources of Heavy Metals

Heavy metals are found on the Earth's surface by natural and anthropogenic activities [52]. Heavy metals are naturally released from volcanic eruptions, metal corrosion, soil erosion, atmospheric sources, and weathering of rocks or minerals. Heavy metals are discharged primarily from industries, domestic wastes, mining, smelting or treating of ores, landfills, and livestock, and secondarily from pesticides and fertilizers. Heavy metals are a broad concept in the metals/metalloids group, and they have a more dominant atomic density of more than 4000 kg/m<sup>3</sup> [14]. Even with low metal ions' concentration in water supplies, nearly every heavy metal is harmful to human beings [53]. The quantity and quality of water resources are affected by the high concentration of heavy metals as well as availability for human consumption.

High quantities of these toxic substances are dangerous to humanity and may interact with several aspects of the earth because of their harmful effects and portability. In addition, these toxic metals are non-biodegradable and challenging to clean. Heavy metal contaminations in water resources and the environment must be monitored, recognized, and regulated. Toxic elements are released mainly from the exploitation of treated wastewater, industrial wastewater, sewage

sludge, fertilizers, mining operation, and soil minerals; thus, the discharge of this waste into water becomes polluted [14]. Moreover, heavy metal concentrations are absorbed into the water bodies by various industries' effluents (tanneries, electrical products, electroplating, dyes, and others) and cause significant environmental problems even at low concentrations of metal ions. These substances are directly or indirectly discharged into the surface water, which increases the concentration of the ions and percolates in the groundwater, as well as polluting both [3].

### 3. Conclusions

Geological processes, natural disasters, climate change, and surface water and groundwater interactions are the main natural causes of contamination. There are case studies available that cover various issues such as surface water and groundwater quality and contaminating sources. However, there are few case studies that examine specific topics such as water resources pollution types, sources, and pathways. The multitude of cases demonstrates the wide range of subjective challenges to water systems as a result of long-term supplies for human utilization and environmental protection. Challenges include food production, urban development, increased drug production and usage, and inadequate sewage facilities, as well as declining scientific evidence on water quality. In such cases, a lack of importance placed on water resources as renewable hampers the complicated problem of maintaining water quality. Transdisciplinary study and practice can serve to gain better knowledge to understand the pollution processes, types, pathways, and their consequences on water resources. This makes for a lot of possibilities for interdisciplinary research areas (environmental sciences and related fields) and transboundary communication.

---

### References

1. Akhtar, N.; Ishak, M.; Ahmad, M.; Umar, K.; Yusuff, M.M.; Anees, M.; Qadir, A.; Almanasir, Y.A. Modification of the Water Quality Index (WQI) Process for Simple Calculation Using the Multi-Criteria Decision-Making (MCDM) Method: A Review. *Water* 2021, 13, 905.
2. Khatri, N.; Tyagi, S. Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Front. Life Sci.* 2014, 8, 23–39.
3. Akhtar, N.; Syakir, M.I.; Rai, S.P.; Saini, R.; Pant, N.; Anees, M.T.; Qadir, A.; Khan, U. Multivariate Investigation of Heavy Metals in the Groundwater for Irrigation and Drinking in Garautha Tehsil, Jhansi District, India. *Anal. Lett.* 2019, 53, 774–794.
4. Nagaraju, A.; Thejaswi, A.; Sreedhar, Y. Assessment of Groundwater Quality of Udayagiri area, Nellore District, Andhra Pradesh, South India Using Multivariate Statistical Techniques. *Earth Sci. Res. J.* 2016, 20, 1.
5. Macdonald, A.M.; Davies, J.; Dochartaigh, B.E.O. Simple methods for assessing groundwater resources in low permeability areas of Africa. British Geological Survey Commissioned Report, CR/01/168N. South Africa. *Br. Geol. Surv.* 2002, 71.
6. Trabelsi, R.; Zouari, K. Coupled geochemical modeling and multivariate statistical analysis approach for the assessment of groundwater quality in irrigated areas: A study from North Eastern of Tunisia. *Groundw. Sustain. Dev.* 2019, 8, 413–427.
7. Akhtar, N.; Rai, S.P. Heavy Metals Concentrations in Drinking Water and Their Effect on Public Health around Moth Block of Jhansi District, Uttar Pradesh, India. *Indian J. Environ. Prot.* 2019, 39, 945–953.
8. Sasakova, N.; Gregova, G.; Takacova, D.; Mojziso, J.; Papajová, I.; Venglovsky, J.; Szaboova, T.; Kovacova, S. Pollution of Surface and Ground Water by Sources Related to Agricultural Activities. *Front. Sustain. Food Syst.* 2018, 2.
9. Manjunatha, S.; Bobade, K.; Kudale, M. Pre-cooling Technique for a Thermal Discharge from the Coastal Thermal Power Plant. *Procedia Eng.* 2015, 116, 358–365.
10. Issakhov, A. Numerical Study of the Discharged Heat Water Effect on the Aquatic Environment from Thermal Power Plant by using Two Water Discharged Pipes. *Int. J. Nonlinear Sci. Numer. Simul.* 2017, 18, 469–483.
11. USEPA. Protecting Water Quality from Agricultural Runoff; United State Environmental Protection Agency (USEPA): Washington, DC, USA, 2005.
12. Parris, K. Impact of Agriculture on Water Pollution in OECD Countries: Recent Trends and Future Prospects. *Int. J. Water Resour. Dev.* 2011, 27, 33–52.
13. Varol, M.; Şen, B. Assessment of nutrient and heavy metal contamination in surface water and sediments of the upper Tigris River, Turkey. *CATENA* 2012, 92, 1–10.
14. Vardhan, K.H.; Kumar, P.S.; Panda, R.C. A review on heavy metal pollution, toxicity and remedial measures: Current trends and future perspectives. *J. Mol. Liq.* 2019, 290, 111197.

15. Bhardwaj, R.; Gupta, A.; Garg, J. Evaluation of heavy metal contamination using environmetrics and indexing approach for River Yamuna, Delhi stretch, India. *Water Sci.* 2017, 31, 52–66.
16. Coelho, L.M.; Rezende, H.C.; Coelho, L.M.; Sousa, P.A.R.; Melo, D.F.O.; Coelho, N.M.M. Bioremediation of Polluted Waters Using Microorganisms. In *Advances in Bioremediation of Wastewater and Polluted Soil*; Shiomi, N., Ed.; IntechOpen: London, UK, 2015; pp. 1–22.
17. Galindo-Miranda, J.M.; Guízar-González, C.; Becerril-Bravo, E.J.; Moeller-Chávez, G.; León-Becerril, E.; Vallejo-Rodríguez, R. Occurrence of emerging contaminants in environmental surface waters and their analytical methodology. *Water Supply* 2019, 19, 1871–1884.
18. Shahabudin, M.M.; Musa, S. Occurrence of Surface Water Contaminations: An Overview. *IOP Conf. Ser. Earth Environ. Sci.* 2018, 140, 012058.
19. Li, H.; Yu, X.; Zhang, W.; Huan, Y. Risk Assessment of Groundwater Organic Pollution Using Hazard, Intrinsic Vulnerability, and Groundwater Value, Suzhou City in China. *Expo. Health* 2017, 10, 99–115.
20. Lyon, S.W.; Grabs, T.; Laudon, H.; Bishop, K.H.; Seibert, J. Variability of groundwater levels and total organic carbon in the riparian zone of a boreal catchment. *J. Geophys. Res. Space Phys.* 2011, 116.
21. Bellin, A.; Fiori, A.; Dagan, G. Equivalent and effective conductivities of heterogeneous aquifers for steady source flow, with illustration for hydraulic tomography. *Adv. Water Resour.* 2020, 142, 103632.
22. Cabral, J.P.S. Water Microbiology. Bacterial Pathogens and Water. *Int. J. Environ. Res. Public Health* 2010, 7, 3657–3703.
23. OECD. Pharmaceutical Residues in Freshwater: Hazards and Policy Responses. In *OECD Studies on Water*; Organisation for Economic Cooperation and Development: Paris, France, 2019.
24. Shwetank; Suhas; Chaudhary, J.K. A Comparative Study of Fuzzy Logic and WQI for Groundwater Quality Assessment. *Procedia Comput. Sci.* 2020, 171, 1194–1203.
25. Akhila, J.S.; Shyamjith, D.; Alwar, C.M. Acute Toxicity Studies and Determination of Median Lethal Dose. *Curr. Sci.* 2007, 93, 917–920.
26. Singh, T.; Wu, L.; Gomez-Velez, J.D.; Lewandowski, J.; Hannah, D.M.; Krause, S. Dynamic Hyporheic Zones: Exploring the Role of Peak Flow Events on Bedform-Induced Hyporheic Exchange. *Water Resour. Res.* 2019, 55, 218–235.
27. Varol, M. Use of water quality index and multivariate statistical methods for the evaluation of water quality of a stream affected by multiple stressors: A case study. *Environ. Pollut.* 2020, 266, 115417.
28. Kumar, M.; Das, A.; Das, N.; Goswami, R.; Singh, U.K. Co-occurrence perspective of arsenic and fluoride in the groundwater of Diphu, Assam, Northeastern India. *Chemosphere* 2016, 150, 227–238.
29. Ntanganedzeni, B.; Elumalai, V.; Rajmohan, N. Coastal Aquifer Contamination and Geochemical Processes Evaluation in Tugela Catchment, South Africa—Geochemical and Statistical Approaches. *Water* 2018, 10, 687.
30. Verlicchi, P.; Grillini, V. Surface Water and Groundwater Quality in South Africa and Mozambique—Analysis of the Most Critical Pollutants for Drinking Purposes and Challenges in Water Treatment Selection. *Water* 2020, 12, 305.
31. Burri, N.M.; Weatherl, R.; Moeck, C.; Schirmer, M. A review of threats to groundwater quality in the anthropocene. *Sci. Total. Environ.* 2019, 684, 136–154.
32. Ben Alaya, M.; Saidi, S.; Zemni, T.; Zargouni, F. Suitability assessment of deep groundwater for drinking and irrigation use in the Djefara aquifers (Northern Gabes, south-eastern Tunisia). *Environ. Earth Sci.* 2013, 71, 3387–3421.
33. Bhaskar, A.S.; Beesley, L.; Burns, M.J.; Fletcher, T.D.; Hamel, P.; Oldham, C.E.; Roy, A.H. Will it rise or will it fall? Managing the complex effects of urbanization on base flow. *Freshw. Sci.* 2016, 35, 293–310.
34. McInnes, R.J. Sustainable Development Goals. In *The Wetland Book*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 631–636.
35. EPA. Point and Non-Point Sources of Water Pollution; United States Environmental Protection Agency: Washington, D C, USA, 1996.
36. Wu, Z.; Wang, X.; Chen, Y.; Cai, Y.; Deng, J. Assessing river water quality using water quality index in Lake Taihu Basin, China. *Sci. Total. Environ.* 2018, 612, 914–922.
37. Singhal, B.B.S.; Gupta, R.P.; Singhal, B.B.S.; Gupta, R.P. Introduction and basic concepts. In *Applied Hydrogeology of Fracture Rocks*; Springer: London, UK; New York, NY, USA, 2010; Chapter 1.
38. UNESCO. The United Nations World Water Development Report 2018: Nature-Based Solutions for Water; United State Environmental Protection Agency: Paris, France, 2018.
39. WHO. Guidelines for Drinking Water Quality; World Health Organization: Geneva, Switzerland, 2017.

40. BIS. Indian Standards Drinking Water Specifications IS 10500:2012; Bahadur Shah Zafar Marg: New Delhi, India, 2012.
41. Abiye, T.A.; Bhattacharya, P. Arsenic concentration in groundwater: Archetypal study from South Africa. *Groundw. Sustain. Dev.* 2019, 9.
42. Hepburn, E.; Northway, A.; Bekele, D.; Liu, G.-J.; Currell, M. A method for separation of heavy metal sources in urban groundwater using multiple lines of evidence. *Environ. Pollut.* 2018, 241, 787–799.
43. Qu, L.; Huang, H.; Xia, F.; Liu, Y.; Dahlgren, R.; Zhang, M.; Mei, K. Risk analysis of heavy metal concentration in surface waters across the rural-urban interface of the Wen-Rui Tang River, China. *Environ. Pollut.* 2018, 237, 639–649.
44. Smedley, P.; Nicolli, H.; Macdonald, D.; Barros, A.; Tullio, J. Hydrogeochemistry of arsenic and other inorganic constituents in groundwaters from La Pampa, Argentina. *Appl. Geochem.* 2002, 17, 259–284.
45. Ali, S.; Thakur, S.K.; Sarkar, A.; Shekhar, S. Worldwide contamination of water by fluoride. *Environ. Chem. Lett.* 2016, 14, 291–315.
46. Thapa, R.; Gupta, S.; Kaur, H.; Baski, R. Assessment of groundwater quality scenario in respect of fluoride and nitrate contamination in and around Gharbar village, Jharkhand, India. *HydroResearch* 2019, 2, 60–68.
47. Nömmik, H. Fluorine in Swedish Agricultural Products, Soil and Drinking Water; Swedish National Institute of Public Health: Stockholm, Sweden, 1953.
48. Popugaeva, D.; Kreyman, K.; Ray, A.K. Study of aluminium in groundwater using chemometric methods. *Environ. Technol.* 2018, 41, 1691–1699.
49. Huan, H.; Hu, L.; Yang, Y.; Jia, Y.; Lian, X.; Ma, X.; Jiang, Y.; Xi, B. Groundwater nitrate pollution risk assessment of the groundwater source field based on the integrated numerical simulations in the unsaturated zone and saturated aquifer. *Environ. Int.* 2020, 137, 105532.
50. Teng, Y.; Zuo, R.; Xiong, Y.; Wu, J.; Zhai, Y.; Su, J. Risk assessment framework for nitrate contamination in groundwater for regional management. *Sci. Total Environ.* 2019, 697, 134102.
51. Pisciotta, A.; Cusimano, G.; Favara, R. Groundwater nitrate risk assessment using intrinsic vulnerability methods: A comparative study of environmental impact by intensive farming in the Mediterranean region of Sicily, Italy. *J. Geochem. Explor.* 2015, 156, 89–100.
52. Tchounwou, P.B.; Yedjou, C.G.; Patlolla, A.K.; Sutton, D.J. Heavy Metal Toxicity and the Environment. In *Molecular, Clinical and Environmental Toxicology*; Springer: Cham, Switzerland, 2012; Chapter 4; pp. 133–164.
53. Briffa, J.; Sinagra, E.; Blundell, R. Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon* 2020, 6.