**Impact of Environmental Factors on Blood Disorders in Animals**

**Abstract**

Climate change is anticipated to have significant adverse effects on both human and animal health. Changes in temperature of the air, precipitation, relative humidity, frequency and the intensity of extreme events are among the environmental factors that can directly or indirectly affect the health of the animal. A wide range of animal species can act as pollution indicators which includes farm and domestic animals. Animals act according to physiological patterns of behavioural changes in response to changing climate and environmental pollutants. Environmental pollutants represent negative stimuli and stressors. Among environmental pollutants air pollution can contaminate all surfaces and poses a significant threat to the environment and all living things. In addition, water pollution also poses a significant environmental issue caused by various human activities and natural sources such as soil erosion, mineral leaching from rocks, and organic matter decay. Exposure to certain pollutants can affect the behavioural changes in animals and humans, such as causing disorientation, difficulty connecting with others, reproductive, digestive and respiratory difficulties. Data on behavioural changes in animals following brief or prolonged exposure to different environmental contaminants have been collected from a number of studies for this review. The focus is to understand the effects of environmental pollutants and stressors on haematological parameters and immune system of animals that affects the productivity, reproduction and normal health of the animals.

**Key words:** Climate Change, Environmental Pollutants, Haematology, Immune System, Pollution

**1 INTRODUCTION**

Global climate change poses a burning problem for all the living organisms. Climate change has the potential to alter disease status and is expected to exert an overwhelming negative effect on the health of humans and animals (Rabinowitz and Conti, 2013). Because of perturbation in air temperature and its relative humidity; precipitation along with the frequency and intensity of extreme events (such heat waves, severe droughts, extreme precipitation events, and coastal floods), climate change can adversely affect the animal health. Although this article focuses on the effects of environmental factors, it’s very significant to consider other factors apart from environmental and climate change. The factors such as ecological and social aspects, economic interests, and individual and community behaviours also contribute the same to animal health (Forastiere, 2010).

**2 ENVIRONMENTAL FACTORS**

2.1Pollution

The introduction of unwanted substances into the environment due to human activity is known as pollution. Pollutants are the substances that contaminate the environment. A physical, chemical, or biological material that is accidentally released into the environment and causes harm to humans or other living organisms on a direct or indirect basis is referred to as a pollutant (Schlerka et al, 2004).

2.1.1Types of pollution

Pollution may be of the following types: Air pollution, water pollution, soil pollution, radiation pollution and noise pollution

**2.1.1.aAir pollution**

Air pollution poses the greatest threat to the environment and all living creatures as it can contaminate all surfaces (water, soil, plants)(Rhai, 2015). Automobiles, industries, and thermal power plants stand as the primary contributors to atmospheric pollution. In addition, quarrying and agriculture also significantly contribute to air pollution. The primary pollutants released into the atmosphere include sulphur and nitrogen oxides, hydrocarbons, carbon dioxide, carbon monoxide, and volatile organic compounds. Secondary pollutants, such as nitric acid, sulfuric acid, ozone, and peroxyacetyl nitrates (PANs), are also formed in the atmosphere. The combination of primary and secondary pollutants produces photochemical smog, which has detrimental effects on livestock, plants, and human health (Prabhakar et al., 2012). Ozone, PANs, and nitrogen and sulphur oxides together induce lung and skin cancer in humans and animals. Substantial quantities of heavy metals released into the air from smelting, waste incineration, and vehicle emissions can lead to high pressure atrophy of bronchial and alveolar ducts, ultimately resulting in death (Swarup et al., 1998).Among the lengthy list of air pollutants, the ones that are most harmful are nitrogen oxide (NO), ammonia (NH3), ground-level ozone (O3), particulate matter (PM), sulphur dioxide (SO2), carbon monoxide (CO), nitrogen dioxide (NO2), and volatile organic compounds (VOC) (Heinecke, 2021; CDC, 2022).

Heavy metal pollution also poses serious health risks to both humans and domestic animals. Various human activities such as mining, metallurgy, industrial operations, transportation, and fossil fuel combustion release toxic heavy metals into the environment, where they persist for extended periods and disrupt ecological balance. These toxicants accumulate in vital organs, causing adverse effects (Liu, 2003). Mercury pollution in the air arises from diesel, jet fuel combustion, and coal burning, while water contamination occurs due to dental clinics, thermometers, and gold mining. Mercury poisoning affects various species, including fish, cats, birds, dogs, pigs, and humans. Clinical manifestations include digestive problems, kidney damage, blindness, and deafness. Cats are particularly affected, exhibiting symptoms such as salivation, staggering, and collapse, leading to the term "dancing-cat disease." The Minamata disaster is a notable example of mercury poisoning in Japan dating back to the mid-1950s (Harada, 1978).

Cadmium (Cd), is a volatile element that accumulates in living organisms through the food chain. Cadmium pollution in the air occurs due to plastic and battery production, electroplating, and alloy manufacturing. In animals, it causes bone softening and reduced productivity as it interferes in calcium metabolism. Selenium (Se) toxicity mainly results from industries emitting fly ash, particularly from soft coal. In dairy ruminants, Se poisoning manifests as alopecia and foot scaling. Se excess has been identified as a significant factor contributing to Degnala disease in cattle and buffalo populations in the Indian subcontinent. Infertility induced by selenium toxicity poses economic challenges to dairy farmers. In birds, symptoms include severe feather loss, stillborn or deformed offspring, muscle atrophy, liver degeneration, and emaciation (Fleming, 1996).The impact of pollution on animal management systems leads to significant financial losses due to poor health and reduced productivity. This adversely affects the quality of milk, meat, or eggs, sometimes rendering these value-added products unfit for human consumption (Schwabe, 1984).

Air currents have the ability to transport pollutants to distant locations from their source. Snow, sleet, hail, or fog can fall, and gasses, dust, and particle debris can form as dry deposition. Pollutants can also change into other chemicals in the atmosphere, causing greater harm than the original ones. Pollutants that are deposited and move through watersheds may convert to different compounds (Swackhamer et al., 2004). Animals may alter their behaviour due to air pollution in a number of ways. For instance, it may discourage birds from singing, drive bees from their hives, or change certain species migratory habits (Penque, 2023). Poor air quality affects milk supply and quality, however dairy cows, do not instantly respond with major behavioural changes (Beaupied et al., 2022).

**2.1.1.b Air Quality Index**

The first crucial step in reducing air pollution is the monitoring and assessment of ambient air quality. Environmental authorities have been employing the air quality index (AQI) for data interpretation and public communication due to the health effects of air pollution. One way to define an AQI is as a single figure that reports on the state of the air and how it affects human health (Thom and Ott, 1976; Bortnick et al., 2002). In its most complex version, it generates a single air quality value by combining several pollutant concentrations in a mathematical equation. This approach to assess air quality is based only on the National Ambient Air Quality Standards (NAAQS) and the measured concentration of contaminants. To bring down the actual concentrations of air pollution (of each pollutant) to a normalized number, we utilized the segmented linear functions. The mathematical technique used to compute the Air Quality Index (AQI), which is very clear and converts different amounts of air pollutants into a single figure for a specific location, has been the subject of numerous investigations (Ott, 1978; Ziauddin and Siddiqui, 2006; Joshi and Mahadev, 2011). For the past thirty years, many industrialized nations have created and implemented the AQI (Suman, 2020), which allows for the classification of the ambient atmosphere (Inhaber, 1976; Dash et al., 2017). An area can be classified as acceptable, satisfactory, poor, extremely poor, moderately polluted or severe based on its AQI (Inhaber, 1976). According to the US Environmental Protection Agency, 2016, the AQI ranges from good to hazardous. The daily AQI is used to report on the area's air quality, including how clean or dirty it is and the consequences it has on local health. AQI can be categorised into six divisions namely Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe.  In 2014, the national AQI was proposed to consider eight pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb) for which short-term (up to 24-hourly averaging period) National Ambient Air Quality Standards are prescribed (PIB GoI, 2014).The Pollutant Standard Index (PSI), a sub-index or part of the Air Quality Index (AQI), is used to estimate the pollution level of each air pollutant. The IEPA (Illinois Environmental Protection Agency – 2013) states that PSI evaluates each pollutant independently, whereas AQI takes into account all contaminants. The fact that PSI and AQI provide the precise concentrations of subsequent air pollutant as well as their impacts makes them valuable tools for studying air quality.

directly on land and water surfaces (“direct” deposition) or they may run off contaminated land and enter

downstream waters (“indirect” deposition). Deposition can occur in wet or dry forms. Wet deposition includes rain,

**2.1.1.cWater pollution**

Water pollution is a significant environmental issue caused by various human activities, including industrial, agricultural, and domestic practices. Water pollution impacts wild life, domestic animals, and aquatic animals. Agricultural runoff containing excess fertilizers and pesticides, industrial effluents with toxic substances, and sewage water containing human and animal waste all contribute to water pollution. Additionally, natural sources of pollution, such as soil erosion, mineral leaching from rocks, and organic matter decay, also contribute to water contamination. Various water bodies, including rivers, lakes, seas, oceans, estuaries, and groundwater sources, can be polluted by both point and non-point sources. Point source pollution happens when pollutants are discharged from a specific location, such as industrial effluents discharged directly into a water body through a drain pipe. On the other hand, non-point sources are those that release pollutants across a wider region or from diffuse sources, like runoff from roads, streets, construction sites, grazing areas, and agricultural fields (European Public Health Alliance, 2009). Waterborne diseases caused by polluted drinking water include typhoid, liver and kidney damage, Alzheimer's disease, hormonal disruptions affecting development and reproductive processes, cancer, heart disease, nervous system damage, DNA damage, and even death. Additionally, contaminated beach water can cause stomach aches, encephalitis, hepatitis, diarrhoea, gastroenteritis, vomiting, respiratory infections, earaches, pink eye, and rashes. Nutrient-polluted water can lead to the overgrowth of toxic algae, which can be consumed by other aquatic animals and cause death. While oil pollution can raise disease susceptibility, interfere with reproductive processes, and harm the development of marine species, chemical contamination can lead to decreases in frog biodiversity and tadpole mass. Reduced fertility, delayed growth and development, aberrant behaviour, and even mortality can result from exposure to mercury in water. Persistent organic pollutants may cause declines, deformities, and death in fish populations. An increased concentration of regular salt, sodium chloride, in water can be fatal to animals (Kopaska-Merkel, 2000). One of the major causes of water poisoning is arsenic poisoning from groundwater, which is released into the environment through industrial and agricultural processes (Kabir and Bilgi, 1993). In cattle, some of the clinical symptoms of arsenic poisoning range from gastrointestinal to nervous signs, including abdominal respiratory distress, ruminal stasis, restlessness, pain, vomiting, dehydration, skin lesions, cognitive impairments, and cancers (Rahman et al., 2001). Chronic cases may present with conjunctival and mucosal erythema, buccal ulceration, weight loss, capricious appetite, and reduced milk yield (Radostits et al., 2000).

**2.1.1.dMicroplastic (𝜇Ps)Pollution**

The number of plastic materials produced globally is steadily rising. In the meantime, poor management practices have led to the hazardous dumping of large amounts of plastic waste (i.e., in the form of macro-, micro-, and nano plastics) in the environment. The irresponsible disposal of garbage opens the door for plastic pollution to enter the ecosystem as microplastics, when they disintegrate. The main sources of 𝜇Ps are raw polymeric materials used for specific household and industrial applications. Larger plastics decompose in the environment into small fragments, which produces secondary sources of 𝜇Ps. One of the largest and secondary sources of pollutants discharged into marine environments is wastewater and water treatment plant (WWTP) effluents (Montecinos et al., 2022). The most common example is when textiles and other materials are washed, releasing plastic particles into the environment (such as the marine environment) (Arias et al., 2021). Apart from textiles and apparel, other consumables including toys, plastics, and single-use plastics, as well as car tires, fishing nets, and ropes, can corrode over time.

There are two and distinct categories of 𝜇Ps: primary and secondary. Additionally, 𝜇Ps can be identified by their chemical makeup and physicochemical characteristics. Several 𝜇Ps with varying physicochemical properties (such as density and chemical compositions) include nylon, polyester, polystyrene (PS), polyethylene terephthalate (PET), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyvinylchloride (PVC), and polypropylene (PP) (Miri et al., 2022). The skeletal structure of 𝜇Ps to differentiate them is dividing them into groups according to the forms in which they occur, including pellets, microbeads, foams, fibres, fragments, films, and microfibers (Okeke et al., 2022). When a particular 𝜇P has a density less than seawater, it is referred to low-density micropollutant; when it has a density greater than seawater, it is referred to high-density micropollutants.

Moreover, a wide range of potentially hazardous compounds are included in 𝜇Ps, such as polychlorinated biphenyls (PCBs), octadecyl trichlorosilane (ODTs), and bisphenols (BPA), all of which have the ability to alter physiological processes (Menéndez-Pedriza et al., 2022; Rios-Fuster et al., 2022). It has been demonstrated that different aquatic animals absorb 𝜇Ps in different ways. Ingestion is the main route of exposure in this type of environment. Following consumption, there is a chance that the substance will be absorbed, distributed via the circulatory system, and then enter some of the body's cells and tissues, which might have a number of extremely harmful effects. A number of studies reveals significant chances of heavy metal transfer from marine prey to predators operating at a high trophic level. Fish, crabs, and shrimp are among the most common aquatic creatures that can harbour 𝜇Ps infection. These animals are then used as food for other aquaculture operations. As of now, there is no effective strategies to eradicate 𝜇Ps from marine environments. But, as previously explained, marine organisms have a great deal of potential for ingesting and getting rid of 𝜇Ps. In this sense, the ability of marine species to adsorb and consume 𝜇Ps is the primary means of partially eliminating marine pollutants. It has been demonstrated by recent studies that marine animals may efficiently consume and absorb 𝜇Ps. For example, corals in the ocean are able to eliminate 𝜇Ps actively (via ingestion) and passively (through surface attachment).

**2.1.1.eSoil pollution:**

Soil pollution is the process of accumulation of pollutants in the soil, which lowers the productivity of the soil. Introducing materials that alter the soil's microorganisms and composition, lower its fertility, and make it unfit for agriculture may result in soil pollution (AI-Taai, 2021). This leaves the soil more susceptible to drought. Many substances can contaminate soil, including pesticides, fertilizers, organic manure, chemicals, radioactive wastes, and leftover food, clothing, leather goods, plastics, paper, bottles, cans, and carcasses. Inadequate and persistent application of herbicides, insecticides, and fungicides to safeguard crops against pests, fungi, and other environmental hazards modifies the basic composition of soil, causing compounds to build up in the soil due to their slow degradation by soil and water microorganisms. As a result, they greatly impair the growth of the plants. Plants take up the degradation product, which then pass through food chains to animals and humans. Water can carry radioactive waste from nuclear power plants and mining operations into the earth. Starting from the soil they reach the plants, livestock, and finally, man via milk, meat, and other sources (Mishra, 2016). Soil contamination is made worse by desertification, a process that results in a loss of soil fertility and natural vegetation. It is the process by which pastures, agricultural lands, and other areas erode and become barren landscapes. Desertification is caused due to a variety of natural and human reasons, which have negative environmental, economic, social, and civilizational consequences. They include, deforestation followed by excessive clearance, pressure from farmers, fires, and military activities; the shifting of sand dunes; and massive sand and dust storms that contaminate the atmosphere. In addition to increasing water erosion, desertification causes the fertile soil layer to erode, which has a detrimental effect on irrigation effectiveness, dam storage capacity, and related expenses. As a result, the loss of forests and other vegetation has contributed significantly to the worsening of the ecosystem and the possibility of drought (Rashid, 2017). Because they release several hazardous components into the environment, natural phenomena like volcanic eruptions and forest fires damage culture (Eugenio et al., 2018). Limiting the use of soil pollutants, switching to organic farming, using improved agricultural practices, etc., can all help reduce soil pollution and its negative effects on civilization.

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**2.1.1.fHeavy Metal Pollution**

Individual metals with high densities, atomic weights, and atomic numbers are referred to as heavy metals. There are numerous ways in which heavy metals are discharged into the environment: mining, urbanization, the chemical industry, sewage treatment plants, pesticide manufacturing facilities, biomedical applications, and hazardous farming methods (Das et al., 2023). Heavy metal contamination is considered as significant and critical environmental issues that reduce crop productivity and directly or indirectly jeopardizes the survival of almost all types of living entities on the planet (Aziz et al., 2023). When plants absorb harmful metals, chemical residues remain on the product which is sold, leading to mutagenic responses and human cancer (Kamaruzaman et al., 2023).Heavy metal pollution affects wildlife because it disrupts the natural balance of the environment and lowers biodiversity as wildlife directly depends on plants for survival (Fei et al., 2022). Many years are spent in the environment by heavy metals because they are usually not biodegradable (Suman et al., 2018). Even at low amounts, heavy metals including arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) are thought to be highly hazardous to unintended living things (Di et al., 2023). Technologies suitable to measure metal mobility and presence in soil, water, and wastewater have been developed with respect to the rising environmental pollution problems. Using living things like bacteria to cut down the hazardous materials in the atmosphere is known as bioremediation (Sonawane et al., 2022). Bioremediation is thought to be a strategy of the future for decreasing the impacts of pollution on the environment produced by human activity. This method is ecologically sound and appropriate for cleaning up pollutants (Bala et a., 2022). Phytoremediation is efficient plant-based method which has emerged recently to solve environmental problems, by collecting and eliminating elemental contaminants or drop down their bioavailability in soil or water, using plants (Liu and Tran, 2021). Both aquatic and terrestrial plant species have been used to remove contaminants from the environment. In view of the technology's great efficacy, cost, and environmental friendliness, it is largely accepted in modern research (Sharma, 2021).

**2.1.1.gNoise pollution:**

Noise pollution, often referred to as environmental noise/sound pollution, that encompasses the dissemination of unwanted sound that can have negative consequences on both human and animal behaviour. It is predominantly generated outdoors through various sources such as industries, transportation systems, and ventilation systems worldwide. Inadequate urban planning can worsen noise dispersion, which can result in pollution, and residential areas may experience increased noise pollution due to the close proximity of industrial and residential structures. Major source of noises in populated areas or residential neighbourhoods include loud activities such as transportation (traffic, railways, aircraft), landscaping services, construction work, power generators, wind turbines, explosions, and human activities. According to the WHO (World Health Organization), anthropogenic noise is very harmful type of induced noise and is a significant global contaminant. People are facing more difficulties as a result of using cars and electronic devices more frequently (Kattakayam, 2022). It has been shown that noise affects a variety of non-auditory systems in addition to the auditory system in both human and animal models. It possesses the capability to adversely affect the CNS (Central Nervous System) of the brain through various mechanisms (Arjunan et al., 2020). The threshold of bearing sound is different among animals and is affected by several factors such as age, shape of the ears, species and breed of the animal and health condition (Raghy et al, 2023). Noise pollution affects behaviour, breeding, growth and well-being of birds. Noise was noted to cause sleep disturbances and affect the endocrine and cardiovascular systems, in laboratory animals (Padodara and Ninan, 2023). However, despite major advancements in research in the rapidly evolving field of noise pollution, the focus has predominantly been on specific aspects such as physiology, behaviour, terrestrial ecosystems, of particular taxa. Experimental evidence indicates that anthropogenic noise may have adverse effects on the development, physiology, and behaviour of both invertebrates and vertebrates (McLaughlin et al., 2016). Compared to natural noise, anthropogenic noise pollution is characterized by a broader scope and volume, thereby posing a wide range of negative consequences on animals.

**3 CLIMATE CHANGE**

Climate change has a huge impact on human, animals, ecosystems, and energy (Padodara and Ninan, 2013). Climate change, driven by greenhouse gas emissions, is anticipated to have significant adverse effects on both human and animal health (Rabinowitz and Conti, 2013). The Earth's average temperature is expected to rise by 1.4°C to 5.8°C by the end of the 21st century, mostly as a result of greenhouse gases, according to the Intergovernmental Panel on Climate Change (IPCC, 2007). This warming trend is expected to profoundly impact the agricultural sector in the foreseeable future. Direct and indirect consequences of climate change on animal health can be attributed to changes in air temperature, relative humidity, precipitation patterns, and the frequency and intensity of extreme weather events (Lacetera, 2019). Direct impacts include changes in ambient temperature, photoperiod, and rainfall, while indirect effects encompass factors like disease prevalence, reduced availability of feed and water, and diminishing grazing lands. Both direct and indirect consequences are predicted to have detrimental effects on livestock productivity. The ideal conditions for the growth and spread of pathogenic microorganisms are greater temperatures and increased humidity (Padodara and Ninan, 2013). The health of cattle is seriously threatened by climate change, which can modify the amount and quality of feed that is available and intensify competition for natural resources (Garnett, 2009). Furthermore, changes in precipitation and temperature may have an impact on the introduction of rare diseases into animal herds. These environmental stressors can negatively impact various aspects of livestock, including health, growth, reproductive functions, and overall yield (Nienaber and Hahn, 2007; Svotwa et al., 2007; Nwosu and Ogbu, 2011). Among all the different meteorological variables, environmental temperature appears to play a crucial role in determining cattle productivity (Reynolds et al., 2010).

**4 HEAT STRESS**

Livestock encounter various stressors throughout their production cycle, with temperature fluctuations being among the most challenging to manage (Ninan, 2024; Bhimte et al., 2018). Heat stress, in particular, poses a significant threat to livestock production (Roth, 2020). It occurs when the core body temperature surpasses the normal activity range due to an excess heat load, prompting physiological and behavioural responses to alleviate the strain (Bernabucci and Mele, 2014). While several bio-meteorological indices aim to predict heat stress events, Temperature-Humidity indices (THI) are widely used due to their accessibility (Bohmanova et al., 2007). As temperatures rise, extreme heat events like heat waves are expected to increase in severity, duration, and frequency (IPCC, 2007). These climate changes have already impacted global biological systems, altering species distribution, population sizes, reproductive timing, and disease outbreaks, particularly in forest ecosystems (Henry et al., 2012). Such changes may lead to the rapid spread of vector-borne diseases and parasites, along with the emergence of new diseases. During heat stress, elevated prolactin circulation may aid in heat dissipation mechanisms, serving as an indicator of heat stress (Alamer et al., 2011). Heat stress negatively affects dairy cow performance across all production phases, leading to decreased growth, reproduction, and increased disease susceptibility, ultimately delaying lactation initiation. Livestock also experience disrupted oestrus activity and fertility during summer, resulting in economic losses, especially in areas exceeding their thermal comfort zone. In developing countries, the impact of adverse weather on animal performance is most noticeable in rural areas where people rely on the production of crops and animals. The existence of housing and management technology can reduce the effects of climate change on livestock, but their sensible application is necessary for livestock companies to remain viable and profitable (Gaughan et al., 2002). India has been experiencing severe and prolonged heat wave since May 2024 (Charmaine, 2024). The Indian dry season (March – July) with the highest temperatures normally occurring in April and May coincided with the heat wave. In the month of May, 2024 Narela, Najafgarh in Delhi recorded > 50 °C whereas Churu in Rajasthan recorded 50.5 °C which was 7 °C above normal and Sirsa in Haryana recorded 50.3 °C (Financial Express, 2024). These were noted to be the country's highest temperatures in eight years. According to the World Meteorological Organization (c.f. Charmaine, 2024) Asia is heating up faster than the global average, with increased casualties and economic losses from floods, storms, and more severe heatwaves. As per the IMD data, the warmest night was noted in Delhi with the minimum temperature being 35.2 °C. The above normal temperatures that were noted contributed to severe heat stress and deaths in humans, poultry and livestock.

**5 COLD STRESS**

The health, wellbeing, and reproductive systems of ruminants are adversely affected by exposure to extreme temperatures (Baumgard et al., 2013; Salama et al., 2016). There are certain parts in the earth where peak temperatures in the summer are reached and lowest temperatures in winter are reached. According to Baumgard et al. (2013), animals in these places find it difficult to adapt to the summer and winter weather due to the significant temperature differences between the seasons. Seasonal variations in the environment and climate are known to affect the growth performance of animals (Birkelo, 1991). These modifications are probably the result of variations in the efficiency of energy usage and response to basic energy demands (Mujibi, 2010). Ruminants have the ability to adapt physiologically and behaviourally to cold temperatures, enabling them to preserve energy balance (Verbeek et al., 2012). According to reports, an animal's energy needs for maintenance might rise by 20% in colder climates and by 100% in rainy and windy conditions (NRC, 2007). Cold Stress (CS), caused by extended exposure to cold environments, is characterized by a range of temperature regulating systems to maintain consistent maintenance requirements until the threshold temperatures are exceeded (Young, 1983). Further, animals' performance and efficiency would decrease due to metabolic acclimatization brought on by cold exposure (Young, 1981).

**6 BLOOD PICTURE**

Haematological parameters vary greatly under different environmental conditions during heat stress. The values of RBC, PCV, Hb, and WBC will rise. The increase in PCV and haemoglobin levels may result from either an increased attack by free radicals on the lipid-rich red blood cell membrane, which lyses the RBC, or from an insufficient supply of nutrients for the synthesis of haemoglobin as the animal consumes more feed or reduces voluntary intake in response to heat stress (Srikandakumar et al., 2003). However, the increased values of leucocytes are suggestive of a well-developed immune system in the animals with such number of immune cells to offer good health (Tambuwal et al., 2002). The body's primary defence system against infection and antigens is the neutrophil. Elevated counts can suggest a persistent infection, while decreased counts might suggest a compromised immune system. Lymphocytes are involved in protection of the body from viral infections. Elevated levels may indicate an exhausted immune system. Being the largest blood cell and the body's second line of defence system against infection, monocytes can aid in the battle against serious illnesses. There will be an increase in neutrophil, eosinophil, lymphocyte and monocyte count during heat stress.

A study conducted by Maurya et al. (2013), on cold stress and its effect on the Malpura lambs state that the concentration of PCV and Hb is higher in cold stressed lambs as compared to lambs protected against cold stress. They noted the rise in PCV and Hb in the lambs may be the result of increased RBC and Hb synthesis to preserve homeostasis. Due to a reduced respiration rate and associated increase in erythropoiesis, the increase in PCV value during cold stress is a sign of tissue hypoxia (Deaton et al., 1969). Birds in cold environments have reduced body temperature, respiration, respiratory water loss, and oxygen consumption. The partial pressure of oxygen in birds' blood is lowered by their reduced oxygen intake (Blahova et al., 2007). The results of Maxwell et al., 1992, which showed that low environmental temperature or cold stress increases total erythrocyte count and Hb level, are consistent with the rise in total erythrocyte count and haemoglobin concentration during a cold stress period.

Total leukocyte count increased in response to cold stress (Sundersan et al., 1990). The increase in leukocyte count might be attributed due to the rise in lymphocyte concentration during cold stress. The heterophil to lymphocyte ratio is a reliable measure of stress in poultry chickens. Heterophil to Lymphocyte ratio decreased after cold stress in birds, this implies that cold stress has immune modulatory effect in birds. Cold stress activates the innate immune system as well as certain components of the adaptive immune system (Hanglapura et. al., 2004). According to Sinclaire et al. (2000), the increase in lymphocyte number due to cold stress suggests improved immunological reactivity

**7 IMMUNE SYSTEM**

Immunity is of two types, innate and adaptive immunity. Innate immunity is a non-specific immunity, forming the first line of defence. The adaptive immune system which gets activated after the entry of the pathogen is divided into i) Cell Mediated Immunity (CMI) and ii) Humoral Mediated Immunity (HMI). Under the Cell Mediated Immunity (CMI), T-lymphocyte plays a significant role while the B-lymphocyte play a vital role in HMI. Under normal condition, the animal maintains equilibrium between T helper1 cells which favours the Cell Mediated Immunity and T helper 2 cells which favours the Humoral Mediated Immunity. Cells involved in the adaptive immune system include natural killer cells, mast cells, eosinophils, basophils and the phagocytic cells (macrophages, neutrophils, and dendritic cells). Heat stress (HS) impairs both humoral and cellular immunity by regulating the synthesis of different inflammatory and anti-inflammatory cytokines and reducing the production of primary and secondary immunoglobulins, which in turn impairs normal immunological function (Bagath and Sejian, 2018). Stress in any form will cause cortisol levels to increase. In line with the observations of other researchers, Ninan and Vadodaria (2000) in their study on peri-parturient periods in sheep noted that plasma cortisol levels are increased during stress. Plasma cortisol decreases the production of L-selectin expression on the surface of neutrophil, which is responsible for recruitment of neutrophil causing inhibition of the movement of the neutrophils into the tissue and their phagocytic activity. During heat stress condition, the Heat Shock Proteins increases and encourages the innate immune system cells to act against the invading pathogen. During heat shock, the migration of circulating leucocytes into the mammary glands diminished. In pigs, during the summer season, the level of IgG and IgM decreased during summer while the level of IgA did not change on comparison with spring autumn and winter (Chu and Song, 2013). In heat stressed calf, the total IgG ingested from colostrum did not differ, which indicated that the calf's capacity for absorption of IgG was compromised. This may be due to the reason that uptake of IgG in the first days of life is associated with turnover (i.e., apoptosis) of the initial population of enterocytes in the small intestine, which are replaced by enterocytes that form tight junctions and limit movement of large molecules such as IgG, impairing its absorption in utero (Ahmed et al., 2021). Serum IgG levels in calves also fall during HS condition (Genc and Coban, 2017), In the broiler, IgG also dropped after HS; this could be because the lymphoid organs reduced in size (Park et al., 2013). HS affects humoral immunity thereby reducing the synthesis of certain immunoglobulin. Heat stress (HS) immunomodulated the function of immune response of the chickens through shifting the B-lymphocyte to a T-cytotoxic and T-helper lymphocyte profile (Honda et al, 2015). During HS condition the balance between the two is disturbed due to secretion of the glucocorticoids. During chronic HS, the immune system favours a shift in the response towards the HMI. The innate and adaptive immune systems may be modified by chronic HS, which could have a deleterious effect on the immune system (Bagath and Sejian, 2018).

Environmental pollution, especially air pollution, is now a widespread worldwide problem that affects not only the health of humans but also the welfare of animals and plants. Depending on a number of variables, including exposure routes, dose levels, and timing, Xenobiotic compounds (a broad category of pollutants) can either strongly increase or decrease immunological response (Kreitinger et al., 2016) of animals. Air pollution can affect many immune cells, such as neutrophils, dendritic cells, lymphocytes, and macrophages, which are important for coordinating adaptive immune responses. The tendency of air pollution to elicit pro-inflammatory immune responses in a number of immune cells has been noted repeatedly. In particular, air pollution has been linked to both a disruption of anti-viral immune responses and an increase in T helper 2 (Th2) and T helper 17 (Th17) cells adaptive immunological responses, which are frequently seen in ailments like allergy and asthma. Furthermore, air pollution can interfere with regulatory immunological and in vitro anti-microbial responses. According to Glencross et al. (2020), these pollutants cause the epithelium and macrophages to release inflammatory cytokines.

Pollutants have the tendency to interfere with the immune responses and induce immunotoxicity (Suzuki et al., 2020). The skin, blood, respiratory system, and digestive tract are the four main routes of entry for these toxicants into the human body. After entering the body, they can affect many organs, including the immune system. Toxicants interact with the immune system, either purposefully or accidentally, and can cause immunological suppression or activation. These effects can be beneficial or harmful, depending on the particular disease situation, since undesirable immune activation or repression may result in negative health outcomes (Kreitinger et al., 2016). Xenobiotic receptors, such as the aryl hydrocarbon receptor (AHR), play a crucial role in detecting and responding to certain environmental pollutants. Upon activation, these receptors trigger the expression of detoxification enzymes, serving to safeguard the body. However, prolonged AHR activation can result in immunotoxic effects. Another vital defence mechanism against environmental pollutants is the KEAP1, Kelch-like ECH-associated protein 1-nuclear factor erythroid 2–related factor 2 (KEAP1-NRF2) system which is important for removing oxidative stress. KEAP1 acts as a sensor protein, detecting environmental toxins and subsequently activating the transcription factor NRF2. By promoting the production of genes involved in detoxification, antioxidant defences, and anti-inflammatory responses, NRF2 in turn protects the body from immunotoxicity. Interventions aimed at these sensor-response systems may be able to reduce the immunotoxic effects that environmental contaminant cause (Suzuki et al., 2020).

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**8 CONCLUSIONS**

The quality of life on earth is intricately linked to the overall quality of the environment. With the mounting demand on air, water, and land resources, alongside the rising problems caused by industrial pollution and human-induced alterations in the environment, there is a global imperative to explore new approaches for sustaining and managing environmental components. The sensitivity of animals exposed to environmental pollutants differs with individual species and almost all pollutants cause noticeable changes in all the systems of the body affecting the behaviour, production and hemogram of the animal. Addressing environmental pollution and changing climatic scenario requires inter-disciplinary collaborative efforts and coordination to effectively tackle this escalating issue.

**9 FUTURE PROSPECTS**

Research initiatives to raise the awareness about environmental pollution and its impact on animals should be established. It is needed to ensure that pertinent long-term choices are made that will meet the demand of an interactive and rapidly evolving world. Research on infectious diseases due to pollution must also be further strengthened.

**CORE POINTS:**

1. Environmental factors causing climate change affect animal health
2. Air, water, microplastic, soil, heavy metal and noise pollutants affect the environment
3. Climate change hugely impacts animals and ecosystems
4. Effect of heat and cold stress is reflected on blood picture and Immunity status of the animal

**ABBREVIATIONS:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Abbreviation** | **Full form** |  | **Abbreviation** | **Full form** |
| PANs | peroxyacetyl nitrates |  | PVC | Polyvinylchloride |
| NO | nitrogen oxide |  | PP | Polypropylene |
| NH3 | Ammonia |  | PCBs | polychlorinated biphenyls |
| O3 | Ozone |  | ODTs | octadecyl trichlorosilane |
| PM | particulate matter |  | BPA | Bisphenols |
| SO2 | sulphur dioxide |  | WHO | World Health Organization |
| CO | Carbon monoxide |  | CNS | Central Nervous System |
| NO2 | nitrogen dioxide |  | CMI | Cell Mediated Immunity |
| VOC | volatile organic compounds |  | HMI | Humoral Mediated Immunity |
| AQI | air quality index |  | AHR | aryl hydrocarbon receptor |
| NAAQS | National Ambient Air Quality Standards |  | KEAP1-NRF2 | Kelch-like ECH-associated protein 1-nuclear factor erythroid 2–related factor 2 |
| MPGs | Microplastics |  | RBC | Red Blood Cells |
| WWTP | wastewater treatment plant |  | PCV | Packed Cell Volume |
| PS | Polystyrene |  | Hb | Hemoglobin |
| PET | polyethylene terephthalate |  | WBC | White Blood Cells |
| LDPE | low-density polyethylene |  | Ig | Immunoglobin |
| HDPE | high-density polyethylene |  |  |  |

**Disclaimer (Artificial intelligence)**

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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