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Desk Research on Pollutants for Ecofriendly Environmental Researchers

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Abstract

Substances of foreign origin called pollutants, play a main part in alarming health hazards. The essentiality of water is being used without considering the dreadful contaminants. Arsenic, the most potential and dreadful element, is always ignored whenever there is a need for the purification of water for drinking. Rehabilitation of any affected area in view of health issues is highly mandatory as per the international provisions of Environmental legislation. In this work, we have tried to identify the potential pollutants, their sources, and contamination limits toward hazardous health effects.

Keywords: Pollutants, toxicants, turbidity, inorganic, organic, acidity and alkalinity

INTRODUCTION

Natural water always mingles with many dissolved organic and inorganic matter due to its pathway through rock, soil, and environment.

Inorganic Materials in Natural Water

Sea water contains a higher salt level (35 g/L) than rainwater, which contains only traces of dissolved matter such as oxidized forms of sulfur, nitrogenous toxicants from fuel combustion, and vegetation.

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Organic Materials in Water

Organic contaminants are purified when they pass through the groundwater systems. The main sources of organic pollutants are living organisms, decomposing matter, drainage, industrial pollution, and atmospheric fall.

Dissolved Organic Substance

This is the source of biological pollutants, such as proteins, amino acids, fat, lignin, sugar, and chlorophyll. They are drawn from natural and synthetic compounds (pesticides), decaying plants, and animals [1].

Standards of Water Pollutants

The parameters describing natural water quality involve many factors. Different territories have different standards and factors for determining the quality of natural water. The European system takes into account around 64 factors, whereas the rules set by Poland consider only 51 factors when determining natural water quality. The stringent rules framed by the Environmental Protection Agency (EPA, 1995) require approximately 120 factors.

Color of Water

The color of water is a better indicator of toxic content, which is mostly due to stains from textile industrial wastes. The apparent color indicates dissolved particles in the colloidal state and dissolved platinum (potassium hexa-chloro-platinum IV—K_2PtCl_6) along with the cobalt complex.

Various Techniques to Determine Pollutants in Water

Photometry

This is a technique of light measurement that uses the principle of absorbance of light by a liquid. The photodetector was placed on one side of the sample solution when monochromatic light passed through the other side. The light absorbed by the sample was calculated based on Beer–Lambert's law. Appropriate wavelength filters were suggested based on the color of the sample. The amount of ingredients can be determined based on the absorbance of light [2].

Coagulation and Sedimentation

By coagulation and sedimentation of pollutant particles using alum, the levels of toxic ingredients can be determined by analytical methods of analysis on sediment.

Turbidity

Turbidity is the principle of measuring scattered light by turbid solutions to determine the quantity of elementary and complex contents in a sample. Turbidity in water is due to suspended organic and inorganic particles, staining complexes of aluminium, manganese, iron, zooplankton, and tiny life forms such as pathogenic bacteria and clay particles. The acceptable turbidity of drinking water ranges from 20 to 50 mg / dm3.

SOURCES OF POLLUTANTS IN WATER

- Suspended solids.
- Colloidal and dissolved substances.
- Dry residues.
- Inorganic chemicals can affect taste but not cause any odor.
- Inorganic chemicals usually affect both taste and odor.
- Certain compounds are detectable at extremely low concentrations.
- Organisms are most often linked with taste and odor, such as:
  - Rust,
  - Plant fibers,
  - Algae, and
  - Indicators of bacterial or hazardous contamination (e.g., through filtration).

Colloidal and Dissolved Substances

Dry Residues

- Residue left after evaporation of water (drying at 105°C).
- Includes mass of dissolved and insoluble inorganic and organic substances, contributing to taste and odor.

Inorganic Chemicals (Pollutants)

Inorganic chemicals can affect taste but not cause any odor, including:

- Salt (NaCl),
- Minerals,
- Metals,
- Iron,

- Zinc,
- Manganese, and
- Copper.

Inorganic chemicals that usually affect both taste and odor include:
- Humic substances,
- Hydrophilic acids,
- Carboxylic acids,
- Peptides,
- Hydrocarbons,
- Biological decay products,
- Petroleum products, and
- Pesticides.

Compounds Detectable at Extremely Low Concentrations
- Chlordane,
- Dichlorobenzene,
- Trichloroethylene,
- Phenol,
- Chlorophenol,
- Hydrogen cyanide.

Organisms Linked with Taste and Odor Problems
- Actinomyocytes,
- Various types of algae,
- Aquatic organisms such as protozoa and fungi.

Earthy or Musty Tastes and Odors are Produced By
- Cyanobacteria (blue-green algae),
- Actinomyocytes, and
- Some fungi.

Growing Algae Produces Numerous Volatile and Nonvolatile Organic Substances, Including
- Aliphatic alcohols,
- Aldehydes,
- Ketones,
- Esters,
- Thioesters, and
- Sulfides.

Occasionally, Taste and Odor Problems in Water are Caused By
- Other bacteria,
- Fungi,
- Zooplankton,
- Nemathelminths,
- Ferrobacteria, and
- Some species of *Pseudomonas*.

Sulfur-Containing Amino Acids and Related Substances
- Hydrogen sulfide (H_2S),

- Methyl thiol, and
- Dimethyl polysulfide.

Hydrogen sulfide (H2S) is formed from the decomposition of sulfide minerals combined with CO_2.

Physicochemical Parameters

- pH (ranges from 0 to 14); acidic water is highly corrosive (Table 1).

Table 1. pH value of different types of water.

Type of water	Values in pH
Surface water	6.5–8.0
Groundwater	5.5–7.5
Acid rain	<3.0
Drinking water	6.5–8.5

Temperature of surface water depends on:

- Water origin,
- Climatic zone,
- Season,
- Altitude,
- Degree of riparian coverage,
- Inflow of industrial sources (power plants, industrial cooling), and
- Municipal sewage.

Temperature can exert great control over aquatic communities, especially influencing biological activity and growth. An increase of 10°C in water temperature almost doubles the speed of chemical and biological reactions occurring in water.

Temperature increase leads to:

- Decreased amount of dissolved oxygen (DO),
- Increased biochemical oxygen demand (BOD),
- Acceleration of nitrification and oxidation of ammonia to nitrates (III) and (V), leading to oxygen deficits in water.

High temperatures increase the toxicity of many substances (e.g., pesticides, heavy metals) and make organisms more susceptible to toxicants [3, 4]. Organisms, including fish, are also sensitive to temperature. The acceptable temperature of surface water in Poland is 22°C to 26°C.

Alkalinity

- Refers to the capability of water to neutralize acids.
- The basic species responsible for alkalinity in water are:
  - Bicarbonate ions,
  - Carbonate ions,
  - Hydroxide ions,
  - Calcium carbonate, or
  - Magnesium carbonate (compounds).

Minor contributors to alkalinity

- Ammonia and
- Conjugate bases of
  - Phosphoric,

- Silicic,
- Boric and
- Organic acids.

Alkalinity is often related to the hardness of water because its main sources usually include:

- Carbonate rocks (limestone), mostly $CaCO_3$
- Sodium carbonate and
- Potassium carbonate (does not contribute to hardness)

Alkalinity (as well as pH) can be determined using inexpensive test strips.

- More sophisticated electromagnetic measurement is performed using a computer-aided titrimeter (CAT) and a pH electrode.
- Alkalinity are important for
  - Fish and
  - Aquatic life (best functions at a pH range of 6.0 to 9.0)

The acidity of a natural water system refers to its capacity to neutralize bases.

Hydroxide Ions (OH^-)
Acidity is due to the presence of weak acids such as,

- H_2PO^{4-}
- H_2S
- Proteins
- Fatty acids and
- Acidic metal ions particularly Fe^{3+}

Acidity originates from various sources, including:

- CO_2
- Soil (CO_2 and humic acids)
- H_2SO_4 and HCl in water
- Hydrated metal ions
- Pickling liquor (to remove corrosion from steel)
- Acidic metal ions
- Excess of strong acids

Conductivity is a measure of the capacity of an aqueous solution to carry an electric current.

Electric Current
Conductivity depends on the presence of ions, including:

- Cations (+) and anions (−) in water
- Their total concentration
- Mobility and valence
- Temperature of the water

Conductivity increases with the amount of dissolved salts in water, such as:

- Calcium
- Magnesium
- Sodium
- Potassium
- Carbonate
- Bicarbonate

- Sulfate
- Chloride
- Nitrate

Conductivity is commonly used to determine salinity.

- High salinity interferes with the growth of aquatic vegetation.
- Salt decreases osmotic pressure.
- High salinity may cause:
  - Leaf tip burn
  - Marginal leaf burn
  - Bleaching
  - Defoliation
- Hardness

Cations of Ca^{2+}

- Mg^{2+} (magnesium), Fe^{3+} (iron), and Mn^{2+} (manganese)

Dissolved Oxygen

- The volume of oxygen present in water
- A basic indicator of ecosystem health
- Consumed by microorganisms during the decomposition of organic matter
- Biochemical Oxygen Demand (BOD) indicates poor water quality
- Chemical Oxygen Demand (COD) refers to the amount of oxygen required for the degradation of organic compounds in wastewater

Common Oxidizing Agents in Water Treatment

- Potassium permanganate ($KMnO_4$)
- Potassium dichromate ($K_2Cr_2O_7$)
- Mercury sulfate ($HgCl_2$) or $HgCl_4$

Carbon Dioxide (CO_2)

- Present in the atmosphere and in all types of natural water
- Reacts with water to form:
  - $CaCO_3$ (calcium carbonate)
  - $Mg(OH)_2$ (magnesium hydroxide)

Chlorine in Water

- Chlorine present in water is toxic to living organisms
- In its elemental form, it does not exist in natural water
- Sewage undergoes chlorination with chlorine or chlorinated compounds

Ammonium Nitrate

- Present in water, its reaction leads to the formation of chloramines:
  - NH_2Cl (monochloramine)
  - $NHCl_2$ (dichloramine)
  - NCl_3 (trichloramine)
- Chlorine causes oxidation of:
  - Iron(II) compounds
  - Manganese(II) compounds
  - Nitrate(III) compounds
  - Sulfides

  - Sulfates(IV)
- Forms:
  - Aliphatic and
  - Aromatic chloro-derivatives

Chlorides
- HCl (hydrochloric acid)
- AgCl (silver chloride)

Sulfur
- In natural water, sulfur is present in the form of dissolved hydrogen sulfide (H_2S), hydrogen sulfide ions (HS^-), or soluble and insoluble sulfides (S^{2-}).

Sulfates
- Sulfate(VI) commonly occurs in natural waters.
- Sulfate is rarely present in natural water in high concentrations.
- Sulfates are among the least toxic anions.
- High sulfate levels may cause health disorders such as diarrhea-like symptoms.

Silica
- Colloidal SiO_2
- Silica metal compounds, such as:
  - Na_2SiO_3 (sodium metasilicate)
  - Ca_2SiO_3 (calcium metasilicate)
  - Mg_2SiO_3 (magnesium metasilicate)
  - K_2SiO_3 (potassium metasilicate)
- Polynuclear silicate species, such as:
  - $Si_4O_6(OH)_6^{2-}$
  - Silicic acid (H_4SiO_4)
- Sources of silica in water:
  - Sodium feldspar albite ($NaAlSi_3O_8$)

Calcium
- Cations found in most freshwater systems have the highest concentration.
- Different mineral forms of $CaCO_3$:
  - $CaSO_4 \cdot 2H_2O$ (gypsum)
  - Anhydrite ($CaSO_4$)
  - Dolomite ($CaMg(CO_3)_2$
  - Calcite ($CaCO_3$)
  - Aragonite ($CaCO_3$)

Magnesium
- Similar to calcium, Mg^{2+} is commonly found in natural water.
- Main sources of Mg^{2+} ions:
  - Dolomite ($CaMg(CO_3)_2$)
  - Magnesite ($MgCO_3$)
- Mg^{2+} shares similar properties with Ca^{2+}.

Sodium
- The main sources of sodium in natural waters include:
  - Hydrolytic decomposition of magma rocks

  - Presents in the form of:
    - $NaCl$ (sodium chloride)
    - Na_2SO_4 (sodium sulfate)
    - $NaHCO_3$ (sodium bicarbonate)
    - Na_2CO_3 (sodium carbonate)
    - $NaNO_3$ (sodium nitrate)
- Well soluble in water
- Sodium bicarbonate contributes to water hardness

Potassium
- The main source of potassium in natural water is hydrolytic decomposition of magma rock.
- Erosion of sedimentary rocks (e.g., feldspar $KAlSi_3O_8$**)** due to weathering.
- Other sources include:
  - Forest fire runoff
  - Municipal, industrial, and agricultural sewage
- Potassium chloride (KCl) is rarely found in the form of sulfates.
- Other potassium compounds in water:
  - Potassium sulfate (K_2SO_4)
  - Carbonic acid salts ($KHCO_3$, K_2CO_3)
  - Potassium nitrate (KNO_3)
- All potassium salts are highly soluble in water.

Aluminium
- Aluminium ions (Al^{3+}) have weak solubility, leading to lower concentrations in water.
- Sources of aluminium in water:
  - Industrial sewage
  - Corrosion of aluminium tanks
  - Water treatment processes, such as coagulation with alum **(**$Al_2(SO_4)_3$**).**
- Aluminium salts can be harmful to humans.

Microbiological Parameters
Disease-causing (pathogenic) organisms include:
- Bacteria
- Viruses
- Protozoa

Water contamination sources:
- Water polluted with feces from humans or other warm-blooded animals.
- Coliform count—measures coliform bacteria present in water.
- Fecal coliforms—indicate pollution from animal or human feces.
- Raw sewage or untreated river water contains high levels of these bacteria.
- Chlorine is used in water treatment to kill these bacteria.

Nitrates
- Some studies have shown that there may be a relationship between nitrate presence in water and gastric cancer as well as methemoglobinemia.
- In infants, methemoglobinemia is often referred to as “blue baby syndrome.”
- Nitrites (NO_2^-) can have either organic or inorganic origins.

Ammonia

- Originates from organic sources.
- Easily undergoes nitrification.
- Can cause pollution due to excessive use of ammonia fertilizers, atmospheric deposition, and sewage contamination.
- Toxic to aquatic organisms.
- Can increase body pH levels.

Total Organic Carbon (TOC)

- Carbon enters the biosphere during photosynthesis through the reaction:

  $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2 + H_2O$

- Carbon is returned to the biosphere through cellular respiration via the reaction:

  $O_2 + H_2O + C_6H_{12}O_6 \rightarrow CO_2 + H_2O + \text{energy}$

Hydrogen Sulfide

- Originates from inorganic sources.
- Formed by the biochemical decomposition of plant and animal proteins.
- Produces a strong "rotten egg" smell and an unpleasant taste.
- Presence in drinking water can cause nausea, illness, and, in extreme cases, death.

Iron

- The main source of iron in natural water is the erosion of minerals from rocks and soil.
- Also introduced through sewage from metallurgical, dyeing, and galvanizing plants, as well as pipeline erosion.
- Exists in Fe^{2+} (ferrous) and Fe^{3+} (ferric) forms.
- Essential for blood formation.
- High concentrations can cause turbidity, yellowish coloration, and an unpleasant taste in water.

Manganese

- Exists as Mn^{2+} and Mn^{4+}.
- Sources include magma rocks and sedimentary rocks.
- Commonly found as $MnO_2 \cdot H_2O$, which can undergo further sedimentation.

Phosphorus

- Found as anions of orthophosphoric acid:
  - H_3PO_4
  - $H_2PO_4^-$
  - HPO_4^{2-}
- These anions are predominant within the normal pH range of water.
- Can also be present as organic phosphorus compounds.
- Phosphates are sometimes added to drinking water to reduce corrosion.
- Participates in precipitation reactions with certain compounds.
- Common sources include:
  - Fertilizer runoff from agricultural activities.
  - Erosion of rocks and mining.
  - Domestic waste (e.g., detergents).
  - Industrial waste.
  - Decomposition of organic matter from plants and animals.

Fluoride

- Naturally present in minerals, soils, and natural waters.
- Also introduced through industrial sewage, agricultural runoff, and coal combustion.
- Fluoride in drinking water can significantly reduce dental cavities.
- Excess fluoride consumption can be harmful to bones and teeth.

Dissolved and Emulsified Hydrocarbons

- Mineral oils and crude oil are complex mixtures of hydrocarbons (approximately 90% carbon atoms).
- Minor constituents include sulfur, nitrogen, and oxygen.

Phenols

- Common types of phenols in water:
  - Phenol
  - o-Cresol
  - m-Cresol
  - p-Cresol
  - 1-Naphthol
  - Hydroquinone
  - Chlorophenol
- Phenols are generally biodegradable, except in high concentrations, which can be toxic to microorganisms.
- Acute toxicological effects of phenol:
  - Affect the central nervous system—death can occur within 30 minutes of exposure.
  - Severe gastrointestinal disturbances.
  - Kidney malfunction.
  - Circulatory system failure.
  - Lung edema and convulsions.

Surfactants (Surface-Active Agents)

- Commonly found in synthetic detergents.
- Classified into two groups:
  - Hydrophobic (water-repelling).
  - Hydrophilic (water-attracting).
- Harmful to aquatic environments, affecting fish, plankton, plants, and humans at high concentrations.
- Some surfactants contain phosphates and polyphosphates, which contribute to eutrophication.

Trihalomethanes (THMs)

- Group of four toxic chemical compounds.
- Toxic to aquatic ecosystems and unsuitable for human consumption.
- Associated with an increased risk of cancer.
- Exposure factors include:
  - Irrigation water contamination.
  - Viruses.
  - Internal health factors.
- Lowering of immune function caused by:
  - Genetic predisposition.
  - Aging.
  - Lifestyle changes.
- According to the World Health Organization (WHO), 35% of carcinogenic substances are derived from food and beverages.

Heavy Metals

- Arsenic (III and V)
  - Low concentrations in drinking water are linked to a higher risk of lung and bladder cancer.
- Cadmium
  - Permissible concentration set by WHO.
- Chromium
  - Permissible concentration set by WHO.
- Lead
  - Excessive levels can negatively impact human health.
- Cyanides
  - Highly toxic and exist in water as hydrogen cyanide (HCN), a very weak acid.
  - Used in industrial processes such as metal cleaning and electroplating.
  - Presence in water is an indicator of serious pollution.

Selenium

- Naturally occurring in the Earth's crust, primarily found in sedimentary rocks.
- Commonly combined with:
  - Sulfide minerals.
  - Silver.
  - Copper.
  - Lead.
  - Nickel minerals.

Inorganic Forms of Selenium

- Exists in multiple oxidation states:
  - Selenide (Se^{2-}, oxidation state -II).
  - Elemental selenium (Se, oxidation state 0).
  - Selenite (SeO_3^{2-}, oxidation state +IV).
  - Selenate (SeO_4^{2-}, oxidation state +VI).

Organic Forms of Selenium

- Includes organic compounds and methylated derivatives.
- Toxicity depends on the form:
  - Less toxic, volatile methylated selenium compounds:
    - Dimethylselenide (DMSe).
    - Dimethyldiselenide (DMDSe).

Radioactive Compounds

- Radioactivity is a spontaneous process.
- Nuclear transformation occurs when one nuclide transforms into another through the emission of nuclear radiation.
- Sources of natural radioactivity include:
  - Radium-226 (^{226}Ra)
  - Radon-222 (^{222}Rn)
  - Uranium-239 (^{239}U)
  - Thorium-230 (^{230}Th)
  - Lead-210 (^{210}Pb)
  - Potassium-40 (^{40}K)
  - Atmospheric isotopes: Tritium (^{3}H) and Carbon-14 (^{14}C)

Acquired Radioactivity

- Caused by water contamination with radioactive isotopes.

- Common isotopes found in polluted water:
  - Strontium-90 (^{90}Sr)
  - Strontium-89 (^{89}Sr)
  - Yttrium-90 (^{90}Y)
  - Yttrium-91 (^{91}Y)
  - Iodine-131 (^{131}I)
  - Iodine-132 (^{132}I)
  - Cesium-137 (^{137}Cs)
  - Cesium-141 (^{141}Cs)
  - Calcium-144 (^{144}Ca)
  - Phosphorus-32 (^{32}P)

Radioisotopes Found in Sewage
- Sodium-24 (^{24}Na)
- Phosphorus-32 (^{32}P)
- Potassium-40 (^{40}K)
- Cobalt-60 (^{60}Co)
- Zinc-85 (^{85}Zn)
- Strontium-90 (^{90}Sr)
- Iodine-131 (^{131}I)
- Cesium-137 (^{137}Cs)

Mercury
- A highly toxic heavy metal.

Most Toxic Radioactive Isotopes
- Strontium-90 (^{90}Sr)
- Yttrium-90 (^{90}Y)
- Lead-210 (^{210}Pb)
- Polonium-210 (^{210}Po)
- Radium-226 (^{226}Ra)
- Uranium-238 (^{238}U)

Persistent Organic Pollutants (POPs)
- Includes polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs).
- Over 200 different compounds are present in water environments, with 60 identified as hazardous.

Pesticides
- Divided into three major groups:
  - Insecticides
  - Herbicides
  - Fungicides

Dioxins
- Found in industrial sewage and linked to severe environmental pollution.

Key Water Facts

Aquatic species decline every year due to increased toxic pollutants from rivers flowing into the bay. A study from 1983 to 1993 showed a reduction in aquatic species by 84% to 75 species. Approximately 85% of the total pollutants from the rivers flow into the bay. Rivers contribute 90% of the earth's source of contaminants and nutrients into Bhai Bay. From 1990 to 2010, worsening seawater quality, the extent of pollution, and the affected area increased continuously.

In Singapore, used (polluted) water is recycled into purified drinking water, known as NEWater. An assessment of wastewater recycling in Kuwait and its effect on ocean pollution shows that Kuwait recently implemented a rigorous campaign to reclaim and reuse all treated wastewater and preserve seawater quality. This has significantly reduced the amount of pollutants discharged into the sea. Results showed a 50% reduction in the volume of wastewater discharged into the sea from 2000 to 2010.

In 2020, due to a shortage of storage capacity for reclaimed wastewater, approximately 880 million people lacked access to safe water. About 3.6 million people die every year due to illnesses originating from polluted water. Approximately 80% of waterborne casualties occur in children. Approximately 14% of these casualties are due to diarrhea. On average, approximately 65 million people are at risk of arsenic toxicity in India, Bangladesh, and Nepal [8–10].

CONCLUSION

Earth covers approximately 79% of water, of which 94.2% is in oceans and only 4.13% in the ground. Arsenic is a cumulative poison claiming a loss of life due to cancer, cardiac ailments, and other symptoms. Research works claim that as small as three parts per billion (ppb) of arsenic is a dreadful weapon that causes loss of life. Arsenite (As^{3+}) was more toxic than arsenate (As5+). The typical distance that Africans and Asians walk to carry water is 6 km. 98 % of casualties occur due to water-borne ailments around the world. Wastewater reuse is restricted to agricultural applications. The Ministry of Public Works (MPW) is expected to overcome this problem by zero discharge of wastewater into the sea. The aim of future development is the rehabilitation of polluted water and the reuse of wastewater project implementation in Tamil Nadu, India, as in Kuwait and Singapore. Arise due to water-borne ailments worldwide. Wastewater reuse is restricted to agricultural applications. The MPW aims at the nil release of wastewater into the sea. The aim of future development is the rehabilitation of polluted water and the reuse of wastewater project implementation in Tamil Nadu, India, as in Kuwait and Singapore.

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