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Title: Self-Harm in India: Cost-Effectiveness Analysis of a Proposed Pesticide Ban

Author (1): Aditi Nigam  
[nigam@cddep.org](mailto:nigam@cddep.org) (corresponding author)  
Center for Disease Dynamics, Economics, and Policy

Author (2): Neha Raykar  
Public Health Foundation of India

Author (3): Daniel Chisholm  
World Health Organization, Department of Mental Health and Substance Abuse

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## **Abstract:**

**Context:** India reported an estimated 187,000 suicide deaths in 2010, which amounts to 3 percent of total surveyed deaths in individuals aged 15 years or older and about half of all suicide deaths were mainly due to ingestion of pesticides. Public health interventions that restrict access to pesticides, either through their safe storage or through a ban on their use, may significantly reduce suicide deaths in India.

**Aims:** In this paper, we use the example of Sri Lanka's ban on pesticides in the 1990s to evaluate the cost-effectiveness and insurance value of suicide prevention through a pesticide ban in India.

**Methods and Material:** An extended cost-effectiveness analysis was undertaken, comprising an analysis of the population-level costs and health gains associated with a pesticide ban, and also the financial risk protection benefits of publicly financing health care services for individuals who self-harm. Costs associated with a ban, as well as treatment costs following attempted suicide via pesticide poisoning, were estimated in US dollars and health gains expressed in terms of disability-adjusted life years averted.

**Statistical analysis used:** Latin Hypercube Sampling using Monte Carlo simulations

**Results:** Considering only the mortality implications of a pesticide ban, the cost per Disability-Adjusted Life Year (DALY) averted is in the range of US\$ 1,000. If we consider both the mortality and morbidity implications of a pesticide ban, the cost per DALY averted falls below \$200. In terms of financial risk protection benefits, we find that the lowest income quintile has a considerably higher annual insurance value (\$717) than the highest income quintile (\$117).

**Conclusions:** Our findings indicate that a pesticide ban is a cost-effective use of resources and is associated with a greater value of insurance and thus financial protection for the poor relative to the rich, which is important given that the former have greater access to pesticides due to their greater concentration in agricultural settings.

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## Introduction:

Regional studies show that self-poisoning with pesticides is a common method of suicide in low- and middle-income countries.[1] Pesticide poisoning accounts for two-thirds of all suicide deaths in Sri Lanka, half of 187,000 suicide deaths in India, and more than 55 percent in a catchment area of Suriname in South America.[2–4] Access to pesticides in population subsamples or restricted access to pesticides through safe storage can also affect pesticide-related suicides.[4–7] Restricted access to pesticides through safe storage in a container kept close to or within a house has been shown to have mixed effects on the likelihood of a person ingesting a pesticide.[6] Aside from safe storage of pesticides, other proposed measures for addressing the high rates of suicide by self-poisoning include investments in medical resuscitation programs and equipment, but these are costly, vary according to the pesticide ingested, and are sometimes impractical because of high transport costs or distance.[8] Restricting access to pesticides, achieved via pesticide bans, legislation, or the reduced sale and import of pesticides (such as paraquat in Samoa, parathion in Argentina, endosulfan in Sri Lanka, and parathion in Jordan), is seen as an effective way to reduce deaths by self-poisoning in low- and middle-income countries.[9]

## **BACKGROUND**

In India, self-poisoning is the most common suicide method, followed by hanging, burning, or drowning.[3] Forty-nine percent of all male suicides and 44 percent of all female suicides in India are attributed to self-poisoning, often from agricultural pesticides.[3] The Pesticide and Documentation Unit of the Government of India directorate of plant protection, quarantine and storage recorded that the highest demand for organophosphate pesticides in India from 2009-2010 were for endosulfan, chlorpyrifos, and phorate.[10] As different crops require different pesticides and varying soil types, which can be found in certain regions within India, it is likely that various pesticides would be used across regions. Moreover, because attempted suicide is a punishable offense in India, it is difficult to obtain nationwide estimates of attempted suicides or the exact pesticide ingested.[11] The law to make suicide illegal was enacted to reduce the number of suicides, but as a consequence of the law, hospitals deny treatment or, to avoid legal difficulties, mark the death as accidental rather than intentional.[12] Nevertheless, studies show that restricting access and availability of pesticides can decrease suicides by self-poisoning.[13]

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The purpose of our analysis is to consider the costs and effects of restricting access to pesticides through a pesticide ban in India from a public health perspective. In addition, we consider the consequences of publicly financing the high and potentially catastrophic costs of health care for households following suicide attempts through self-poisoning.

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Subjects and Methods:

**Analytical approach: cost-effectiveness analysis**

We set out to capture the population-level costs and health gains associated with a pesticide ban. We do this by calculating disability-adjusted life years (DALYs) averted as a result of the pesticide ban, as well as the costs associated with its introduction and implementation. We also include costs associated with the management of self-poisoning in hospital-based care settings.

A pesticide ban is not expected to lead to the complete removal of disability for all cases of self-harm through self-poisoning. In fact, more resources may be needed to reduce the non-fatal burden of self-poisoning, such as a more proactive outreach or identification of high-risk cases. Due to the inherent uncertainty in estimating morbidity, we use two approaches to determine overall DALYs averted. The first approach simply considers the mortality implication of self-harm by pesticide poisoning. This can be summarized in terms of Years of Life Lost (YLL) averted (number of deaths averted \* life expectancy). Since self-harm in children is extremely rare, we use the life expectancy of individuals over the age of 14 years.

The second method considers both the mortality and morbidity implications of reduced self-harm by poisoning, summarized as follows:  $\text{DALYs averted} = \text{Years of Life Lost averted} + \text{Years Lived with Disability (YLD) averted}$ , where  $\text{YLD averted} = \text{number of prevalent cases} * \text{disability weight} * \text{treatment coverage in the population}$ . Using this method, we are therefore allowing for a significant proportion of the non-fatal burden of self-poisoning to be averted, as well as lives saved / YLL averted. We include here the total annual costs of treating patients with self-harm by considering the out-of-pocket expenses and the cost to the government of treating a patient in a hospital.

**Analytical approach: Value of insurance**

In addition to health gain, a further potential “nonhealth” benefit of specific interventions or policies, such as public financing of suicide prevention efforts, is the value that some form of health insurance bestows on households that who would otherwise pay privately for health services and goods. Public financing provides

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financial risk protection (FRP) benefits to households by shielding them from the OOP costs and impoverishment-related consequences of health care utilisation. [14] In this study, we used as our FRP metric the money-metric value of insurance provided by public financing, which quantifies ‘insurance risk premiums’; it reflects risk aversion, in which individuals would prefer the certainty of insurance over the uncertainty/risk of possible OOP expenditures, and hence are willing to pay a certain amount of money to avoid that risk.[15] To estimate the FRP we first estimated the individual’s expected income (before public financing, which depends on treatment coverage and associated costs). We then estimated the individual’s ‘certainty equivalent’ by assigning individuals a utility function that specifies their risk aversion, which is equivalent to calculating their willingness to pay for insurance against risks of medical expenditures. Finally, we derived a money-metric value of insurance provided (risk premium) as the difference between the expected value of income and the certainty equivalent.[15] Aggregating the money-metric value of insurance provided using an income distribution in the population (with a proxy based on country gross domestic product per capita and Gini coefficient) yielded a dollar value of FRP at the societal level.

Another essential component of an extended cost-effectiveness analysis is its examination of the distribution of health and economic benefits by population subgroup (for example, by geographical location, care setting or income quintile). Such an analysis enables policy makers to better understand how an intervention or a policy such as public financing would affect different segments of the population, particularly those with low incomes or high vulnerability.

## **Data**

We perform a cost-effectiveness analysis of a proposed pesticide ban in a population of 1 million, split into five evenly distributed cohorts of 200,000 individuals. Mortality estimates are taken from a *Lancet* study on suicides in India.[3] We apply the sex- and age-specific mortality rates from this study to Round 3 of the District Level Household Survey to derive the weighted average mortality rate for the total population.[16] DLHS-3, conducted in 2007–2008, is a nationally representative data set on reproductive and child health indicators, covering 720,320 households and 3.7 million individuals from 601 districts across India.[16] The survey reports the wealth quintile

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for each household, based on its composition of owned assets, and includes demographic information (age, sex, socioeconomic status) for each member of the household. We assign the age- and sex-specific mortality rates from a *Lancet* study on suicides in India to the individual-level DLHS-3 sample and compute the weighted average mortality rate in India.[3] Similarly, using data on life expectancy (at birth) by age group and sex, we derive the average life expectancy (at birth) in India.[17]

We use the disability weight of all poisoning (with or without treatment) from the Global Burden of Disease 2010 and an effectiveness rate of 50 percent from restricting access to pesticides in Sri Lanka over a 10-year period.[18,19] In 1995, Sri Lanka restricted the import and sale of World Health Organization (WHO) Class I pesticides; this was followed by a ban on endosulfan imports in 1998. From 1995 to 2005 there was a coinciding 50 percent decline in suicide rates.[19] Even though suicide rates in Sri Lanka were higher than in India, we assume that a restriction on pesticides in Sri Lanka has the same effectiveness rate as a restriction on access to pesticides in India via a pesticide ban.[20] The effectiveness rate is assumed constant *ceteris paribus* over 10 years to obtain an annual effectiveness rate of 5% from restricting access to pesticides.[19] We assume that the estimate of attempted suicide is representative of the prevalence of suicide attempts in India, irrespective of any risk factors that may result in suicide (e.g., alcohol use, depression). We use a study from Andhra Pradesh, the fourth-largest state in India which accounts for more than 11 percent of all suicide cases, for the population prevalence rate of 640 to 760 per 100,000.[21] Recognizing that 100 percent coverage is idealistic, we use a target coverage rate of 80 percent (that is, the ban is assumed to take effect in 80% of the country).

The costs associated with implementing a ban are estimated to be similar to the cost of implementing an alcohol and tobacco ban in low and middle income countries. Since India is a middle income country, we assume that the cost of implementing a ban on pesticides is approximately \$20,000 per year per one million population, , or \$.02 per capita.[22] Annual per patient cost data are derived from the WHO costing tool for India and a district study on the costs to the Sri Lankan government of treating patients after self-poisoning.[23,24] We assume that costs (\$80.6 - in real terms) incurred by the Sri Lankan government for the treatment of patients after self-poisoning apply to the Indian government. The average annual government cost of treating a patient after self-poisoning

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includes the cost of care in the intensive-care unit, capital and maintenance costs, the cost of general ward staff, the cost of laboratory investigation testing, and drug and nondrug treatment costs.[24] Using a small hospital study in Kerala, we determine that 35 percent of all suicide attempt patients survive due to hospital treatment and assume that they incur these costs.[25] Given these assumptions, we estimate the average cost per case for the Indian government to treat patients after self-poisoning at \$28.13. Since out-of-pocket spending on health care in India is 70 percent of total health expenditure, the average out-of-pocket cost per case at baseline is \$19.69.[26,27]

#### Results:

The estimated cost-effectiveness of a pesticide ban in India was derived with reference to the two alternative methods described above (Table 2). When considering only the mortality implications of a pesticide ban, just over 3 deaths or 94 YLL are averted per one million population. Extrapolated to the whole of India, this is equivalent to around 3,740 deaths averted each year. If just the administrative costs of imposing the ban are considered (US\$ 20,000 per one million population), this yields a cost per death averted of \$ 6,510 and a cost per DALY averted of \$212. If treatment costs are also included (\$70,000 per one million population or \$0.07 per capita) – but no other health gain in the form of YLD averted - a cost-effectiveness ratio of \$959-1,103 per DALY averted is reached. When YLD averted are also factored into overall health gain - amounting to 521 to 603 per one million population - a cost-effectiveness ratio \$172-173 per DALY averted is arrived at.

In terms of financial risk protection associated with a move to publicly financed health care for individuals who self-harm by poisoning themselves with pesticides, the overall value of insurance – or risk premium that individuals would be willing to pay - shows a clear gradient across income groups (Figure 1). The lowest income quintile has an insurance value of \$717 while the highest income quintile has an insurance value of \$117 (Table 2).

These findings are evidently associated with some uncertainty. Accordingly, an uncertainty analysis using Latin Hypercube Sampling was undertaken. Results are shown in the Appendix, and demonstrate that baseline results are indeed quite sensitive to a number of plausible changes to key analytical parameters, including treatment cost,

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coverage and expected health gain. Cost-effectiveness ratios, for example, change by as much as 40% from their baseline value.

#### Discussion:

Our results show that by considering the mortality implications of a pesticide ban, close to 100 years of healthy life can be gained per one million population. If we consider both the mortality and morbidity implications of a pesticide ban, and assuming a complete reduction in disability among persons receiving hospital treatment for pesticide poisoning, over 500 years of healthy life per one million population are realizable, at a cost below \$180 per DALY averted. As expected, we see a downward trend in the money metric value of insurance. This indicates that a pesticide ban will have a greater effect for the poor than the rich; the former of whom have greater access to pesticides due to their greater concentration in rural, agricultural settings.

In May 2011, Kerala banned the production, consumption and sale of endosulfan.[28] Substitutes were recommended but there is currently no published study on the effects of the ban on deaths or emergency pesticide intoxication treatment in the state. The absence of evidence from India limits the comparability of our results.

The analysis has certain caveats and limitations that must be considered while interpreting the results for policy implications. Most importantly, the analysis is limited in scope because of the overall paucity of reliable, nationally representative data on self-harm in India. For instance, many of the epidemiological and efficacy parameter values used in this analysis rely on average regional (South Asia) estimates. Furthermore, data on emergency treatment costs are based on a small sample of individuals from a relatively small study site in Sri Lanka (Anuradhapura district) and India (Sehore, Madhya Pradesh). These costs may vary considerably both by region and between rural and urban areas. Thus, lack of nationally representative data (or at least data that vary by region or urban versus rural residence) makes it difficult to generalize the results for India as a whole.

Further in relation to the costs, besides the regulatory cost of implementing a pesticide ban, it may also be worth considering the loss of revenue, if any, to domestic pesticide manufacturers (assuming these pesticides are produced domestically) as well as the productivity loss to farmers, who must use less toxic substitutes. Data on Working papers are in draft form. This working paper is distributed for purposes of comment and discussion only. It may not be reproduced without permission from the author. Copies of working papers are available from the author or at [www.dcp-3.org](http://www.dcp-3.org)

these costs are similarly scarce and were therefore excluded from consideration.. Furthermore, our model does not consider the effects of any substitution of a still-available but less harmful or less toxic pesticide for the more potent banned pesticide. Substitution is likely to affect not only the mortality rate but also the prevalence rate of attempted suicide cases that are given emergency care for intoxication management. We lack sufficient evidence on typical patterns of pesticide substitution in India or other comparable countries, such as Sri Lanka, and cannot account for this in the model.

A family member who has ingested a pesticide may impose a severe economic burden on the household, whether he or she survives or not. In case of death, the burden is lost income. In the event of a survival, the household may incur emergency treatment costs as well as loss of income due to reduced productivity, prolonged disability, or permanent unemployment. In the absence of such cost data, we are unable to determine the overall household burden of a family member's ingesting a pesticide.

We look at a one-period static model and assume that the pesticide ban is already well regulated and implemented in the economy. This disregards the incremental effects of phasing in a ban. Based on the evidence of a 50 percent reduction in suicide deaths over 10 years in Sri Lanka, we assume an average annual decline of 5 percent in suicide deaths. A priori, we expect the effectiveness of a ban to vary over time from the roll-out.

Lastly, the analysis was unable to take into account potential differences in specific regions of the country. Pesticide use varies by geographical region and agricultural patterns. Moreover, locally available pesticides determine how many poisoned people survive to hospitalization. In regions where highly toxic pesticides are available, fewer patients will survive long enough to receive emergency treatment. Therefore, the cost-effectiveness of a ban on highly toxic pesticides is likely to vary by region and should be accounted for.

## **CONFLICT OF INTEREST**

The authors have no conflict of interest.

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## References:

1. Patel V, Andrade C. Pharmacological Treatment of Severe Psychiatric Disorders in the Developing World: Lessons from India. *CNS Drugs*. 2003. p. 1071–80.
2. Gunnell D, Eddleston M. Suicide by intentional ingestion of pesticides: a continuing tragedy in developing countries. *Int J Epidemiol*. IEA; 2003;32(6):902.
3. Patel V, Ramasundarahettige C, Vijayakumar L, Thakur JS, Gajalakshmi V, Gururaj G, et al. Suicide mortality in India: A nationally representative survey. *Lancet*. 2012;379(9834):2343–51.
4. Graafsma T, Kerkhof a., Gibson D, Badloe R, Van De Beek LM. High rates of suicide and attempted suicide using pesticides in Nickerie, Suriname, South America. *Crisis*. 2006;27(2):77–81.
5. Saddichha S, Manjunatha N. Effect of Olanzapine, Risperidone, and Haloperidol Treatment on Weight and Body Mass Index in First-Episode Schizophrenia Patients in India: A Randomized, Double-Blind, Controlled, Prospective Study. *J Clin Psychiatry*. 2007;1794–9.
6. Pearson M, Konradsen F, Gunnell D, Dawson AH, Pieris R, Weerasinghe M, et al. A community-based cluster randomised trial of safe storage to reduce pesticide self-poisoning in rural Sri Lanka: study protocol. *BMC Public Health*. 2011;11(1):879.
7. Madsen LB, Eddleston M, Hansen KS, Pearson M, Agampodi S, Jayamanne S, et al. Cost-effectiveness analyses of self-harm strategies aimed at reducing the mortality of pesticide self-poisonings in Sri Lanka: a study protocol. *BMJ Open*. 2015;5(2):e007333–e007333.
8. Eddleston M, Buckley N a, Gunnell D, Dawson a H, Konradsen F. Identification of strategies to prevent death after pesticide self-poisoning using a Haddon matrix. *Inj Prev*. 2006;12(5):333–7.
9. Roberts DM, Karunarathna A, Buckley N a, Manuweera G, Sheriff MHR, Eddleston M. Influence of pesticide regulation on acute poisoning deaths in Sri Lanka. *Bull World Health Organ*. 2003 Jan;81(11):789–98.
10. Ministry of Agriculture Government of India. *Statistics of Pesticides*. 2015.
11. Ministry of Home Affairs India National Crime Records Bureau. *Suicides in India*. 2012.
12. Vijaykumar L. Suicide and its prevention: The urgent need in India. *Indian J Psychiatry*. 2007;49(2):81–4.
13. Vijayakumar L, Satheesh-Babu R. Does “no pesticide” reduce suicides? *Int J Soc Psychiatry*. 2009;55(5):401–6.
14. Verguet S, Olson ZD, Babigumira JB, Desalegn D, Johansson KA, Kruk ME, et al. Health gains and financial risk protection afforded by public financing of selected interventions in Ethiopia: an extended cost-effectiveness analysis. *Lancet Glob Heal*. 2015;3(5):e288–96.
15. Verguet S, Laxminarayan R, Jamison DT. Universal public finance of tuberculosis treatment in India: An extended cost-effectiveness analysis. *Health Econ*. 2014;24(3):318–32.
16. IIPS. DLHS-3 District Level Household and Facility Survey, 2007-2008. International Institute of Population Sciences, Mumbai, India: IIPS; 2010.

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17. Office of the Registrar General and Census Commissioner I. Sample Registration Survey- based abridged life tables 2006-10. 2011.
18. Institute for Health Metrics and Evaluation. Global Burden of Disease Study 2010 (GBD 2010) Disability Weights. 2012.
19. Gunnell D, Fernando R, Hewagama M, Priyangika WDD, Konradsen F, Eddleston M. The impact of pesticide regulations on suicide in Sri Lanka. *Int J Epidemiol.* 2007;36(6):1235–42.
20. Hendin H, Phillips MR, Vijayakumar L, Pirkis J, Wang H, Yip P, et al. Suicide and Suicide Prevention in Asia. World Health Organization Department of Mental Health and Substance Abuse. Geneva; 2008.
21. Saddichha S, Prasad MN V, Saxena MK. Attempted suicides in India: a comprehensive look. *Arch Suicide Res.* 2010 Jan;14(1):56–65.
22. World Health Organization. Scaling up action against noncommunicable diseases: How much will it cost? Geneva; 2011.
23. Chisholm D, Burman-Roy S, Fekadu A, Kathree T, Kizza D, Luitel N, et al. Estimating the cost of implementing district mental health care plans in five low- and middle-income countries: the PRIME study. *Submitt Publ.* 2014;
24. Wickramasinghe K, Steele P, Dawson A, Dharmaratne D, Gunawardena A, Senarathna L, et al. Cost to government health-care services of treating acute self-poisonings in a rural district in Sri Lanka. *Bull World Health Organ.* 2009;87(3):180–5.
25. Suresh Kumar PN. An analysis of suicide attempters versus completers in kerala. *Indian J Psychiatry.* 2004;46(2):144–9.
26. National Commission on Macro-economics and Health. Financing and delivery of health care services in India. The report of the National Commission on Macroeconomics and Health - India. 2005.
27. Mahal A, Karan A, Engelgau M. The economic implications of non-communicable diseases for India. Washington D.C.; 2010 p. 1–142.
28. Rawat. Endosulfan: A year of the ban. Centre for Science and Environment. 2012.

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