Medicine and Society

A case for banning paraquat in India: A public health concern

BHARADWAJ SAI SATYA MURTHY MALLA, ANANTH RUPESH KATTAMREDDY

Paraquat (N, N2-dimethyl-4,42-bipyridinium dichloride) is a non-selective herbicide widely used in Indian agriculture. It is a highly toxic compound that can cause serious health effects, including death if ingested, inhaled or absorbed through the skin. Paraquat (PQ) has been banned in many countries due to its health risks, but it is still available in India for sale and use. A major concern for Indian doctors is the high number of deaths caused by intentional or accidental exposure to PQ. PQ poisoning is often fatal, and also causes high morbidity including hepato-renal failure, progressive fibrosis of the lung and Parkinson disease. The lack of an effective antidote for PQ poses a challenge in the management of poisoning with PQ, providing a compelling rationale for its ban.

The ADME (Absorption, Distribution, Metabolism, and Elimination) of PQ is unique in humans. Once absorbed, it is initially concentrated in the kidneys and then in the lungs. The pulmonary effect can be explained by the accumulation of PQ in alveolar type I and type II epithelial cells through a pathway that has been shown to accumulate endogenous diamines and polyamines. At the toxicodynamic level, the molecular mechanism of PQ toxicity is based on redox cycling-induced intracellular oxidative stress. When PQ accumulates, it undergoes a one-electron nicotinamide adenine dinucleotide phosphate hydrogen (NADPH)-dependent reduction to generate a free radical. The free radical interacts strongly with molecular oxygen to reform a cation and produce a superoxide anion, which subsequently dismutases to form H_2O_2. This triggers a cascade of more reactive radicals, which tend to initiate lipid peroxidation, mitochondrial damage, apoptosis, cell death and inflammatory response[3] in multiple organs including the lung, liver and kidney.[1] PQ is not completely metabolized in the human body and is excreted unaltered through the urine and faeces with a mean distribution half-life of 5 hours and an elimination half-life of 84 hours. The elimination phase of PQ toxicokinetics is linked to death from pulmonary fibrosis. The urine sodium dithionite test confirms the poisoning. Although there is no specific antidote, immunosuppression by using steroids, antioxidants such as N acetyl cysteine, and charcoal haemoperfusion are being used for the management of PQ poisoning without much success.[1]

PQ is a highly toxic herbicide affecting the health of pesticide applicators, farmers and people living within the vicinity of farmlands. With its known acute toxicity and potential link to Parkinson disease, PQ has been banned in many countries. Several studies have shown adverse effects of PQ ranging from birth defects to learning and developmental disorders.[2] Recently, it has come to light that Syngenta, the manufacturer of PQ, was aware of the compound's extreme toxicity. To address regulatory toxicology concerns, they incorporated an emetic, coded as PP796, into the formulation. This was aimed to maintain PQ in the market, despite its hazardous nature. However, it is important to note that the quantity of emetic added to the PQ formulation was less than what is necessary to induce emesis in humans.[3]

Due to the easy availability and low cost of PQ, people from non-agricultural backgrounds also started abusing it for self-harm. In an Indian study, young illiterate people from non-farm backgrounds attempted more to self-harm with PQ. It was also observed that most of such suicides were a result of impulsive behaviour rather than being a consequence of chronic depression wherein the easy availability of PQ is also a culprit. PQ has gained an infamous reputation as a weapon for intentional self-harm among Indians. A weed scientist proposed a potential solution to the issue, recommending the sale of diluted PQ for immediate spraying instead of offering the concentrated 24% formulation. However, companies are reluctant to consider this suggestion, citing concerns about increased transportation costs.[4]

PQ, being a contaminant in soil and aquatic environments has the potential to infiltrate the food chain and undergo biomagnification.[5,6] It has a half-life of up to 20 years in soil and in the aquatic environment, and it may pair with suspended or precipitated sediments. The half-life of PQ in water ranges from 2 to 820 years, depending on sunlight and water depth.[7] Residues of PQ were observed in the contents of surface water, ground water and drinking water indicating its potential of being a persistent organic pollutant. PQ is known to cause toxicity in zebrafish and snakehead fish. The pollutive effects of PQ on the environment can be mitigated through the utilization of PQ encapsulated with nanoparticles consisting of pectin, chitosan and sodium tripolyphosphate. This approach has demonstrated high effectiveness and a delayed release pattern of PQ.[8] However, such approaches may have a bearing on the production costs and are not industry friendly.

PQ is a known reproductive and developmental toxicant. Pregnant women living in the vicinity of agricultural areas where PQ is used may be exposed to PQ through multiple routes. The risk for pregnant women due to PQ is high because of its extremely small diameter and low molecular weight. PQ can cross the placenta and impact foetal growth and development.[9] The PQ level in foetal blood was found to be 4–6 times greater than that in the mother's blood in cases of attempted suicide during pregnancy. Based on the analysis of hair, cord blood and

Andhra Medical College, Visakhapatnam, Visakhapatnam 530002, Andhra Pradesh, India
BHARADWAJ SAI SATYA MURTHY MALLA, ANANTH RUPESH KATTAMREDDY
Department of Forensic Medicine and Toxicology

Correspondence to ANANTH RUPESH KATTAMREDDY; *ananth.kattam@gmail.com*

[**To cite:** Murthy Malla BSS, Kattamreddy AR. A case for banning paraquat in India: A public health concern. *Natl Med J India* 2024:**37:** 270–1. DOI: 10.25259/NMJI_875_2023]

meconium samples, PQ has been linked to organ toxicity and intrauterine death of the foetus.

PQ is approved for use in row middles on a variety of crop species. With new PQ restrictions in effect in some parts of the world, farmers attempted to search for alternate herbicide choices to suppress emerging weeds.[10] The Pesticide Action Network UK has found a diverse array of farming practices that can directly replace PQ, encompassing both non-herbicide and herbicide methods. Non-herbicide choices include living mulches, controlled grazing, mechanical weeding and thermal weeding. Additionally, alternative synthetic herbicides were identified; however, potential health and environmental repercussions were cautioned against. There are several selective herbicides that are less toxic than PQ such as glyphosate, glufosinate ammonium, carfentrazone-ethyl and diuron.[11]

Despite the potential increase in costs in adopting alternatives to PQ, it is imperative to find alternatives to PQ in India. Herbicide substitutes may increase expenses by a factor of 2–10, while non-herbicide methods might incur costs ranging from 10s to 100s of times the original. However, with widespread implementation, economies of scale could eventually lead to cost reductions. It is crucial to recognize that the additional costs associated with health impacts and lives lost due to PQ far outweigh any potential savings.

PQ is used extensively in India, even in crops where its use is prohibited. State-level attempts to ban it have proven ineffective due to the exclusive authority of the central government in pesticide regulation. As the central government considers amending the Insecticides Act for better oversight of pesticide use, there is a critical need for thorough scientific risk assessments to understand the adverse effects of PQ. A study in Delhi's Pusa agricultural fields revealed high PQ levels in wheat grains, surpassing the 0.1 mg/kg threshold. Notably, even the control crop, without PQ application, showed background residue at 3.1 mg/kg.[13]

PQ has been banned in approximately 60 countries, including Switzerland, where the herbicide manufacturer Syngenta (Chinese owned) is headquartered. In ongoing litigation, an activist moved the Supreme Court of India asking to prohibit the use of 99 pesticides and herbicides, including PQ. Kerala prohibited the pesticide, but in February 2022 the ban was revoked. Syngenta is also in violation of the International Code of Conduct on Pesticide Management according to several public health and environmental activists. It is alleged that herbicides as hazardous as PQ should be sold only where protective equipment is commonly used to mitigate the risk from spillage, inhalation or direct contact.[14] PQ usage has been banned in many areas of the world, and an appeal for searching alternatives is seriously being considered for the same reason.[11]

In Taiwan, once the use of PQ was prohibited, there was a 58% decrease in PQ suicides and a 37% decrease in total pesticide suicides. In South Korea, after the use of PQ was prohibited, pesticide suicide fatalities per 100 000 decreased from 5.26 to 2.67 in the next 2 years.[12]

In conclusion, PQ has a severe impact on farmers, agricultural workers and potential for misuse and self-harm. This requires immediate regulatory action in India, preferably a total ban. The Government of India should encourage the adoption of alternatives to PQ by implementing measures such as subsidies, awareness campaigns and educational programmes. Financial incentives can motivate farmers to choose less harmful herbicides and other non-herbicide alternatives, while awareness initiatives and education can inform them about the associated health and environmental risks, fostering a shift towards safer and sustainable agricultural practices. The urgency is underscored by the compelling evidence and international consensus on the dangers of PQ including its association with Parkinson disease. A cost–benefit analysis of banning PQ can be accessed here.[3]

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