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Using ex-ante economic evaluation to inform research priorities in pesticide self-poisoning prevention: the case of a shop-based gatekeeper training programme in rural Sri Lanka

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Abstract

OBJECTIVES Suicide by pesticide self-poisoning is a major public health challenge in low- and middle-income countries. While effectiveness studies are required to test alternative prevention approaches, economic evidence is lacking to inform decision-making in research priority setting. Therefore, this study aimed to estimate the costs of a shop-based gatekeeper training programme for pesticide vendors seeking to prevent pesticide self-poisoning in rural Sri Lanka and assess its potential for cost-effectiveness.

METHODS Ex-ante cost and cost-effectiveness threshold (CET) analyses were performed from a governmental perspective based on a three-year analytic horizon, using 'no programme' as a comparator. A programme model targeting all 535 pesticide shops in the North Central Province and border areas was applied. Total programme costs (TPC) were estimated in 2019 USD using an ingredients approach and 3% annual discounting. The Sri Lankan gross domestic product per capita and life years saved were used as CET and effectiveness measure, respectively. Sensitivity analyses were performed.

RESULTS TPC were estimated at 31 603.03 USD. TPC were sensitive to cost changes of training material and equipment and the programme lifetime. The programme needs to prevent an estimated 0.23 fatal pesticide self-poisoning cases over three years to be considered cost-effective. In the sensitivity analyses, the highest number of fatal cases needed to be prevented to obtain cost-effectiveness was 4.55 over three years.

CONCLUSIONS From an economic perspective, the programme has a very high potential to be cost-effective. Research assessing its effectiveness should therefore be completed, and research analysing its transferability to other settings prioritised.

keywords pesticide self-poisoning, ex-ante economic evaluation, suicide prevention, research priority setting, cost-effectiveness threshold analysis, Sri Lanka

Sustainable Development Goals (SDGs): SDG 3 (good health and well-being), SDG 17 (partnerships for the goals)

Introduction

Pesticide self-poisoning is one of the most common suicide methods worldwide [1]. Being accountable for an estimated 13.7% of global suicides [2], this method is particularly prevalent in rural settings in low- and middle-income countries (LMICs) where small-scale farming prevails [1]. This is deemed to be due to a high accessibility of pesticides in these settings [3,4], for example in the domestic environment of small-scale farmers [5–8] or at local pesticide shops [6,7], alongside an often high toxicity and limited capacity to manage pesticide poisoning cases [3,4]. Accordingly, WHO highlights means restriction as a key approach to prevent pesticide self-poisoning [1,5].

Despite having great success in reducing suicide rates through regulation of the most hazardous pesticides

[9–11], pesticide self-poisoning continues to be a major public health challenge in Sri Lanka. This is reflected by a recent study conducted in Sri Lanka's rural Anuradhapura district, which estimated the incidence of fatal and non-fatal pesticide self-poisoning to be 293.3 per 100 000 person-years [12].

Several means restriction approaches have been considered to further prevent pesticide self-poisoning in Sri Lanka. One example is the provision of lockable storage devices to restrict access to pesticides in the domestic environment of farming households. Yet, despite being widely promoted [5,12], a recent large-scale cluster randomised controlled trial (RCT) conducted in rural Sri Lanka found this approach to be ineffective [12]. Therefore, further effectiveness studies testing alternative approaches to means restriction are required to guide local policy-making on best policies for suicide prevention.

Meanwhile, limited research resources and ethical considerations call for a targeted research priority setting. Focussing on approaches with a high likelihood of policy relevance in case of proven effectiveness seems a sensible approach for prioritisations. In contexts of scarce healthcare resources, the real-life costs of an intervention and its potential to be cost-effective seem crucial preconditions for a later sustained implementability and thus policy relevance [13]. Ex-ante economic evaluation may therefore be a key tool for decision-making in research priority setting. Yet, no economic evaluations aiming at informing prioritisations of effectiveness studies regarding means restriction approaches for self-poisoning prevention could be identified [14].

Using a shop-based means restriction approach as a case, this study therefore aimed to estimate the costs of a gatekeeper training programme for pesticide vendors seeking to prevent pesticide self-poisoning in rural Sri Lanka and assess its potential for cost-effectiveness.

Methods

Ex-ante economic evaluation was performed to assess the costs of a novel shop-based gatekeeper training programme and its potential for cost-effectiveness. Cost analysis was used to estimate total programme costs (TPC) and cost-effectiveness threshold (CET) analysis to assess the potential for cost-effectiveness. The analyses were informed by the initiation phase of a large-scale stepwedge cluster RCT (swcRCT) that tests the effectiveness of shop-based gatekeeper training to prevent pesticide self-poisoning in Sri Lanka's rural North Central Province (NCP). For that purpose, pesticide vendors are trained to assume a gatekeeper role by identifying at-risk customers and restricting their access to pesticides by applying strategies to deny sales [15].

In line with the planned swcRCT implementation period, a three-year analytic horizon was set. All analyses were conducted from a governmental perspective. The NCP, one of Sri Lanka's nine administrative provinces with approx. 1.3 million inhabitants [16], was chosen as the study area. The NCP is a rural area with a high prevalence of small-scale farming where pesticides are frequently used and widely available. In this area, easy access to pesticides is facilitated by an extensive network of small private pesticide shops which offer pesticides for over-the-counter purchase and unsafe storing practices in the domestic environment. This is thought to contribute to a high prevalence of pesticide self-poisoning in this setting [6,17]. Thus, the study area shares key characteristics not only with other rural areas in Sri Lanka, but also with other LMIC settings with a high burden of pesticide self-poisoning [18]. Microsoft Excel for Mac version 16.27 was used for all data analyses.

Programme model

In line with the approach tested in the swcRCT, a programme model comprising eight sequential steps was defined (Figure 1, for a complementary detailed description cf. Appendix A, available from https://doi.org/10.17605/OSF.IO/U4B6Z). The core of the modelled programme is the gatekeeper training (Step 5). This training was modelled to take place at local pesticide shops in standardised two-hour sessions in accordance with a structure tested and described in a the swcRCT preceding pilot study which tested the feasibility and acceptance of the approach [15,19]. This was complemented by the use of training films. All training sessions were set to be carried out by already employed field staff members of the agricultural administration authorities operating across the NCP. All persons involved in pesticide sales at all pesticide shops in the NCP and its bordering areas were determined as the programme's target population. Based on the baseline assessment of the swcRCT, these were estimated at 1070 persons at 535 pesticide shops (438 shops in the NCP and 97 in bordering areas) (data not published) [15]. Bordering areas, defined as a 10-km belt around the NCP, were included in line with the swcRCT design to mitigate contamination in effectiveness estimates potentially arising from cross-border purchases of NCP inhabitants (data not published) [15]. The imputed programme lifetime was set to five years.

Total programme cost estimation

TPC were defined as all direct costs associated with the initiation and implementation of the gatekeeper training

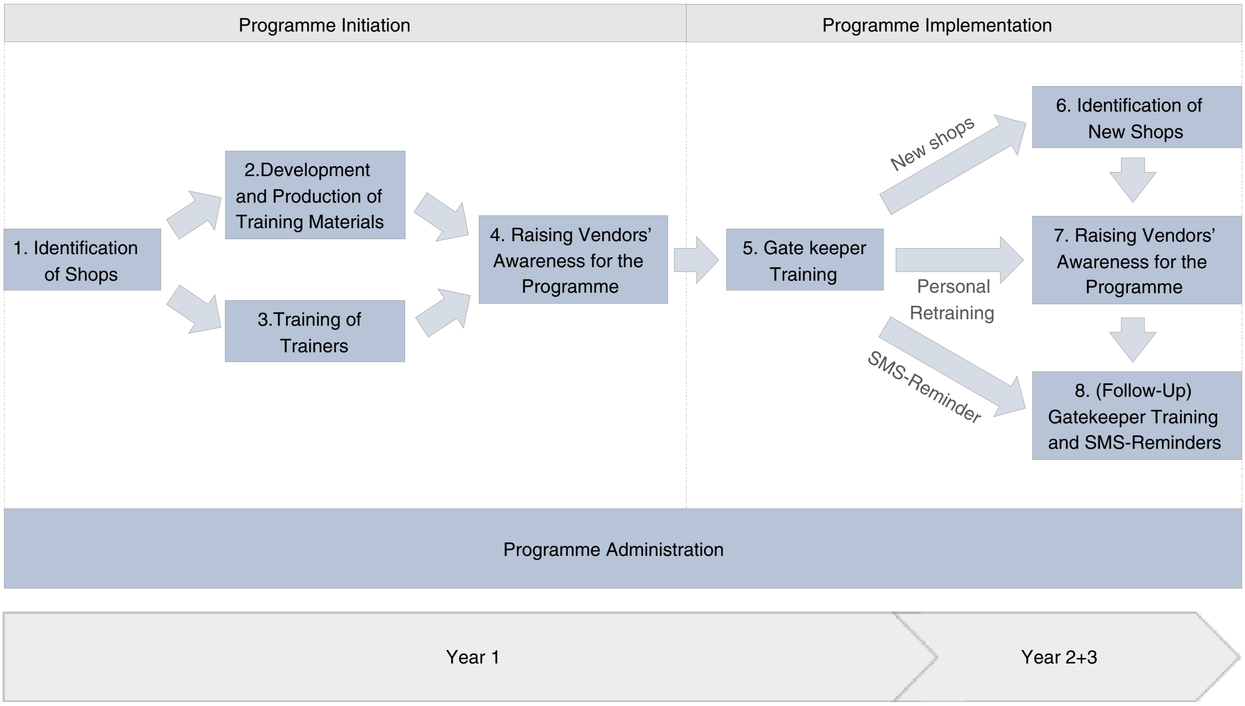

Figure 1 Programme model. [Colour figure can be viewed at wileyonlinelibrary.com]

programme under real-life conditions which are assumed to be attributable to a Sri Lankan governmental funding agency. Research costs, costs borne by non-governmental stakeholders, and indirect costs such as productivity and tax losses were thus excluded. All costs were expressed in 2019 US Dollar (USD).

Data collection

TPC were estimated using an ingredients approach based on the identification, quantification and valuation of required resource inputs in line with the programme model. All resource inputs were assigned to cost categories (direct personnel, travel, catering, programme administration, training materials and equipment, and communication). The valuation was performed according to economic cost principles (opportunity costs). Tradable goods and services were valued according to Sri Lankan gross market prices and salaries and wages according to locally customary remunerations including fringe benefits, allowances and taxes. Data sources comprised key informant interviews supplemented by accounting data from the swcRCT, local price quotations and estimates from WHO's Choosing Interventions that are Cost-Effective Project (WHO-CHOICE) [20]. Key informants were four researchers involved in the swcRCT and five officials from the three agricultural administration authorities operating across the NCP.

Data adjustments

Sri Lankan Rupee (LKR) was converted to USD based on official exchange rates obtained from the World Bank [21] for values referring to 2017 or earlier. For values referring to 2018 and 2019, conversions were performed at 1 USD = 158.2569 LKR and 178.2860 LKR, respectively. Adjustments for inflation were based on US consumer price index rates derived from the International Monetary Fund [22]. Since collected salaries of governmental and semi-governmental employees did not include pension benefits and employer contributions to social protection schemes, respectively, these benefits were imputed post hoc to reflect full economic costs. Time units across resource input items were harmonised assuming 17.7 monthly working days and 8 daily working hours. Following standard practice [13,23–25], capital costs were converted into equivalent annual costs (EACs), as were programme start-up costs over the imputed programme lifetime in line with WHO recommendations [25]. Following standard recommendations [25–27], discounting was performed at an annual real discount rate of 3%. Further details on the adjustments are provided in

Appendix B (available from https://doi.org/10.17605/OSF.IO/U4B6Z).

Data analysis

TPC were estimated by totalling all resource input quantities multiplied by their unit values.

Cost-effectiveness threshold analysis

To assess the programme's potential for cost-effectiveness, the minimum number of fatal pesticide self-poisoning cases needed to be prevented by the programme was estimated. For this purpose, a CET equation in line with an incremental cost-effectiveness ratio was defined which related the difference in costs between the programme and status quo, that is no gatekeeper training programme, to the difference in effects resulting from these two options.

The difference in costs was equated to TPC. Spill over effects in the form of cost savings due to decreased case numbers, for example reduced medical costs or social transfers, were excluded. Life years saved (LYS) were chosen to measure the difference in effects. They were defined as the local standard life expectancy (LE) at age of death from pesticide self-poisoning multiplied by fatal pesticide self-poisoning cases averted by the programme. The CET was equated to the local annual gross domestic product (GDP) per capita in line with WHO criteria [28,29]. The before-mentioned definitions led to the following equation:

$$\mathrm{GDP}_{\text{per capita}} = \frac{\text{Total programme costs}}{\text{Standard LE at age of death} \times \text{Fatal cases averted}}$$

Data collection

The Sri Lankan GDP per capita from 2017, amounting to 4291.41 USD in 2019 USD, was derived from World Bank data [30] (adjusted for inflation). TPC were derived from the preceding cost analysis. The local standard LE at age of death from pesticide self-poisoning was set to 31.86 years. This estimate was derived from a previous RCT that tested the effectiveness of pesticide self-poisoning prevention through the provision of lockable storage devices to farming households in the NCP (data not published) [12,31].

Data analysis

The minimum number of fatal pesticide self-poisoning cases that need to be prevented by the programme was estimated by solving the above equation for fatal cases averted.

Sensitivity analyses

Deterministic one-way sensitivity analyses reflecting three distinct sources of uncertainty in the TPC estimation were conducted: cost estimates of cost categories, the discount rate and the imputed programme lifetime. Cost estimates of cost categories were varied by ± 25%, 50% and 75% based on expert opinion from researchers involved in the swcRCT. Discount rates were altered to 0%, 6%, 10% and 15% in line with recommendations derived from the literature [25,32,33]. These were concurrently applied in salary adjustments, EAC and discounting computations. The imputed programme lifetime was altered to three and ten years while keeping the analytic horizon constant at three years based on expert opinion from researchers involved in the swcRCT. In this context, potential resale values of capital assets were excluded from the evaluation and related residual EACs therefore added to the estimated TPC in the three-year scenario.

In addition, a deterministic three-way sensitivity analysis of the CET assessment was conducted. It was based on the concurrent alteration of both the CET, TPC and LE at age of death from pesticide self-poisoning values (all possible combinations). The CET was altered in accordance with a range of CET values suggested by Woods et al. [34] reflecting opportunity cost estimates for healthcare spending in Sri Lanka. Their estimated lower and upper bound was used, that is 495.25 USD and 1843.26 USD in 2019 USD [34], respectively (adjusted for inflation). TPC were altered according to minimum and maximum levels derived from preceding one-way sensitivity analyses of TPC. The local standard LE at age of death from pesticide self-poisoning was altered by ± 40% based on expert opinion from researchers involved in the swcRCT.

Results

Total programme costs

TPC were estimated at 31 603.03 USD over the three-year analytic horizon, equalling average costs of 59.07 USD per pesticide shop trained. The highest shares of TPC were attributable to the cost category training materials and equipment (37.68%), programme administration (32.18%) and direct personnel (24.11%). Table 1 provides a breakdown of TPC per cost category and items. A complementing detailed account of resource input quantities and values is provided in Appendix C to Appendix E (available from https://doi.org/10.17605/OSF.IO/U4B6Z).

Cost-effectiveness threshold analysis

Based on the input values specified in Table 2, the minimum number of fatal pesticide self-poisoning cases that need to be prevented by the programme to be cost-effective was estimated at 0.23 over the three-year analytic horizon.

Sensitivity analyses

In the sensitivity analyses of the TPC estimation, alterations in cost category estimates led to minimum and maximum TPC values accounting for 22 671.00 USD and 40 535.05 USD, respectively. These resulted from altering training materials and equipment costs by ± 75%. Alterations in discount rates led to minimum and maximum TPC values accounting for 30 394.15 USD and 33 486.00 USD at 15% and 0% discounting, respectively. Alterations in the imputed programme lifetime led to minimum and maximum TPC values accounting for 24 383.04 USD and 43 053.56 USD at an imputed programme lifetime of ten and three years, respectively. Detailed results are provided in Appendix F (available from https://doi.org/10.17605/OSF.IO/U4B6Z).

Table 1 Total programme costs, three years analytic horizon

Cost categories	Cost items	Costs in USD (2019)	% of total programme costs
Direct personnel	Trainer of trainers	24.94	0.08%
	Field staff	7595.35	24.03%
		7620.29	**24.11%**
Travel	Motorcycle usage	**725.43**	**2.30%**
Catering	Lunch and tea	**121.25**	**0.38%**
Programme administration	Administrative personnel	7348.61	23.25%
	Facilities incl. utilities		
	Venues for training of trainers	62.36	0.20%
	Office facilities	2405.47	7.61%
	Office equipment		
	Laptop	303.13	0.96%
	Printer	38.11	0.12%
	Feature phone	12.13	0.04%
		10 169.81	**32.18%**
Training materials and equipment	Training material:		
	Films	8412.50	26.62%
	Wall poster	736.86	2.33%
	Participation certificates	206.81	0.65%
	Training equipment		
	Projectors	1037.56	3.28%
	Laptops	1515.64	4.80%
		11 909.37	**37.68%**
Communication	SMS reminder	74.42	0.24%
	Newspaper advertisement	924.97	2.93%
	Sri Lanka Gazette publication	0.00*	0.0%*
	Flyer	57.49	0.18%
		1056.88	**3.34%**
Total programme costs		**31 603.03**	**100.00%**

*Costs per unit for the Sri Lanka Gazette publication were set to zero as related notices are mainly published online. Cost for the development and editing of the notice were factored into the programme administration.

Table 2 Input variables cost-effectiveness threshold analysis

Input variable	Value
Total programme costs	$31 603.03
Cost-Effectiveness Threshold	$4291.41
Local standard life expectancy at age of death from pesticide self-poisoning	31.86 years

Table 3 Sensitivity Analysis Cost-Effectiveness Threshold Analysis: Impact of Input Variable Changes on Minimum Number of Fatal Cases that Need to be Prevented by the Programme to be Cost-Effective, Three Years Analytic Horizon

	Cost-effectiveness thresholds		
Total programme costs	Lower value ($495.25)	Upper value ($1843.26)	Baseline value ($4291.41)
(a) *Local standard life expectancy at age of death from pesticide self-poisoning:* Lower value (19.12 years)			
Lower value ($22 671.00)	2.39	0.64	0.28
Baseline value ($31 603.03)	3.34	0.90	0.39
Upper value ($43 053.56)	4.55	1.22	0.52
(b) *Local standard life expectancy at age of death from pesticide self-poisoning:* Baseline value (31.86 years)			
Lower value ($22 671.00)	1.44	0.39	0.17
Baseline value ($31 603.03)	2.00	0.54	0.23
Upper value ($43 053.56)	2.73	0.73	0.31
(c) *Local standard life expectancy at age of death from pesticide self-poisoning:* Upper value (44.60 years)			
Lower value ($22 671.00)	1.03	0.28	0.12
Baseline value ($31 603.03)	1.43	0.38	0.17
Upper value ($43 053.56)	1.95	0.52	0.22

The three-way sensitivity analysis of the CET assessment indicated a range of 0.12 to 4.55 minimum fatal pesticide self-poisoning cases that need to be prevented by the programme to be cost-effective over the three-year analytic horizon. The former value, 0.12 cases, occurred at the baseline CET and a concurrent alteration of TPC to the minimum value obtained from preceding sensitivity analyses and an increase of the LE at age of death from pesticide self-poisoning by 40%. The latter value, 4.55 cases, occurred at a concurrent alteration of the CET to the lower bound suggested by Woods et al. [34], of TPC to the maximum value obtained from preceding sensitivity analyses and a decrease of the LE at age of death from pesticide self-poisoning by 40% (Table 3).

Discussion

This study estimated TPC of the assessed shop-based gatekeeper training programme at 31 603.03 USD over three years. The minimum number of fatal pesticide self-poisoning cases that need to be prevented by the programme to be considered cost-effective was estimated at 0.23 over three years.

No comparable published research using ex-ante economic evaluation for an early assessment of suicide prevention approaches in LMICs was identified. This is likely due to a general scarcity of related evidences [14]. Furthermore, those economic evaluations obtainable are based on available effectiveness estimates and therefore directly evaluate cost-effectiveness rather than estimating effect sizes to assess a potential for cost-effectiveness as done by this study [35,36]. While this compromises the comparability of the results of this study, it suggests that its method provides a new approach to prioritise effectiveness studies testing alternative suicide prevention approaches in LMICs. This was realised by explicitly accounting for economic preconditions of a later policy relevance and implementability of suicide prevention programmes.

Research from rural Sri Lanka has found that 14% [6] to 20% [17] of pesticide self-poisoning patients bought pesticides specifically to self-harm from local pesticide shops and a similar proportion (17.6%) was observed in a study from rural southern India [37]. This suggests a general high relevance of the assessed approach both in Sri Lanka and other settings with high prevalences of pesticide self-poisoning. At the same time, shop-based sales restrictions have been implemented in differing settings such as Hong Kong to prevent suicide by charcoal burning [38] and Norway to prevent suicide by firearms [39]. Training pesticide vendors to assume a gatekeeper role may therefore be a highly promising strategy to effectively prevent pesticide self-poisoning.

In this study, the estimation of costs was based on an existing extensive network of field staff of agricultural administration authorities operating across the NCP, thus assuring a high local validity. The estimated TPC make up approx. 0.1% of the total annual expenditure on health promotion and disease prevention and 0.001% of the total health expenditure of Sri Lanka's Ministry of Health in 2016 on a yearly basis (adjusted for inflation) [40]. In addition, the evaluation showed that the programme only needs to prevent a single case of fatal pesticide self-poisoning over a three-year period to be considered cost-effective.

These results indicate a general financial feasibility of a sustained programme implementation. Moreover, they indicate that, from an economic perspective, the programme has a very high potential for cost-effectiveness. This suggests that the programme meets crucial economic preconditions for a later sustained implementability and thus a high policy relevance. Therefore, the completion of research on the effectiveness of this approach seems of paramount importance to conclusively guide policy decision-making and determine its cost-effectiveness.

Uncertainty assessments

Being grounded in a framework of ex-ante economic evaluation, this study is based on assumptions and projections which bring about uncertainties. Deterministic sensitivity analyses were conducted to account for them.

While one-way sensitivity analyses of TPC showed a rather high robustness of TPC to changes in discount rates, they indicated a high sensitivity to changes in cost category estimates, especially of training materials and equipment, and the imputed programme lifetime. Whereas the high sensitivity to cost estimate changes of training materials and equipment is explicable by this category's high share of TPC, the high sensitivity to changes in the programme lifetime is explicable by the application of EACs. These distributed programme start-up costs evenly over the imputed programme lifetime, thus leading to reduced TPC at a longer programme lifetime. These findings imply a risk of substantial excess expenditure. Furthermore, a long programme lifetime seems highly preferable which may likely be attainable in a potential government intervention.

The three-way sensitivity analysis of the CET assessment indicated that a range of up to five fatal pesticide self-poisoning cases need to be prevented by the programme over three years for it to be considered cost-effective. Accordingly, even if the least favourable input values tested in this analysis would occur, the programme still promises to have a very high potential to achieve cost-effectiveness.

Study limitations

Several limitations need to be taken into account in the interpretation of the study results. Firstly, the results must be interpreted in view of the study design specifications such as the adopted governmental perspective, the three-year analytic horizon, the study setting and target population. This becomes especially relevant when using provided cost estimates for comparisons across settings and programmes. The chosen study setting furthermore determines a high context specificity of provided cost estimates, thus limiting a direct transferability of cost estimates to other regional settings. Yet, the determined programme model seems easily transferable to other settings while the chosen costing approach creates transparency over all estimated resource input quantities and values. This provides a comprehensive framework for context-specific validations of cost estimates across settings.

In the TPC estimation, resource input quantities per shop needed to be based on average values derived from expert opinion as the chosen ex-ante design required their estimation before the intervention was implemented. Thereby, the study design did not allow for a consistent micro-costing approach with precise measurements of resource input requirements per shop. This may have led to inaccuracies specifically regarding travel expenses (direct personnel costs and travel costs) and time requirements for raising awareness at pesticide shops (direct personnel costs). In addition, possible in-between-shop variations of programme costs could therefore not be assessed. Moreover, administrative costs were likely underestimated in the TPC estimation since overhead costs of central functions such as human resources and accounting departments were unknown by the interviewed key informants. Further inaccuracies in TPC estimates may have occurred due to data limitations in the inflation adjustment and currency conversion. These were based on consumer price index values and a determination of currency conversion rates for 2018/2019 instead of using current GDP deflator values and official averaged market exchange rates, respectively. Additional inaccuracies may have arisen from assumptions made in the post hoc adjustment of collected salaries and the EAC computations.

In the CET analysis, no spill over effects in the form of cost savings were included due to data limitations. For the same reason, the analysis was limited to LYS instead of taking full disability-adjusted life years (DALYs) into account. This restricted the assessment to fatal cases and may have led to an underestimation of the potential of the programme to be cost-effective. Further inaccuracies may have occurred as effect estimates where not discounted. Moreover, the local GDP per capita was used as a threshold value although it is usually applied in relation to DALYs rather than LYS [28,29]. Possible inaccuracies arising from this seem, however, limited since LYS appear to be the key contributor to local DALYs due to pesticide self-poisoning as the related average duration until remission or death and disability weight appear to be very low. Accordingly, a recent study conducted in the NCP estimated the local average length of stay in hospitals due to pesticide self-poisoning at approx. 26.5 h [41], while the disability weight for short-term poisoning with or without treatment is 0.171 [42].

While deterministic sensitivity analyses were conducted to account for inaccuracies in input parameters of the TPC and CET analysis, the chosen approach only assessed the impact of alterations of individual parameters on TPC and did not factor in likelihoods of alterations. The chosen ex-ante design furthermore determined uncertainties in relation to plausible variations of cost category estimates, the imputed programme lifetime and the local standard LE at age of death from pesticide self-poisoning. In absence of empirical values, large variation intervals were chosen to subject the TPC and CET analysis to rigorous sensitivity analyses. This may have led to over- and underestimations of the upper and lower bounds reported in the related sensitivity analyses, respectively.

Conclusion

The present ex-ante economic evaluation indicates that the assessed shop-based gatekeeper training programme meets crucial economic preconditions for a later sustained implementability, that is a presumed financial feasibility and a very high potential for cost-effectiveness. Therefore, this programme promises to be highly policy relevant. Research assessing the effectiveness of this approach should therefore be completed, and research analysing its transferability to other regional settings be prioritised.

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