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# Atypical Monsoon Downpour and the Potential Rise of *Salmonella*-oriented Typhoidal Cases in Pakistan: A Call for Proactive Water Supply and Drainage System Overhaul

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## ABSTRACT

Typhoid fever is primarily caused by the *Salmonella* species and its associated hundreds of serotypes, many of which are prevalent in Pakistan. The country has been in the limelight for the first ever reported cases of highly drug-resistant *Salmonella* and then its subsequent recovery from many edibles, including meat sources. While efforts are underway to find new anti-microbials for targeting drug-resistant *Salmonella*, it still remains a concerning issue. *Salmonella enterica* is a global issue which pertains not only to the health sector but also impacts the socioeconomic status of people in developing countries, such as Pakistan. Although the transmission of *Salmonella* has also been significantly reported from developed countries as well, developing countries are mostly affected as there are a high number of mortalities and morbidities reported from the underdeveloped countries. This short opinion article highlights the key factors responsible for the increased surge of *Salmonella*-based typhoidal cases underscoring the importance of a well-maintained sewage system, as well as the socioeconomic importance and surveillance of typhoidal cases, particularly in the rainy season, to mitigate a major issue pertaining to public health.

**Keywords:** monsoon, public health, *Salmonella*, typhoid, water contamination

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## 1. INTRODUCTION

For the 2025 monsoon season, the Pakistan Meteorological Department (PMD) forecasted normal to slightly above-normal rainfall over central and southern Pakistan, with enhanced rainfall in northeastern Punjab and Kashmir. It was also predicted that the rains would cause numerous floods, both in rural and urban areas of the country. PMD warned of increased risks of riverine floods, as well as flash/urban flooding. Associated with this, it was also predicted that there would be Glacial Lake Outburst Flood (GLOFs), along with dust storms, hail, and strong winds. In an advisory issued by the same department, various concerning departments were warned and directed to stay updated about the changing weather patterns and be ready for any emergency and rescue/relief operations.

Major reservoirs, including Tarbela and Mangla, currently maintain healthy water levels, indicating favorable water availability. As the monsoon season approaches, it brings relief from the scorching heat. However, associated with these rains is a surge in *Salmonella* causing typhoidal infections, primarily due to factors such as the clogging and rupture of water supply pipes, which consequently results in the mixing of drinking water and (poorly maintained) sewage water systems. Various serotypes, such as *S. enteritidis*, *S. typhimurium, S. typhi*, and *S. paratyphi*, cause significant health problems. However, S. *typhi* remains the leading serovar that remains highly prevalent during rainy and monsoon seasons. Monsoon rains result in urban flooding and cross-contamination of drinking water reservoirs which, in turn, results in the rise of typhoidal cases [1-8]. As *Salmonella* spreads through the oro-fecal route, its dissemination results in its consumption by the masses, majority of whom are already deprived of clean drinking water facilities. Thus, this pattern of drinking water contamination adds to an already overburdened and fragile health system of Pakistan [9-11].

There are various risk factors that contribute to this pattern of cross-contamination. Firstly, there is a significant rise in humidity and overall weather remains humid and warm, which is perfect for the growth of

*Salmonella*. The sewage water disposal system is already aged and barely sees any improvement and repairing. There is a parallel network of clean water supply pipes to homes along with the sewage disposal system. In monsoon, the extraordinary accumulation of water results in the mixing of water reservoirs which, in the absence of proper treatment, contributes to the significant rise of *Salmonella*-based typhoidal cases. This is because water is not only used for drinking or cooking but also for sprinkling the fresh produce available in the markets. Also, there is a general lack of awareness about the consumption and availability of clean drinking water since there is a huge gap in public health education, on top of which poor surveillance and fragile infrastructure contribute significantly to the transmission of these pathogenic microbes [12-17].

Other than inflicting serious damage to the health system, the *Salmonella*-oriented typhoidal cases can be of socioeconomic importance (Figure 1).

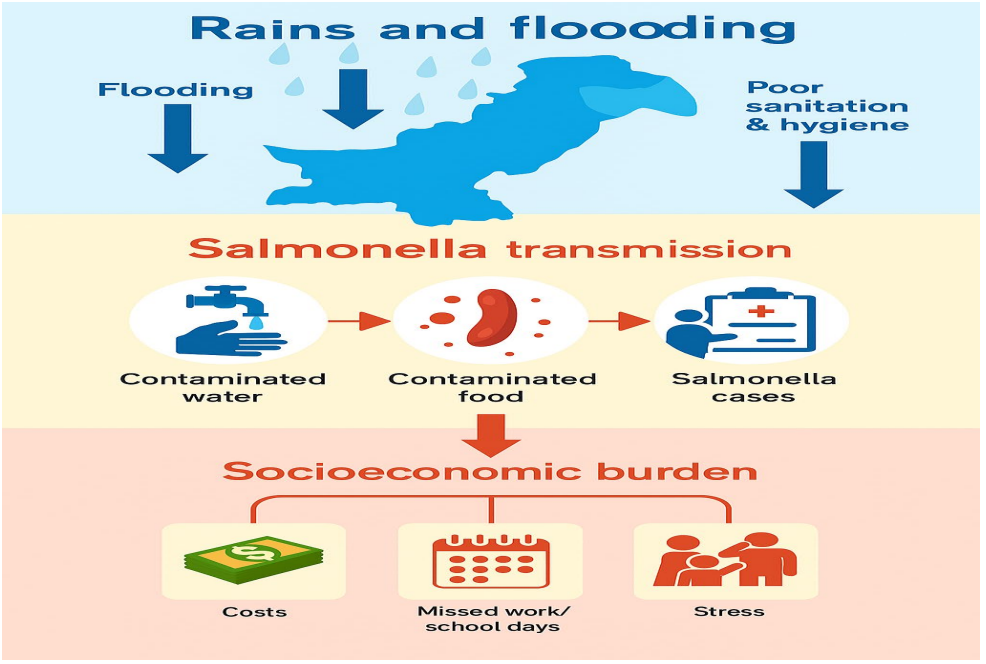


**FIGURE 1.** Schematic Representation of the Rainfall–Contamination–Infection Cycle

Figure 1 shows how monsoon rainfall leads to sewage overflow, drinking water contamination, typhoid transmission, and the socioeconomic impact. The figure also highlights critical intervention points including sanitation improvement, chlorination, vaccination, and public awareness

Typhoidal fever can result in decreased productivity among masses, from infected children missing their school days to adults losing their wage hours. Associated with these is the cost of diagnosis, as well as other medical expenditures including physician's fee and drug costs, that can imbalance the overall budget of families. Reports suggest that there can be 7-10 lost workdays per adult and 3-5 missed school days per child, while treatment and associated costs can exceed USD 100 per case in urban settings—substantial in regions where the average monthly income remains below USD 150 [11,18-20]. These facts and figures are sufficient to call for the urgency of preventive strategies, including improved sanitation, vaccination coverage, and surveillance.

The introduction of conjugate vaccines to curb *Salmonella* and typhoid was seen as a game changer since its efficacy is very well established [20]. However, even vaccine alone cannot protect the masses from typhoidal cases, especially in the rainy season. Long-term solutions must focus on upgrading urban drainage and water systems, improving rural sanitation, and strengthening surveillance to detect and respond to outbreaks early [21].

## 2. CONCLUSION

Rainy season is an exponential risk factor in terms of *Salmonella*-based typhoidal cases; however, the pattern remains somewhat predictable and in the presence of suitable measures is avoidable or preventable. There is a need of a huge mass awareness campaign, especially during monsoon. Additionally, and necessarily, pre-season chlorination of water supplies, targeted vaccination drives in high-risk districts, and stricter regulation of street food hygiene during rainy months could substantially reduce disease burden.

As scientists, clinicians, and policymakers, we must move from reactive

crisis response to proactive risk reduction. The monsoon should remain a season of life and joy—not of some waterborne diseases which add to the problems of the already overburdened and less equipped health system. Recognizing and addressing the link between seasonal rain and rising typhoid cases is a critical step towards that goal. Government and public health agencies can enlighten the masses by spreading necessary awareness about the importance of safe water and typhoidal health hazards. This can be done through telephonic dial tune messages, TV ads, radio messages, and utilizing buses and social media.

## CONFLICT OF INTEREST

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

## DATA AVALIABILITY STATEMENT

The data availability is not applicable as no new data was created.

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