# Testudines as Bio-indicators of Water Pollution

Muhammad Qasim Raza[1,*], Zaib-un-Nisa[1], Khazara Ashraf[1], Umar Rashid[2], Nisha Liaqat[2], Nimra Saleem[1], Tanzila Shakoor[1], Muhammad Usama Fareed[3], Zahira Batool[1] and Zahra Sajjad[1]

[1]Department of Zoology, Government College University Faisalabad, Pakistan
[2]Department of Zoology, Division of Science and Technology, University of Education Lahore, Punjab, Pakistan
[3]Department of Physiology, Government College University Faisalabad, Pakistan
*Corresponding author: qasimraza9214@gmail.com

## Abstract

Testudines such as freshwater turtles are long-lived, sedentary organisms that accumulate pollutants (such as OCPs, PHAs, heavy metals and plastic) in their fat tissues, shell and internal organs. This bioaccumulation makes them effective bio-indicators of aquatic ecosystem. These accumulated pollutants impair the reproductive success, cause shell deformities and lead to organ damage. The aim of this study was to compile the information on the use of testudines as aquatic bio-indicators of inorganic and organic pollution. The study concludes that use of testudines in environmental monitoring is valuable due to their ability to reveal integrated changes in ecosystem and support decision-making and improved the water management strategies. The Pleurodira (side-necked turtles) and Cryptodira (hidden-necked turtles) are the two major groups of modern turtles, and they diverge by the way their heads retract. Although many species dwell in or near water, they do not lay eggs beneath the water and breathe air, just like other amniotes (mammals, birds, and reptiles). Even though there is very little information about mycobacteria, chlamydiae, and leptospirae infections in cold-blooded animals. The captive's reptiles, which are always more frequently found in residential settings as pets, can carry and release a wide variety of zoonotic pathogens, of which Salmonella is the most well-known agent.

**Keywords:** Testudines, Marine heatwaves, Sentinel species, Marine turtles, Distribution, Origin of zoonotic bacteria.

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## Introduction

Turtles, tortoises, and terrapins—collectively known as Testudines—play a crucial role as bioindicators of aquatic ecosystem health. Due to their long lifespans, limited mobility, and dependence on land and water habitats, these reptiles are particularly vulnerable to pollutants in their environment. As a result, they often reflect the ecological conditions of the areas they inhabit (Keller et al., 2014). Exposure to human-induced pollutants such as heavy metals, pesticides, and industrial chemicals has been linked to various negative outcomes, including impaired physiological functions, reduced reproductive success, and increased mortality (Keller et al., 2014).

Among them, the green sea turtle (*Chelonia mydas*) holds ecological importance as a keystone species in tropical marine ecosystems. Turtles also help to controlling algae growth on coral reefs and help to protect the health of seagrass beds by grazing. On a global scale their classification as endangered due to the human activities like habitat destruction, overfishing, bycatch and climate change have severely impacted their population (Komoroske et al., 2012).

Sea turtles are magnificent bioindicators of the health of the marine ecosystem because they are hyper sensitive to environmental pollutants. Those contaminants disturb their physiological functions and reduce the strength of their immune system, serving as insight into the effect of environmental reduction (Komoroske et al., 2012). Latest advances in non-native procedure such as blood analysis improve the capability to assess the fitness of turtles with greater precision. Biomarkers, in particular, are increasingly being used to evaluate the physiological state and well-being of these threatened animals (Register et al., 2011; Cortés-Góomez et al., 2018).

Turtles are distinguished by their unique shell structure, which evolves from the fusion of their ribs. They are classified into two major groups; Pleurodira (side-necked turtles) and Cryptodira (hidden-necked turtles), differing mainly in how they retract their heads into their shells. With over 360 recognized species, testudines include terrestrial tortoises and freshwater turtles, and they inhabit a wide range of environments including continents, islands, and oceans. Despite their strong association with aquatic environments, turtles breathe air and must lay their eggs on land, similar to other amniotes such as birds, mammals, and reptiles (Cortés-Góomez et al., 2018).

### Turtles as Indicators of Marine Heatwaves

Extreme weather events are increasingly altering the structure and function of ecosystems across the planet. Among these, marine heatwaves (MHWs)—extended periods of unusually warm ocean temperatures—pose serious ecological and socio-economic threats

(Wernberg et al., 2012; Zinke et al., 2015; Genevier et al., 2019). Even though their effect on coral reefs and marine habitats has been properly verified, the effects on contiguous terrestrial environments such as sandy beaches are poorly understood. This is specifically involved for species like sea turtles which are dependent on beaches for shelter (Schoeman et al., 2014).

Incubation conditions for sea turtles also affect increasing temperature linked with MHWs affecting both survivals of hatchling and sex ratio_ aspects critical to long-term population viability (Hays et al., 2017). Rising temperature often leads to gender imbalance favoring females and can reduce the hatchling success rate for increasing the population survival rate. (Poloczanska et al., 2009).

**Turtles as Indicators of Water Ph**

The red-eared slider (*T. s. elegans*) is well suited, but its gut health still affected when the water pH is very low. In acidic water the variety and balance of its gut microbes decrease, and easily affected by diseases. Slightly acidity can disturb its gut ecosystem this show the key health indicator of ecosystem. Some microbes adapted to the acidic environment, that weakening the overall immune system of turtle. These slight changing in water pH show the sensitivity of its internal health (Niu et al., 2024). Testudines are long lived animals that can live in the same habitats for long time periods; turtles serve as valuable bioindicators that are easily affected when the water chemistry changes (Niu et al., 2024).

**Turtles and Persistent Pollutants**

Turtles, specifically sea turtles, are easily affected by heavy metals, persistent pollutants (PPs), organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), substances which are heaving long term affects. These contaminants deposit in the ocean and gradually enter the food chain, ultimately becoming the part of the turtles' tissues (Barraza et al., 2020; Montes et al., 2020; Canzanella et al., 2021; Esposito et al., 2022). Due to their vast migratory structure and prolonged life, sea turtles are in contact with a wide range of pollutants making them highly susceptible to persistent exposure.

These chemicals can disturb the physiological functions of turtles or might be understand the immune system of turtles. In most cases exposure of these contaminants can cause fibro-papillomatosis, a disease that causes tumor growth on the skin and internal damage. There are so many other health problems that are included such as hormonal imbalances, digestive issues, respiratory problems, organ damage and disrupt reproductive system that reduce the reproductive capacity (Esposito et al., 2022).

**Marine Turtles as Sentinel Species**

Although they are physically resistant and strengthen but marine turtles are defenseless against the environmental stressors. Exposure to contaminants like crude oil can cause instant and severe damage. Exposure for short time with crude oil has been shown to lead to accidental death of skin tissues and structural deformities in green sea turtles, enhancing the risk of infection in them (Lutcavage et al., 1995). Long term contact with pollutants and other anthropogenic stressors can cause long term effects, weaken immune responses, and reduce immune responses and greater health risk (Aguirre et al., 1995; Lutz, 1998).

As sentinel species, sea turtles provide critical information about the overall health of marine ecosystems. Their responses to environmental changes serve as early warning signals, helping researchers and conservationists identify emerging threats and develop effective protection strategies.

**Turtles are Indicator of Metal and Metalloid**

Turtles have a prolonged life span so they can accumulate the huge number of metals in their tissues as compared to the aquatic column (De la Lanza-Espino et al., 2000; Aguilar et al., 2002). So they are well known indicators of chemical pollutants (Caurant et al., 1999). When turtles are exposed to metals their enzymes become inactive and the denaturing of protein starts, causing injurious effects like developmental disability, nerve damage, cancer causing effect or even death (Fossi & Marsili, 2003; Decataldo et al., 2004).

Sea turtles which are exposed to metals or pollutants develop fibropapillomatosis (Keller et al., 2014; da Silva et al., 2016). Herpesvirus is responsible for this condition of turtles that cause growth of tumor on different body parts like eye, oral cavity and skin or about 25 -30% species are internally affected (Herbst, 1994; Aguirre et al., 2002; Aguirre & Lutz, 2004). According to the International Union for Conservation of Nature classes of turtles are becoming vulnerable, threatened or critically endangered (Aguirre & Lutz, 2004).

**Distribution and Trends over Years in the Arabian Sea's Nesting Sea Turtle Fauna**

Throughout successions, these turtles converge to breed at certain locations and times, and their high allegiance to breeding habitats has produced unique germplasm within the species' distribution (Jensen et al., 2013). The sandbars where females lay their eggs are the main locations for reproduction. The created dangers to nesting sites comprise spoilage or renewal of appropriate breeding shores, luminosity from housing and business construction and high whirlwinds carried on by temperature shifts, sea-surge and warming (Fuentes et al., 2010; Pendoley & Kamrowski, 2016). Along with incidental boat hits, fisheries discards, purposive adult hunting, egg harvesting and wild animals hunting on newborns and adult females (Campbell, 2003; Shimada et al., 2017; Gronwald et al., 2019), these hazards have contributed to the long-term decrease of major sea turtle populations across their home range. The International Union for the preservation of Nature's Red List still tags many sea turtle species as vulnerable or severely threatened, despite the fact that some populations have begun to revitalize (Gronwald et al., 2019).

The susceptibility of adults, eggs, and newborns at this stage of development, in addition to the dispersion of brooding marine turtles, offer a patent target point for moderate preservation and supervisory systems designed for stopping or reversing population decreases (Fuentes et al., 2010). Stocks with inadequate documentation and/or ones which are in imminent danger from changes brought on by expanding communities in coastal areas are of special concern. Critically Endangered Hawksbill (*Eretmochelys imbricata*) and Threatened

Green (*Chelonia mydas*) turtle populations can be found in the Red Sea which are considered as hereditarily isolated from the turtles found in the deeper Indian Ocean (Jensen et al., 2019).

There are currently no figures of current and ongoing trends in abundance that may be utilized to ascertain these populations' trajectories. Turtles in the Arabian Gulf also breed on beaches and peninsulas that are currently changing quickly due to massive developments (Wallace et al., 2018). Three schemes in the sovereign state of Saudi Arabia (hence referred to as Saudi Arabia) in particular cover hundreds of kilometers of the mainland's borders and a number of close proximity islands. Statistics on breeding patterns is therefore desperately needed to enable suitable conservation measures for marine turtles in the area. By publishing the results of extensive (several hundred-kilometer) assessments of aquatic turtle nesting locations around the northeastern Red Sea's beaches and islands, which have been carried out since 2018, our study seeks to tackle this problem. We combined this new data with previously published information on the abundance, distribution, and seasonality of marine turtle breeding practices in the Arabian Sea to present an in-depth examination of the practice. We also looked at variations in the number of green and turtles with hawk that nest at several sites where surveys had been done several times. A new benchmark for sea turtle sustainability in the area is provided by this effort, which also adds to international evaluations of marine turtle population trends like the IUCN Red List (Shimada et al., 2017).

**The Origin of Zoonotic Bacteria from Domestic Reptiles**

Cold-blooded animals are more likely to be found in the homes of people who chose them as companion pets, either in addition or in place of dogs and cats. The member states of the European Union that now import the most reptiles have seen the biggest expansion of this trend (Engler & Parry-Jones, 2007). In community locations turtles & the tortoises are among the most frequent reptiles. Many people, however, also maintain lizards and snakes in their homes. These creatures are sometimes housed in cages, but more often than not, they are allowed to roam freely throughout the rooms, coming into intimate touch with the owners' belongings. Although asymptomatic, both confined and free-ranging reptiles may harbor and excrete a wide variety of pathogens that can cause diseases in humans. Most cases of zoonosis are brought on by bacterial infections (Ebani, 2017). A few of them, like salmonellae, are known to cause diseases in people. However, nothing is known about how other zoonosis, such mycobacteriosis, chlamydiosis, and leptospirosis, which can cause serious illnesses in humans, spread among reptiles. Since numerous humans can get zoonotic illnesses from contaminated plants and animals, it represents a major risk to the health of society. Primarily, caged reptiles pose a risk to their owners, especially to youngsters who interact closely with them, as well as to professionals like veterinarians, zookeepers, and circus performers. Furthermore, as they aid in the spread of diseases in nature, free-ranging animals appear to have a role in the transmission of certain zoonotic infections. With a focus on the diseases that these animals can contract, the current study summarizes the most recent findings about leptospirosis, chlamydiosis, mycobacteriosis, and salmonellosis in reptiles (Ebani, 2017).

**Salmonellosis**

Numerous investigations have demonstrated that various *Salmonella spp*. serovars frequently infect reptiles (Pedersen, 2009). Salmonellae are occasionally excreted in the feces of reptiles. Actually, the excretion is not constant, which could make it difficult to identify sick reptiles if they are only subjected to one bacteriological test. Reptiles infected with salmonella typically infect other cold-blooded species directly. However, eating contaminated food—both vegetables and live prey animals like mice or chicks—is a common way for poikilothermic animals to contract the disease. The salmonellae that pet reptiles provide to other domestic animals, especially dogs and cats, increase the risk of human infestations and aid in the spread of pathogens within the home.

Salmonella may infest captive reptiles in a variety of settings, including traveling, the nation of origin prior to export, or animal retailers. Animal anxiety is always influenced by travel and new surroundings, which encourages intestinal pathogens to be excreted in the feces. Turtles are especially susceptible to tension since they frequently reside in spawning pools with large populations, which significantly raise their chance of contracting intestinal diseases. As chelonian eggs move through the cloaca or are buried in wet ground or the sand, these may become contaminated with salmonellae. In less than an hour after exposure, these germs can swiftly penetrate the shell (Feeley & Treger, 1969). Furthermore, there are also allegations of transovarial transmission (Austin & Wilkins, 1998).

**Mycobacterium**

Phidians, saurians, and chelonians are susceptible to infections brought on by non-tuberculous mycobacteria (NTM), which typically create granulomas at different body locations (Soldati et al., 2004). The surroundings include plenty of NTM in the way of soil, dust, water, and plants. Mycobacterial infestations are transmitted by livestock via skin lesions and infected food and/or water. The animals most probably to be in risk are frigid-blood ones with weakened immunity (Montali, 1998). Significant risk factors include stress, poor diet, and coexisting illnesses. The physical position that mycobacterium target in turtle's influences presenting symptoms. Even still, a lot of animals lose weight even when their appetites remain intact. All NTM can cause bacteremia and spread to the kidney, liver, spleen, heart, lungs, bones, gonads, nervous system, and joints (Greer et al., 2003). NTM produces gray-white in color tumors in these locations, which histological examinations reveal to contain lymphocytes, heterophils, blood cells, macrophages, and multiple nuclei large cells. The fibrous connective tissues may encircle older granulomas (Montali, 1998).

**Clamydiosis**

Numerous Chlamydia agents led to serious cases of *chlamydiosis* in both caged and free-ranging reptiles and amphibians during the 1990s. According to the microbiological instruments available at the time, the researchers identified the chlamydial agents found in the initial survey as *Chlamydia psittaci (C. psittaci*). From liver samples of certain Nile crocodiles *(Crocodylus niloticus*) that had fulminant hepatitis and generalized swelling (Huchzermeyer et al., 1994), isolated *C. psittaci* in 1994. The *chlamydiosis* susceptibility of crocodiles was confirmed

by the same authors, who also documented an epidemic of the disease in newborn and young Australasian crocodiles (*Crodylus porosus*) with exudative blindness and hepatitis (Huchzermeyer et al., 2008). Several *chlamydioses* have been linked to cold-blooded animals in in order. The microorganism known as *chlamydia*-like representatives have been found in tissue specimens via certain reptiles that have granulomatous swelling (Soldati et al., 2004; Hotzel et al., 2005). Nevertheless, it is not certain how successful those microbes are in the development of granulomas.

In reptiles, *Chlamydia abortus* and *Chlamydia pneumoniae* (*C. pneumoniae*) have been identified in different instances. These two infections, in addition to *Neochlamydia* sp., have specifically been spotted in the hematoma myocarditis of the heart of a bound green sea turtle (*Chelonia mydas*) that died pursuing a period of anorexia, lethargy, and hesitation to dive.

**Leptospirosis**

The investigation of reptiles' involvement in leptospirosis distribution has attracted a lot of focus over the past few decades. This illness is believed to be a re-emerging zoonosis that is prevalent around the world, but especially in tropical and sub-tropical areas where a significant number of cold-blooded animals live in captivity and roam freely. watery reptiles may be especially susceptible to Leptospirae because of their historical association with watery environments. Leptospirae may be able to endure in both freshwater and salty water, as indicated by the finding of a seropositive crocodiles. Since salt lowers the existence ratio of these spirochaetes, fresh water is more favorable for them (Andre-Fontaine et al., 2015). Nonetheless, some writers claimed that leptospirae could endure in seawater for three days (Saito et al., 2014).

**Conclusion**

It has been concluded that freshwater and marine turtles are vital bioindicators, offering key insights into the state of aquatic ecosystems. Their health reflects the presence of contaminants such as pollutants, shifts in water pH, and temperature changes. As a result, turtles often suffer from growth impairments and other health issues when exposed to environmental stressors. Many turtle species are now facing the threat of extinction, and it is clear that increasing water pollution plays a major role. It has been concluded that anthropogenic activities like discharging toxic sewage, untreated industrial waste, and discard plastic into rivers and oceans are promoting the degradation of these habitats. These contaminants cause the oxygen depletion in the water, disrupt ecosystems, and cause serious issues to aquatic ecosystem. Due to a combination of habitat loss, coastal development, overfishing, climate changes and other human activities leading to the declining of sea turtle population in Arabian sea. Some specific regions where the environment undergoing the rapid changes critically endangered and vulnerable species which are present in that area are at high risk. In conclusion protecting these sentinel specie not only support their survival but also play a vital role in conserving the health of aquatic ecosystem.

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