Journal of Affective Disorders 219 (2017) 93–104

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Review article

The global burden of fatal self-poisoning with pesticides 2006-15: Systematic review

Emma J. Mew[a,1], Prianka Padmanathan[b,1], Flemming Konradsen[c], Michael Eddleston[d], Shu-Sen Chang[e], Michael R. Phillips[f,g], David Gunnell[b,*]

[a] Dalla Lana School of Public Health, University of Toronto, Toronto, Canada
[b] School of Social and Community Medicine, University of Bristol, Bristol, UK
[c] Department of Public Health, University of Copenhagen, Copenhagen, Denmark
[d] Pharmacology, Toxicology and Therapeutics, University of Edinburgh, Edinburgh, UK
[e] Institute of Health Behaviors and Community Sciences and Department of Public Health, College of Public Health, National Taiwan University, Taipei City, Taiwan
[f] Suicide Research and Prevention Center, Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine, Shanghai, China
[g] Departments of Psychiatry and Global Health, Emory University, Atlanta, USA

ARTICLE INFO

Keywords:
Systematic review
Pesticides
Suicide
Self-harm
Self-poisoning
Epidemiology
Global health

ABSTRACT

Background: Agricultural pesticide poisoning is a major contributor to the global burden of suicide. Over the last decade there has been a marked decrease in the incidence of suicide worldwide. It is unclear whether pesticide poisoning still plays a significant role in the global incidence of suicide.

Methods: WHO method-specific suicide data were supplemented by a systematic review of the literature between 2006 and 2015, including searches of thirteen electronic databases and Google, citation searching and a review of reference lists and personal collections. Our primary outcome was the proportion of total suicides due to pesticide poisoning. Weighted estimates were calculated for seven WHO regional and income strata.

Results: We identified data from 108 countries (102 from WHO data, 6 from the literature). A conservative estimate based on these data indicates that there were approximately 110,000 pesticide self-poisoning deaths each year from 2010 to 2014, comprising 13.7% of all global suicides. A sensitivity analysis accounting for under-reporting of suicides in India resulted in an increased estimate of 168,000 pesticide self-poisoning deaths annually, that is, 19.7% of global suicides. The proportion of suicides due to pesticide self-poisoning varies considerably between regions, from 0.9% in low- and middle-income countries in the European region to 48.3% in low- and middle-income countries in the Western Pacific region.

Limitations: High quality method-specific suicide data were unavailable for a number of the most populous countries, particularly in the African and Eastern Mediterranean regions. It is likely we have underestimated incidence in these regions.

Conclusion: There appears to have been a substantial decline in fatal pesticide self-poisoning in recent years, largely driven by a reduction in overall suicide rates in China. Nonetheless, pesticide self-poisoning remains a major public health challenge, accounting for at least one-in-seven suicides globally.

1. Introduction

Self-poisoning with agricultural pesticides is a major contributor to the global burden of suicide (World Health Organisation, 2014). In a review of the international literature from 1990 to 2007, we estimated that this method was used in approximately one-third of the world's suicides, accounting for an estimated 260,000 deaths per year (Gunnell et al., 2007a).

Pesticide self-poisoning is particularly prevalent in South Asia, South East Asia and China. China is the world's most populous country and previously had relatively high rates of suicide; a previous review (Phillips et al., 2002) indicated that 62% of suicides in China were due to pesticide poisoning. However, since the publication of this review, overall suicide rates have fallen by over one third in China (Liu et al., 2015) and by approximately 10% globally (World Health Organisation, 2014), and a number of countries have implemented strategies to

* Corresponding author.
E-mail addresses: emmajmew@gmail.com (E.J. Mew), prianka.padmanathan@gmail.com (P. Padmanathan), flko@sund.ku.dk (F. Konradsen), m.eddleston@ed.ac.uk (M. Eddleston), shusen.chang@gmail.com (S.-S. Chang), mphillipschina@outlook.com (M.R. Phillips), d.j.gunnell@bristol.ac.uk (D. Gunnell).
[1] Equal contribution.

http://dx.doi.org/10.1016/j.jad.2017.05.002
Received 7 February 2017; Received in revised form 3 May 2017; Accepted 6 May 2017
Available online 12 May 2017

reduce the burden of pesticide suicides (Cha et al., 2016; Pearson et al., 2015). For this reason a review of the continued contribution of pesticide poisoning to the global incidence of suicide is timely.

This paper presents an updated systematic review of the contribution made by pesticide self-poisoning to the global burden of suicide. The review is based on method-specific suicide mortality data drawn from World Health Organisation (WHO) mortality statistics (Ajdacic-Gross et al., 2008; World Health Organisation, 2015). We supplemented this data with research published since 2006, drawing on a wider range of bibliographic databases than previously used.

2. Methods

This systematic review is reported according to the PRISMA guidelines for systematic reviews and is registered through PROSPERO (Protocol No. CRD42015023804) (Mew et al., 2015; PRISMA, 2009).

The primary outcome of interest when identifying and extracting data was the proportion of total suicides due to pesticide poisoning. In this review, the term pesticides includes insecticides, rodenticides, herbicides and fungicides.

2.1. Data searches

2.1.1. World Health Organization mortality data

Where available, the number of suicides for all ages (sum of deaths coded using International Classification of Disease (ICD), Tenth Revision (ICD-10) codes X60-X84) and the number of suicides (all ages) by pesticide poisoning (ICD-10 X68) for each country were obtained using the World Health Organization Cause of Death Query Online Database for the most recent year with available data (or the two most recent years if there were less than 500 suicides per year) between 2007 and 2015 (World Health Organisation, 2015). The median year from which data were used was 2012, ranging from 2006 to 2014.

2.1.2. Published literature

We searched thirteen electronic databases to identify papers published between 2006 and 2015, which document the use of pesticides in self-harm (Appendix A): African Journals Online, African Index Medicus, AGRIS, Global Health Library, IMEMR, IMSEAR, INDMED, KOREAM ED, LILACs, PubMed, PsycInfo, Web of Science, WPRIM. All searches were performed in English. The database search was supplemented with: (1) A review of the reference lists of papers from which data were extracted; (2) Citation searches of eight key publications including our original review (Bertolote et al., 2006a, 2006b; Eddleston, 2000; Eddleston et al., 2002; Eddleston and Phillips, 2004; Gunnell et al., 2007a; Gunnell and Eddleston, 2003; Jeyaratnam, 1990) using Google Scholar; (3) A review of papers from personal collections; and (4) An Internet-based search using Google for suicide data of the three most populous countries in each region for which data remained unavailable.

A full description of the search terms for each database can be found in Appendix A. The WHO librarian was consulted regarding the development of the search strategy. The search terms, where possible, combined the concepts: pesticides AND (suicide OR self-harm) AND epidemiologic methods. A second search was performed without using the 'epidemiologic methods' search term as a filter and did not yield any additional articles meeting the inclusion criteria.

2.2. Data selection and extraction

The inclusion and exclusion criteria are listed in Table 1. For regions lacking data that met the inclusion criteria, studies that provide an insight into the burden of pesticide self-poisoning but did not meet the inclusion criteria have been discussed in the results section. These studies did not however inform the regional and global estimates.

We identified relevant papers in three stages (Fig. 1). The first stage involved title and abstract screening (EM). If it was unclear whether a paper fit the inclusion criteria, the paper was included for full-text retrieval. Mid-way through the title/abstract review, the inter-rater agreement between EM and an experienced reviewer (DG) based on 100 citations yielded a kappa score of 0.86, suggesting good agreement. The second stage involved the screening of full-text articles (EM) for eligibility. At the early stages of full-text review, based on 20 full-text articles, the kappa score was 0.57. This suggested moderate levels of inter-rater agreement between EM and an experienced reviewer (DG). The less experienced reviewer tended to be over-inclusive compared to the more experienced reviewer. Following both exercises EM modified the criteria for article inclusion.

The final stage involved thorough evaluation of the remaining full-text articles by PP and DG independently. Data extraction forms were completed for each article. Where there was disagreement regarding inclusion or the quality score, this was resolved through discussion between reviewers. There was no disagreement on any papers that were included in the final estimates.

The data extraction form, which includes a quality assessment tool, was created and finalised by DG after a pilot and discussion with co-authors (Appendix B). Factors included in the quality assessment tool were: representativeness of the study sample, size of study, recency of data, quality of suicide death ascertainment and availability of information on both pesticide and total suicides.

2.3. Data synthesis

Data were categorised according to seven strata described in the 2014 WHO Preventing Suicide Report (World Health Organisation, 2014). High-income countries form a single stratum whilst low- and middle-income countries (LMICs) are divided into six strata: Africa (AFRO), the Americas (AMRO), Europe (EURO), Eastern Mediterranean (EMRO), South-East Asia (SEARO) and Western Pacific (WPRO).

Where there were several sources of data available for a single country, WHO data was prioritised unless more recent national data were available in the published literature. There were eight countries for which both national published literature and WHO data were available; the estimates of pesticide suicides in all eight countries differed by less than 5% between the two sources. The quality rating was used to differentiate between published papers from the same country. If there were two papers with the same quality rating, we considered geographical comprehensiveness, recency of data and whether the data were disaggregated by year.

Where the data sources only present data for a subset of pesticide deaths (e.g. insecticide deaths, rather than combined deaths from insecticides, rodenticides, herbicides and fungicides), we specify this in the text; such figures will lead to under-estimates of the overall number of pesticide suicides.

Pesticide suicides as a proportion of overall suicides were calculated for each data source. This calculation was based on the most recent year for which data were provided. Where there were fewer than 500 total suicides reported in the most recent year, the percentage of pesticide suicides was calculated based on the two most recent years.

Table 1
Inclusion and exclusion criteria.

Field	Inclusion criteria	Exclusion criteria
Language	Any language Where only the title was available in English, papers were only translated if the title suggested the paper may yield relevant results	Where only the title was available in English, papers were not translated if the title indicated the paper would yield irrelevant results
Years included	Data from 2006 onwards Where suicide data is available for a range of years without a breakdown by individual year, papers were included if the median year was 2006 or later	Pre – 2006 data
Publication status	Research published in peer-reviewed journals, government reports, WHO data	Grey literature such as research reports and PhD theses
Type of data	Quantitative	Qualitative
Study design	Ecological, case-control, cohort, cross-sectional and case series. Studies were only included if they reported >10 suicides	Reviews, small cohort and case reports which report less than 10 suicides, ethnographic studies, biochemical studies, laboratory studies, editorials, letters, clinical studies evaluating treatment or clinical outcomes
Study population	General population	Hospital-based studies a) where the catchment population is unclear or b) that only present in-hospital deaths Restricted age groups (e.g. 10–25 year olds) or children Restricted gender
Setting	National data on any country Regional data of any country if total suicides for the population covered are provided	Regional data of any country if total suicides for population covered are not provided.
Exposure	Pesticides: herbicides, insecticides, fungicides and rodenticides	Data limited to a sub-group of pesticides
Outcome	Number of completed suicides using pesticides as a proportion of all suicides in the area studied	Suicidal ideation, non-fatal suicide attempt

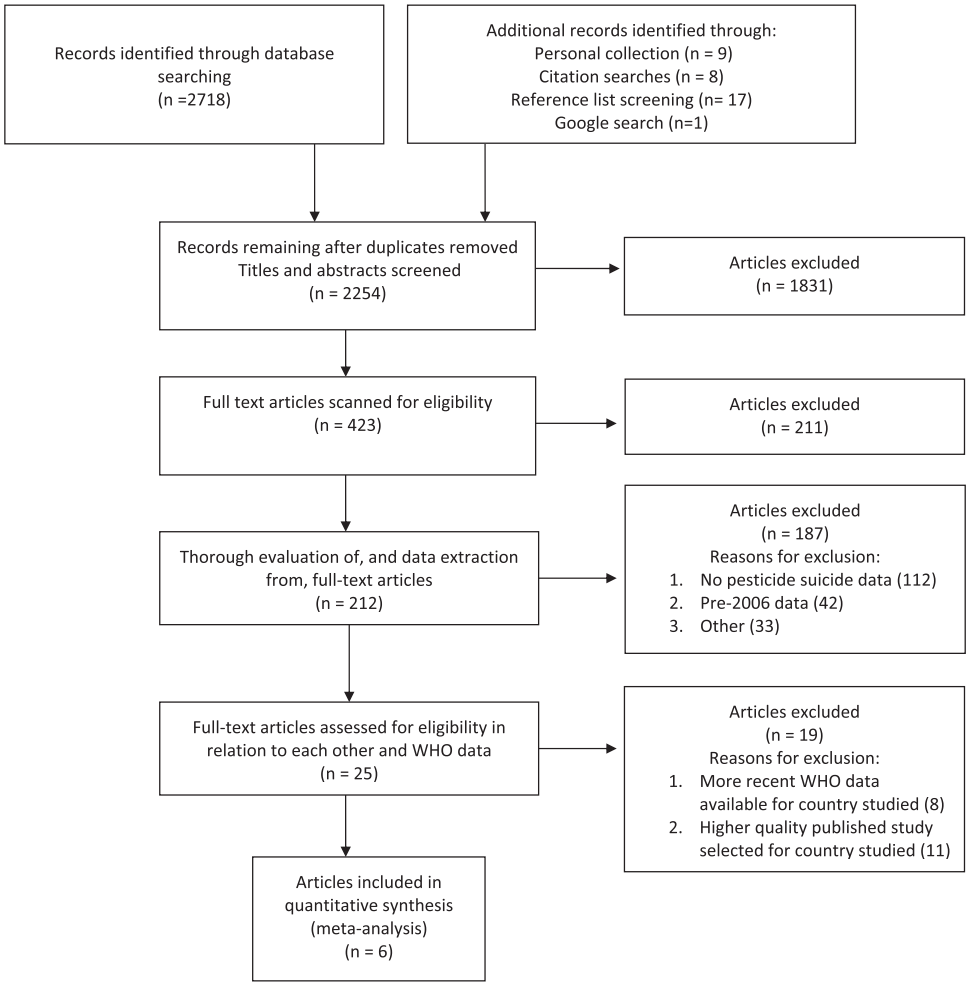

Fig. 1. Flow diagram illustrating stages of the review process.

Table 2
Annual estimated number and percentage of pesticide suicides in each WHO region (2010–2014).

WHO Region	Total no. suicides (World Health Organisation, 2014)	Estimated % of suicides due to pesticide poisoning in the region	Estimated no. pesticide suicides[a]	% of each region's population contributing to the estimate[b]	Sources used for estimates
HICs	192000	1.7	3300	89.7	(Chang et al., 2012; Kastanaki et al., 2010; World Health Organisation, 2015)
AFRO LMICs	61000	3.5	2100	5.9	(World Health Organisation, 2015)
AMRO LMICs	35000	8.8	3100	95.7	(World Health Organisation, 2015)
EMRO LMICs	30000	7.1	2100	33.4	(World Health Organisation, 2015)
EURO LMICs	35000	0.9	300	56.2	(World Health Organisation, 2015)
SEARO LMICs	314000	11.3	35500	69.1	(de Silva et al., 2012; National Crime Records Bureau, 2014; World Health Organisation, 2015)
WPRO LMICs	131000	48.3	63300	92.3	(National Suicide Registry, 2011; Page et al., 2016; World Health Organisation, 2015)
Total	798000[c]	13.7	109700		

[a] Rounded to the nearest 100 (As the number of pesticide suicides were calculated from the percentage of suicides due to pesticide poisoning prior to rounding, there are some discrepancies between the rounded estimated numbers and the percentages from which they were derived).
[b] The availability of country-specific estimates of the number /% of pesticide suicides varies from region to region. For example, estimates of the proportion of total suicides due to pesticide poisoning for African LMICs are based on countries that comprise only 5.9% of that region's population
[c] Differs from the total in WHO report (804,000) as the report total includes data for three territories that are not Member States of WHO

A weighted average of the percentage of pesticide suicides was calculated for each of the seven WHO strata. Weightings were based on the national total number of suicides reported. Where this was not reported in a paper, an estimate was obtained from 2012 WHO data (World Health Organisation, 2014). We obtained population data from The World Bank (The World Bank, 2015).

To estimate the global burden of pesticide suicides, the weighted average percentage of pesticide suicides for each regional mortality stratum was applied to the total number of suicides in each stratum, as reported by the WHO (World Health Organisation, 2014). We did not attempt to capture uncertainty in the estimate for each region (e.g. through interquartile ranges or 95% confidence intervals) because the quality and quantity of data differed for each region, making such estimates non-comparable and in some cases implausible.

To account for under-reporting in India, a sensitivity analysis was performed, based on Patel *et al.*'s nationally representative survey conducted between 2001 and 2003 and used to estimate the overall and method-specific suicide mortality in 2010 (Patel et al., 2012). We performed this analysis for India because: (1) it is the second largest country in the world; (2) has a high incidence of pesticide suicides (which makes a significant contribution to the global estimate); (3) there are strong grounds for concern that the official estimates of the incidence of suicide in India may be under-estimates (Patel et al., 2012); and (4) this approach is consistent with the approach taken in our previous review (Gunnell et al., 2007a).

3. Results

The estimate of the global burden of fatal self-poisoning with pesticides is based on data from 108 countries. The data for 102 of these countries were obtained from the WHO's Mortality Database (World Health Organisation, 2015). Data for the remaining six countries, which include the world's most populous countries, India and China, were derived from published literature. Method-specific WHO data were unavailable for five of these six countries, including India and China. Table 2 provides a summary of overall and pesticide suicides annually for each of the regions/income strata.

3.1. High-income countries

The estimate for high-income countries is based on national data from 56 countries (Chang et al., 2012; World Health Organisation, 2015) as well as published regional data from Greece (Kastanaki et al., 2010), overall covering 89.7% of the stratum's population. Out of the three most populous countries within this stratum, data were available for the United States of America and Japan, but not for the Russian Federation.

The weighted estimates of the percentage and annual number of suicides due to pesticides in high-income countries are 1.7% and 3300 respectively. Many countries (44%) reported no suicides due to pesticides.

3.2. LMICs in WHO African Region (AFRO)

Data on suicide, and more specifically on methods used, are scarce in LMICs in the African region. A number of studies did not meet the inclusion criteria as they either did not disaggregate poisoning by type, provided only pre-2006 data or included data on hospital admissions only. No studies met the inclusion criteria for the three most populous countries in the region: Nigeria, Ethiopia and the Democratic Republic of Congo. The estimate of the proportion of suicides using pesticides is based on WHO data from Mauritius and South Africa (World Health

Organisation, 2015), which account for only 5.9% of the region's population and have relatively higher incomes than many other countries in the region.

The weighted estimate of the percentage and annual number of suicides due to pesticides in the African region is 3.5% and 2100 respectively. However published data indicate this may be a substantial under-estimate (see below).

Given the lack of data for the African region, we describe findings from a number of regional studies that did not meet the inclusion criteria for this review to provide an insight into the burden of pesticide poisoning. Between 22–42% of hospital-presenting acute poisoning cases in Ethiopia, Burkina Faso and Zambia were the result of pesticide ingestion, of which 28–97% were deliberate (Abula and Wondmikun, 2006; Desalew et al., 2011; Toe et al., 2013; Z'gambo et al., 2016). In the Rivers and Abia states of Nigeria, out of 32 suicides between 2001 and 2010, one was due to chemical poisoning although the type was unspecified (Offiah and Obiorah, 2014). Pesticides were identified as the cause of 36 of the 47 suicides in the Guidiguis health district of Cameroon between 1999 and 2008 (Keugoung et al., 2013).

A systematic review of suicide in Africa, which included data from 1998 to 2013, concluded that pesticide poisoning was one of two most frequently used methods of suicide in the continent (Mars et al., 2014). In our previous review, based on literature published up to 2007, we estimated that 15–33% of suicides (n = 34,000 deaths) in Africa were from pesticide self-poisoning (Gunnell et al., 2007a); we are unaware of any recent pesticide control measures in Africa, so we suspect this range is more plausible than our current estimate of 3.5% (n = 2100 deaths) for recent years.

3.3. LMICs in WHO Region of the Americas (AMRO)

The estimate for LMICs in the Americas is based on national WHO data from 23 countries, including the three most populous countries, Brazil, Mexico and Colombia. Coverage is 95.7%. All data for this region were extracted from the WHO Mortality Database (World Health Organisation, 2015).

There are an estimated 3100 suicides due to pesticides in the Americas annually, accounting for 8.8% of suicides in this region.

3.4. LMICs in WHO Eastern Mediterranean Region (EMRO)

The estimate for LMICs in the Eastern Mediterranean region is based on national WHO data from six countries, accounting for 33.4% of the region's population. Out of the three most populous countries, Pakistan, Egypt and Iran, data meeting the review's inclusion criteria were only available for Egypt.

An estimated 2100 (7.1%) of the region's suicides annually are due to pesticide poisoning. Half the countries in the region, for which data meeting the inclusion criteria were available, reported no suicides due to pesticides. However published data suggest this may be a substantial under-estimate.

Pesticides are reportedly a common method of self-poisoning and suicide in Pakistan (Khan, 2007; Khan et al., 2008; Shahid and Hyder, 2008). Amongst patients admitted to hospital due to deliberate self-poisoning in Rawalpindi, Pakistan in 2006, 17 (21.3%) ingested organophosphate compounds; 82.5% of those admitted were from an urban residence (Khurram and Mahmood, 2008). In the Mianwali District, in which 80% of the population reside in rural areas, 33 of the 108 suicide attempts identified in 2011 were the result of pesticide poisoning (Tahir et al., 2014).

Likewise, pesticides are commonly responsible for poisoning amongst hospital-presenting patients in Iran (Ahmadi et al., 2010; Islambulchilar et al., 2009; Mohseni Saravi et al., 2013). Of note, there was evidence of an increase in aluminum phosphide self-poisoning and mortality in Tehran following its ban in 2007 (Hosseinian et al., 2011; Shadnia et al., 2009; Soltaninejad et al., 2007).

3.5. LMICs in WHO European Region (EURO)

The use of pesticides in acts of self-harm is uncommon in LMICs within Europe. The estimate for Europe is based on national data from 13 countries from the WHO mortality database, covering 56.2% of the region (World Health Organisation, 2015). Data were only available for two out of the three most populous countries in this category: Turkey and Romania but not Ukraine.

Amongst LMICs in the European region there are an estimated 300 suicides due to pesticides each year, which account for approximately 0.9% of suicides in the region; 31% of countries reported no suicides due to pesticides.

According to WHO data 0.7% of suicides in Turkey were due to pesticides in 2013 (World Health Organisation, 2015). However published data suggest this may be an under-estimate. A paper based on data between 1999 to 2005, reported that 16.3% of suicides were the result of chemical ingestion (Asirdizer et al., 2010). During a similar time period 10.1% of 955 suicides in Bursa Province, Turkey (population approximately 2.8 million), and 17% of 285 fatal poisoning deaths, were the result of insecticide poisoning (Birincioglu et al., 2011; Odabasi, 2009). In the latter study, 84% of deaths were suicidal or of undetermined intent (Birincioglu et al., 2011). Out of 427 patients presenting to an Emergency Department in Adana, Turkey in 2004 with suicidal poisoning, 17.6% had ingested pesticides (Akbaba et al., 2007). In other Emergency Departments in Turkey, pesticides accounted for 9–24% of acute poisoning, of which 73–80% were with suicidal intent (Avsarogullari et al., 2012; Aydin et al., 2014; Satar et al., 2009). Case fatality is higher after pesticide self-poisoning than after other forms of poisoning.

3.6. LMICs in WHO South East Asia Region (SEARO)

Data from three countries, which contribute to 69.1% of the region's population, formed the basis of the estimate for the South East Asia region. Sri Lankan and Indian data were obtained from published literature (de Silva et al., 2012; National Crime Records Bureau, 2014), whilst the WHO Mortality Database provided data for the Maldives (World Health Organisation, 2015). Data meeting the inclusion criteria were unavailable for Indonesia and Bangladesh, the two most populous countries in the region after India.

The estimated percentage of pesticide suicides out of all suicides in the region is 11.3%. Pesticides contribute to approximately 35,500 suicides annually. However published data suggest this may be a substantial under-estimate. In Bangladesh, an estimated 7.1% of hospital admissions were due to poisonings since 2000, of which 39.1% were due to pesticides (Dewan, 2014). Although the intent of the pesticide poisonings was unspecified, 72.2% of poisoning cases of all forms were with suicidal intent. In 2003, 30 (49%) of the 61 suicides identified by a nationally representative study in Bangladesh, were due to pesticides (Mashreky et al., 2013).

Official Indian data from the National Crime Records Bureau (NCRB) contributed to the South East Asia region estimate in this review (National Crime Records Bureau, 2014). The official data estimated that in 2014, 10.9% (14,352) of India's 131,666 suicides resulted from insecticides, compared with 19.4% (21,414) of 110,417

suicides in 2002 (National Crime Records Bureau, 2002).

A nationally representative survey of suicide mortality in India conducted between 2001 and 2003 indicated, however, that the national data may substantially underestimate suicide in India (Patel et al., 2012). Furthermore with regards to method-specific data, the national data only disaggregates self-poisoning into "insecticides" and "other poisons". The lack of a more general "pesticides" category, which also includes rodenticides, fungicides and herbicides, is likely to result in an underestimation of the number of pesticide suicides. Patel *et al.*'s survey estimated, based on data for 2001 to 2003, that in 2010 there were 187,000 suicide deaths in India and in 38.8% of these (a total of 72,500 per year) pesticide ingestion was the method of suicide (Patel et al., 2012), over three times higher than the figure reported in official statistics for India (see above).

For comparison, one other study from India also met the inclusion criteria for this review (Bose et al., 2009). In a predominantly rural part of Vellore in South India, between 2006 and 2007, 36 of 149 (24.2%) suicides resulted from pesticide poisoning.

Our sensitivity analysis indicated that there were likely to be an additional 55,300 suicides and 58,100 pesticide suicides in India. Pesticide suicides would therefore account for 38.5% of suicides in the South East Asia region.

3.7. LMICs in WHO Western Pacific Region (WPRO)

The Western Pacific region estimate is based on national data from four countries, which account for 92.3% of the region's population. Data for China were obtained from a recent study of pesticide suicide mortality (Page et al., 2017), the WHO Mortality Database provided data from the Philippines and Fiji (World Health Organisation, 2015) and data for Malaysia were retrieved from a national report (National Suicide Registry, 2011).

An estimated 63,300 suicides a year are due to pesticides in the Western Pacific Region. Pesticides account for approximately 48.3% suicides in the region.

Data on pesticide suicides were unavailable for Vietnam, the third most populous country in this region after China and the Philippines.

Three published papers presented data on patients admitted to hospital following poisoning in Hanoi (Hung et al., 2008; Tuan et al., 2009) and Gia Luong (Nguyen et al., 2010), Vietnam. In Hanoi, 45.3% of patients who attempted suicide in rural areas between 2007 and 2008 used pesticides compared with 6.5% of patients from urban areas (Tuan et al., 2009). Between 1999 and 2003, 9.1% of those admitted to Vietnam's first Poison Control Centre had experienced pesticide poisoning (Hung et al., 2008); cases in this study were not disaggregated by intent. In Gia Luong 62.6% of suicide attempts between 2003 and 2007 involved pesticide ingestion (Nguyen et al., 2010).

3.8. World total

A conservative estimation suggests at least 109,700 deaths occur from pesticide self-poisoning each year, comprising 13.7% of suicides globally. The additional sensitivity analysis, in which national data from India has been adjusted to account for previous under-reporting and the inclusion of insecticides only, results in an increase in the total number of suicides globally from 798,000 to 853,300, with 167,800 (19.7%) of these deaths resulting from pesticide self-poisoning.

4. Discussion

Based on the data in this review, approximately one in seven (110,000) of the 798,000 suicides worldwide in 2012 were the result of pesticide self-poisoning. In our sensitivity analysis the proportion increases to at least one in six (167,800).

These estimates should be interpreted in light of a number of limitations. In particular, data for several regions, most notably Africa, are lacking; but studies of hospitalisation for pesticide self-poisoning from these regions indicate we have substantially underestimated the number of pesticide suicides. Nevertheless, two countries dominate global suicide and pesticide statistics, China and India, and estimates from research studies were available for both (Page et al., 2017; Patel et al., 2012).

Our estimate indicates that there has been a reduction in the number of pesticide suicides worldwide since 2006 (from 260,000 to 110,000), which has occurred in the context of a 9% decrease in the WHO estimate of the overall number of suicides between 2000 and 2012 (from 883,000 to 804,000) (Gunnell et al., 2007a; World Health Organisation, 2014). These global changes have occurred in the context of marked economic growth, population shifts from rural to urban areas and the introduction of regulation to reduce access to the most toxic pesticides (Cha et al., 2016; Gunnell et al., 2007b; Knipe et al., 2017; Zhang et al., 2014). The biggest drivers of this change are likely to be the decline in suicides in the Western Pacific region combined with the reduction in the proportion of suicides due to pesticides in both China and India where rapid urbanisation has decreased the proportion of the population that has daily access to agricultural pesticides (see below). The percentage of suicides due to pesticides has fallen from approximately 62% (Phillips et al., 2002) to 49% (Page et al., 2017) in China and (for insecticides only) from 19.6% (National Crime Records Bureau, 2005) to 10.9% (National Crime Records Bureau, 2014) in India based on official estimates, which Patel's data indicate under-estimate the contribution of pesticide poisoning (see below) (Patel et al., 2012).

In China, over the last 25 years there has been a reduction in the percentage of people living in rural areas from approximately 80% down to 50% resulting in at least 300 million fewer people having ready access to pesticides (United Nations, 2017). Furthermore the population employed in agriculture has fallen from 50% in 2002 to 31% in 2013 (Food and Agriculture Organisation of the United Nations, 2015). Globally, the percentage of those employed in agriculture has fallen, particularly in East Asia and the Pacific region, which has seen a reduction from 41.6% (average from 2000to 2002) to 8.9% (average from 2011to 2013) of total employment. Less dramatic reductions have been observed in South Asia (59.2% to 49.2%) and Latin America and the Caribbean (18.2% to 14.2%). Whilst across Europe employment in agriculture remains low (4–5%) (The World Bank, 2014). Information on employment from Sub-Saharan Africa is more limited and varies greatly across the continent but is currently estimated at around 65% (2015) down from 70% to 75% over the past decade (The World Bank, 2013).

The number of fatal pesticide self-poisonings may also be influenced by changes over time in treatment capacity, toxicity, formulations, packaging, storage as well as absolute sales of pesticides. India for example has experienced marked fluctuations in insecticide use, beginning with a steady decline from more than 51,000 tonnes of active ingredients in 1992 to 3000 tonnes in 2008, followed by an increase to almost 21,000 tonnes by 2010 (Food and Agriculture Organisation of the United Nations, 2015). Globally the pesticide industry is forecast to grow annually by approximately 6% over the next few years with the highest growth rates occurring in South America and Asia (Reportlinker, 2012; Research and Markets, 2015).

The number of pesticide suicides is an under-estimation of the burden of self-harm resulting from pesticide ingestion. Case fatality

following pesticide ingestion ranges from between 1% to over 40% according to the pesticide ingested and, to a lesser extent, the availability of healthcare (Dawson et al., 2010). However based on the crude assumption that the median case fatality across all pesticide products ranges from 5% to 10%, the annual number of pesticide self-poisonings ranges from one to two million.

It is widely recognised that restricting access to commonly used, high-lethality suicide methods is an effective strategy for preventing suicide (Barber and Miller, 2014; Mann et al., 2005; Yip et al., 2012). This is because commonly used methods differ markedly in their lethality- from greater than 60% for hanging, firearms and some pesticides to < 1% for some medicines commonly taken in overdose (Azrael and Miller, 2016). If a person is prevented from using a highly lethal method, they may instead use a method with a lower lethality, with an increased chance of survival, or the suicidal impulse may pass. For example the reduction in the incidence of suicide in the UK in the 1970s was driven by falls in the toxicity (carbon monoxide content) of the domestic gas supply (Kreitman, 1976). A number of studies indicate that restrictions on the import or sale of high toxicity pesticides have been followed not only by falls in the number of people dying from pesticide self-poisoning, but also in overall suicide rates in Sri Lanka and South Korea (Cha et al., 2016; Gunnell et al., 2007b; Knipe et al., 2017). Equally effective, but less toxic, alternative pesticides and agricultural practices are available and the few studies investigating the impact of pesticide bans on crop yield have found no evidence of an adverse effect on food production (Cha et al., 2016; Manuweera et al., 2008).

Restricting or changing access to methods of suicide is, however, unlikely to reduce the incidence of suicide attempts as such an approach does nothing to alleviate the social and psychological stressors leading to suicidal behaviour (Azrael and Miller, 2016); indeed during the 1990s in Sri Lanka when the incidence of suicide declined, most probably due to regulations banning a number of highly hazardous pesticides, the incidence of suicide attempts increased (Gunnell et al., 2007b).

4.1. Strengths and limitations

This review was more comprehensive than its predecessor (Gunnell et al., 2007a), with the inclusion of data from 108 countries covering approximately 70% of the global population. The findings are strengthened by the sensitivity analysis based on nationally representative data from India, although this analysis assumes that the magnitude and method-distribution of under-reporting has not changed since 2002 (Patel et al., 2012).

The main limitation is the on-going absence of high quality method-specific suicide data for a number of the most populous countries including Indonesia, Pakistan, Nigeria, Bangladesh and Russia. This was particularly problematic in LMICs in the African and Eastern Mediterranean regions, where data were only available for 5.9% and 33.4% of the regions' populations respectively. In these two regions, findings from studies that did not meet the inclusion criteria (Abula and Wondmikun, 2006; Ahmadi et al., 2010; Desalew et al., 2011; Islambulchilar et al., 2009; Keugoung et al., 2013; Khan, 2007; Khan et al., 2008; Khurram and Mahmood, 2008; Mohseni Saravi et al., 2013; Shahid and Hyder, 2008; Tahir et al., 2014; Toe et al., 2013; Z'gambo et al., 2016) indicate our lack of data results in a substantial underestimation of the percentage of pesticide suicides. The African region estimate is particularly unreliable as the two countries on which it is based, Mauritius and South Africa, are unrepresentative of the rest of the region. Nonetheless these regions are likely to have a limited impact on the global estimate as they currently account for less than 12% of the world's suicides (World Health Organisation, 2014).

A second potential limitation of this review is its reliance on WHO data. Under-reporting and misclassification affect the reliability of these data (World Health Organisation, 2014). However, where national published data were available to compare with WHO data (8 countries), the estimates of pesticide suicides differed by less than 5% between the two sources. Furthermore the extent to which WHO estimates are based on the same sources as the national published data is unknown. In comparison, small, focussed studies indicate the WHO data may substantially underestimate the burden of pesticide self-poisoning, particularly in rural areas (Abula and Wondmikun, 2006; Keugoung et al., 2013; Toe et al., 2013).

The third limitation is our crude assumption that the percentage of suicides due to pesticides within each country in a region is likely to be similar.

Within the high-income stratum, data were available and included for a number of countries which were not included in the 2014 WHO suicide estimate for that stratum: Aruba, Bermuda, Cayman Islands, Hong Kong, Puerto Rico, Taiwan, Turks & Caicos Islands and Virgin Islands. The percentage of pesticide suicides for this region may therefore be an over-estimate. The high-income region estimate however has minimal impact on our estimate of the global percentage of pesticide suicides.

Finally, the number and percentage of pesticide suicides globally is likely to be an underestimate due to poor data collection, particularly in rural areas, difficulty determining intent or method, and criminalisation and stigma of suicide.

4.2. Public health implications

This review highlights the ongoing public health burden associated with pesticide self-poisoning. Whilst the absolute number of fatal pesticide self-poisonings has fallen compared to our previous estimates based on pre-2008 data (Gunnell et al., 2007a), using our conservative estimates pesticides still account for at least one in seven of all suicides globally. Although evidence of the effectiveness of pesticide safe storage (e.g. in locked boxes or village storage facilities) is at present limited (Vijayakumar et al., 2013; World Health Organisation, International Association for Suicide Prevention, 2006, World Health Organisation, 2016), there is now a growing evidence-base to support the role of restricting access to pesticides through targeted sales bans in reducing suicide (Cha et al., 2016; Gunnell et al., 2007b; Knipe et al., 2017).

4.3. Conclusions

Pesticide self-poisoning remains a major public health concern. Although there appears to have been a substantial decline in recent years largely driven by a reduction in suicide rates in China, pesticide self-poisoning continues to account for at least one in seven suicides globally. Furthermore, given the lack of data for several regions, this is likely to be a substantial under-estimate. Progress has been made in terms of data collection and policy, but these improvements remain uneven. Low quality method-specific data on suicides is a particular problem in Africa, where the percentage employed in agriculture remains high. Urgent efforts are needed to improve the comprehensiveness and quality of such data in order to obtain better estimates of global pesticide suicides that would aid in the development and assessment of method-restriction approaches to suicide prevention.

Acknowledgements

Dr Alexandra Fleischmann (WHO), Tomas John Allen (WHO librarian)

Appendix A. Search strategy

Electronic database	1st search (2015)	Citations returned	2nd search (2015)	Citations returned	Search terms
PUBMED	31/01	1485	26/12	93	(“Pesticides"[Mesh] OR pesticide* [TIAB] OR herbicide* [TIAB] OR insecticide* [TIAB] OR rodenticide* [TIAB] OR paraquat* [TIAB] OR organophosphate* [TIAB] OR organophosphorous [TIAB] OR agrochemical [TIAB] OR carbamate* [TIAB] OR organochloride* [TIAB] OR “aluminum phosphide" [TIAB] OR fungicide* [TIAB]) AND ("Suicide"[Mesh] OR suicide* [TIAB] OR "self-injurious behaviour" [TIAB] OR suicidal [TIAB] OR "drug overdose" [TIAB] OR self-harm* [tw] OR "self harm" [tw] OR self-destruct* [tw] OR "self destruct" [tw] OR self-poison* [tw] OR poison* [tw] OR "self poison" [tw] OR self-inflicted injur* [tw] OR "self inflict" [tw] OR overdose* [tw]) AND ("epidemiologic methods"[Mesh] OR "Comparative Study"[Publication Type] OR "OUTCOME AND PROCESS ASSESSMENT (HEALTH CARE)"[Mesh] OR "statistics and numerical data "[Subheading] OR "Evaluation Studies "[Publication Type] OR "meta analysis "[Publication Type] OR "multicenter study "[Publication Type] OR mortality [TIAB] OR incidence [TIAB] OR prevalence [TIAB] OR surveillance [TIAB]).
AGRIS	04/02	89	26/12	0	“ “
PSYCInfo (Ovid)	31/01	490	26/12	38	((Pesticide? or insecticide? or rodenticide? or herbicide? or paraquat or organophosphate? or carbamate? or organochloride? or fungicide? or aluminum phosphide or organophosphorus? or agricultural? or agrochemical?).af) and ((suicide/ or suicide, attempted/ or self-injurious behaviour/ or suicidal behaviour/or drug overdose/ or attempted suicide/ or self destructive behaviour/ or drug overdoses/ or suicidal ideation/ or injuries, self inflicted) or (self-harm$ or self?harm$ or suicid$ or self-destruct$ or self?destruct$ or self-poison$ or poison$ or self?poison$ or self-inflict$ or self?inflict $ or overdose$).tw).
Web of Science	02/02	249	26/12	42	(suicide* or self-harm) and pesticide*
African Journals Online	04/02	0	26/12	0	(suicide or self-harm) and pesticide
African Index Medicus	03/02	0	26/12	0	“ “
Global Health Library	02/02	187	26/12	0	“ “
IMEMR	03/02	3	26/12	0	“ “
IMSEAR	04/02	15	26/12	0	“ “
INDMED	04/02	1	26/12	0	“ “
LILACs	04/02	9	26/12	2	“ “
WPRIM	04/02	8	26/12	3	“ “
KOREAMED	04/02	3	26/12	1	1st search: suicide and pesticide 2nd search: self harm and pesticide

Appendix B

Pesticide data extraction sheet

Relevant for suicide estimate Y/N/I

Reference (Author, title, journal, year)		
Country		
WHO Region (AFRO/AMRO/EMRO/EURO/Global/SEARO/WPRO)		
Short Summary of Results OR Reasons for exclusion or omitting. Limitations / Bias arising from study design		
Coverage (national, sub-national, etc. / % total population)		**Page/para no.**
If regional data – name of region		
Rural/urban (%)		
Study Population (sex, age, hospital admissions, forensic cases etc.)		
Year of Study Results (years data cover)		
Sample Size (total observed population)		
Total number of suicides (5 most recent years)	**Undetermined intent**	
Total no. of suicide by pesticide (5 most recent years)		

Total number of self-poisonings (5 most recent years)		
Total number of pesticide self-poisonings (5 most recent years)		
Methodology (e.g. analysis of national death certs / psychological autopsy study/ retrospective evaluation of hospital records/cohort)		
Pesticides Studied (give relative %s of main e.g. top 5 pesticides)		
Additional refs to track down **1.** **2.** **3.** **4.** **5.**		

Risk of bias tool (only complete for studies that will contribute to suicide estimate).

Item	Score (x in appropriate box)*
Representativeness of the study sample	
Nationally representative mix of urban and rural areas (4)*	
Single city /non representative population (0)*	
Size of study and recency of death data:	
> 100 suicides and post 2010 data (4)*	
50–100 suicides and post 2010 data (3)*	
10–50 suicides and post 2010 data (2)*	
> 100 suicides and data between 2006 and 2010 (2)*	
< 100 suicides and data between 2006 and 2010 (1)*	
Quality of suicide death ascertainment	
verbal autopsy/ national reporting system (2)*	
Other (0)*	

Information on pesticide suicides + total suicides

Data on pesticide suicide + total (all method) suicide (2)*

Studies that only give numbers of pesticide suicides (0; in these latter studies we would need to rely on national suicide data for a denominator for proportion of pesticide suicides)*

Total

*Tick zero if unclear/not specified.

References

Abula, T., Wondmikun, Y., 2006. The pattern of acute poisoning in a teaching hospital, north-west Ethiopia. Ethiop. Med. J. 44, 183–189.

Ahmadi, A., Pakravan, N., Ghazizadeh, Z., 2010. Pattern of acute food, drug, and chemical poisoning in Sari City, Northern Iran. Hum. Exp. Toxicol. 29, 731–738. http://dx.doi.org/10.1177/0960327110361501.

Ajdacic-Gross, V., Weiss, M., Ring, M., Hepp, U., Bopp, M., Gutzwiller, F., Rössler, W., 2008. WHO | Methods of suicide: international suicide patterns derived from the WHO mortality database. Bull. World Health Organ. 86.

Akbaba, M., Nazlican, E., Demirhindi, H., Sütoluk, Z., Gökel, Y., 2007. Etiological and demographical characteristics of acute adult poisoning in Adana, Turkey. Hum. Exp. Toxicol. 26, 401–406. http://dx.doi.org/10.1177/0960327107076818.

Asirdizer, M., Yavuz, M.S., Aydin, S.D., Dizdar, M.G., 2010. Suicides in Turkey between 1996 and 2005: general perspective. Am. J. Forensic Med. Pathol. 31, 138–145. http://dx.doi.org/10.1097/PAF.0b013e3181cfc658.

Avsarogullari, L., Senol, V., Akdur, O., Akin, A., Durukan, P., Ozkan, S., 2012. Characteristics of acute adult poisonings in a university hospital emergency department in central Turkey: a three-year analysis. J. Pak. Med. Assoc. 62, 129–133.

Aydin, I., Karadas, S., Gonullu, H., Dulger, A.C., 2014. Epidemiological analysis of poisoning cases in Van, Turkey. J. Pak. Med. Assoc. 64, 560–562.

Azrael, D., Miller, M.J., 2016. Reducing Suicide Without Affecting Underlying Mental Health. In: The International Handbook of SuicidePrevention. John Wiley & Sons, Ltd, Chichester, UK, pp. 637–662. http://dx.doi.org/10.1002/9781118903223.ch36.

Barber, C.W., Miller, M.J., 2014. Reducing a suicidal person's access to lethal means of suicide: a research agenda. Am. J. Prev. Med. 47, S264–S272. http://dx.doi.org/10.1016/j.amepre.2014.05.028.

Bertolote, J.M., Fleischmann, A., Butchart, A., Besbelli, N., 2006a. Suicide, suicide attempts and pesticides: a major hidden public health problem. Bull. World Health Organ. 84, 260 (doi:/S0042-96862006000400004).

Bertolote, J.M., Fleischmann, A., Eddleston, M., Gunnell, D., 2006b. Deaths from pesticide poisoning: a global response. Br. J. Psychiatry 189, 201–203. http://dx.doi.org/10.1192/bjp.bp.105.020834.

Birincioglu, I., Karadeniz, H., Teke, H.Y., 2011. Fatal poisonings in Trabzon (Turkey). J. Forensic Sci. 56, 660–663. http://dx.doi.org/10.1111/j.1556-4029.2011.01624.x.

Bose, A., Sandal Sejbaek, C., Suganthy, P., Raghava, V., Alex, R., Muliyil, J., Konradsen, F., 2009. Self-harm and self-poisoning in southern India: choice of poisoning agents and treatment. Trop. Med. Int. Health 14, 761–765. http://dx.doi.org/10.1111/j.1365-3156.2009.02293.x.

Cha, E.S., Chang, S.-S., Gunnell, D., Eddleston, M., Khang, Y.-H., Lee, W.J., 2016. Impact of paraquat regulation on suicide in South Korea. Int. J. Epidemiol. 45, 470–479. http://dx.doi.org/10.1093/ije/dyv304.

Chang, S.-S., Lu, T.-H., Sterne, J.A., Eddleston, M., Lin, J.-J., Gunnell, D., 2012. The impact of pesticide suicide on the geographic distribution of suicide in Taiwan: a spatial analysis. BMC Public Health 12, 260. http://dx.doi.org/10.1186/1471-2458-12-260.

Dawson, A.H., Eddleston, M., Senarathna, L., Mohamed, F., Gawarammana, I., Bowe, S.J., Manuweera, G., Buckley, N.A., 2010. Acute human lethal toxicity of agricultural pesticides: a prospective cohort study. PLoS Med. 7, e1000357. http://dx.doi.org/10.1371/journal.pmed.1000357.

de Silva, V.A., Senanayake, S.M., Dias, P., Hanwella, R., 2012. From pesticides to medicinal drugs: time series analyses of methods of self-harm in Sri Lanka. Bull. World Health Organ. 90, 40–46. http://dx.doi.org/10.2471/BLT.11.091785.

Desalew, M., Aklilu, A., Amanuel, A., Addisu, M., Ethiopia, T., 2011. Pattern of acute adult poisoning at Tikur Anbessa specialized teaching hospital, a retrospective study, Ethiopia. Hum. Exp. Toxicol. 30, 523–527. http://dx.doi.org/10.1177/0960327110377520.

Dewan, G., 2014. Analysis of recent situation of pesticide poisoning in Bangladesh: is there a proper estimate? Asia Pac. J. Med. Toxicol. 3, 76–83.

Eddleston, M., 2000. Patterns and problems of deliberate self-poisoning in the developing world. QJM 93, 715–731.

Eddleston, M., Karalliedde, L., Buckley, N., Fernando, R., Hutchinson, G., Isbister, G., Konradsen, F., Murray, D., Piola, J.C., Senanayake, N., Sheriff, R., Singh, S., Siwach, S.B., Smit, L., 2002. Pesticide poisoning in the developing world–a minimum pesticides list. Lancet (Lond., Engl.) 360, 1163–1167.

Eddleston, M., Phillips, M.R., 2004. Self poisoning with pesticides. BMJ 328, 42–44. http://dx.doi.org/10.1136/bmj.328.7430.42.

Food and Agriculture Organisation of the United Nations, 2015. FAOSTAT [WWW Document]. URL ⟨http://faostat3.fao.org/browse/R/RP/E⟩ (accessed 5 February 2016).

Gunnell, D., Eddleston, M., 2003. Suicide by intentional ingestion of pesticides: a continuing tragedy in developing countries. Int. J. Epidemiol. 32, 902–909.

Gunnell, D., Eddleston, M., Phillips, M.R., Konradsen, F., Kuo, Y., Sa, C., Chen, S., Deng, J., Azhar, S., Dissanayake, W., Sheriff, M., Szinicz, L., Dawson, A., Buckley, N., Wasserman, D., 2007a. The global distribution of fatal pesticide self-poisoning: systematic review. BMC Public Health 7, 357. http://dx.doi.org/10.1186/1471-2458-7-357.

Gunnell, D., Fernando, R., Hewagama, M., Priyangika, W.D.D., Konradsen, F., Eddleston, M., 2007b. The impact of pesticide regulations on suicide in Sri Lanka. Int. J. Epidemiol. 36, 1235–1242. http://dx.doi.org/10.1093/ije/dym164.

Hosseinian, A., Pakravan, N., Rafiei, A., Feyzbakhsh, S.M., 2011. Aluminum phosphide poisoning known as rice tablet: a common toxicity in North Iran. Indian J. Med. Sci. 65, 143–150. http://dx.doi.org/10.4103/0019-5359.104777.

Hung, H.T., Du Nguyen, T., Höjer, J., 2008. The first poison control center in Vietnam: experiences of its initial years. Southeast Asian J. Trop. Med. Public Health 39, 310–318.

Islambulchilar, M., Islambulchilar, Z., Kargar-Maher, M.H., 2009. Acute adult poisoning cases admitted to a university hospital in Tabriz, Iran. Hum. Exp. Toxicol. 28, 185–190. http://dx.doi.org/10.1177/0960327108099679.

Jeyaratnam, J., 1990. Acute pesticide poisoning: a major global health problem. World Health Stat. Q. 43, 139–144.

Kastanaki, A.E., Kraniotis, C.F., Kranioti, E.F., Nathena, D., Theodorakis, P.N., Michalodimitrakis, M., 2010. Suicide by pesticide poisoning: findings from the island of Crete, Greece. Crisis 31, 328–334. http://dx.doi.org/10.1027/0227-5910/a000042.

Keugoung, B., Kongnyu, E.T., Meli, J., Criel, B., 2013. Profile of suicide in rural Cameroon: are health systems doing enough? Trop. Med. Int. Health 18, 985–992. http://dx.doi.org/10.1111/tmi.12140.

Khan, M.M., 2007. Suicide prevention in Pakistan: an impossible challenge? J. Pak. Med. Assoc. 57, 478–480.

Khan, M.M., Mahmud, S., Karim, M.S., Zaman, M., Prince, M., 2008. Case-control study of suicide in Karachi, Pakistan. Br. J. Psychiatry 193, 402–405. http://dx.doi.org/10.1192/bjp.bp.107.042069.

Khurram, M., Mahmood, N., 2008. Deliberate self-poisoning: experience at a medical unit. J. Pak. Med. Assoc. 58, 455–457.

Knipe, D.W., Chang, S.-S., Dawson, A., Eddleston, M., Konradsen, F., Metcalfe, C., Gunnell, D., 2017. Suicide prevention through means restriction: impact of the 2008–2011 pesticide restrictions on suicide in Sri Lanka. PLoS One 12, e0172893. http://dx.doi.org/10.1371/journal.pone.0172893.

Kreitman, N., 1976. The coal gas story. United Kingdom suicide rates, 1960-71. Br. J. Prev. Soc. Med. 30, 86–93.

Liu, S., Page, A., Yin, P., Astell-Burt, T., Feng, X., Liu, Y., Liu, J., Wang, L., Zhou, M., 2015. Spatiotemporal variation and social determinants of suicide in China, 2006–2012: findings from a nationally representative mortality surveillance system. Psychol. Med. 45, 3259–3268. http://dx.doi.org/10.1017/S0033291715001269.

Mann, J.J., Apter, A., Bertolote, J., Beautrais, A., Currier, D., Haas, A., Hegerl, U., Lonnqvist, J., Malone, K., Marusic, A., Mehlum, L., Patton, G., Phillips, M., Rutz, W., Rihmer, Z., Schmidtke, A., Shaffer, D., Silverman, M., Takahashi, Y., Varnik, A., Wasserman, D., Yip, P., Hendin, H., 2005. Suicide prevention strategies: a systematic review. JAMA 294, 2064–2074. http://dx.doi.org/10.1001/jama.294.16.2064.

Manuweera, G., Eddleston, M., Egodage, S., Buckley, N.A., 2008. Do targeted bans of insecticides to prevent deaths from self-poisoning result in reduced agricultural output? Environ. Health Perspect. 116, 492–495. http://dx.doi.org/10.1289/ehp.11029.

Mars, B., Burrows, S., Hjelmeland, H., Gunnell, D., 2014. Suicidal behaviour across the African continent: a review of the literature. BMC Public Health 14, 606. http://dx.doi.org/10.1186/1471-2458-14-606.

Mashreky, S.R., Rahman, F., Rahman, A., 2013. Suicide kills more than 10,000 people every year in Bangladesh. Arch. Suicide Res. 17, 387–396. http://dx.doi.org/10.1080/13811118.2013.801809.

Mew, E., Fleischmann, Alexandra Gunnell, D., Padmanathan, PriankaEddleston, Konradsen, Michael, Flemming Phillips, M., 2015. The global distribution of fatal pesticide self-poisoning between 2006 − 2015: systematic review. PROSPERO.

Mohseni Saravi, B., Kabirzadeh, A., Asghari, Z., Reza Zadeh, I., Bagherian Farahabbadi, E., Siamian, H., 2013. Prevalence of Non-drug Poisoning in Patients Admitted to Hospitals of Mazandaran University of Medical Sciences, 2010–2011. Acta Inform. Med. AIM J. Soc. Med. Inform. Bosnia Herzeg. Časopis. Druš. za Med. Inform. BiH. 21, 192–195. http://dx.doi.org/10.5455/aim.2013.21.192-195.

National Crime Records Bureau, 2014. Accidental deaths and suicides in India. New Delhi.

National Crime Records Bureau, 2005. Accidental Deaths and Suicides in India. New Delhi.

National Crime Records Bureau, 2002. Accidental deaths and suicides in India. New Delhi.

National Suicide Registry, 2011. Annual Report for 2009. Kuala Lumpur.

Nguyen, T.V., Dalman, C., Le, T.C., Nguyen, T.V., Tran, N.V., Allebeck, P., 2010. Suicide attempt in a rural area of Vietnam: incidence, methods used and access to mental health care. Int. J. Ment. Health Syst. 4, 3. http://dx.doi.org/10.1186/1752-4458-4-3.

Odabasi, A.B., 2009. The characteristics of suicidal cases regarding the gender. Turk. J. Med. Sci.
Offiah, S., Obiorah, C., 2014. Pattern of suicide in Nigeria: the niger Delta experience. J. Med. Investig. Pract. http://dx.doi.org/10.4314/jomip.v9i1.
Page, A., Liu, S., Gunnell, D., Astell-Burt, T., Feng, X., Wang, L., Zhou, M., 2017. Suicide by pesticide poisoning remains a priority for suicide prevention in China: analysis of national mortality trends 2006–2013. J. Affect. Disord. 208, 418–423. http://dx.doi.org/10.1016/j.jad.2016.10.047.
Patel, V., Ramasundarahettige, C., Vijayakumar, L., Thakur, J.S., Gajalakshmi, V., Gururaj, G., Suraweera, W., Jha, P., 2012. Suicide mortality in India: a nationally representative survey. Lancet 379, 2343–2351. http://dx.doi.org/10.1016/S0140-6736(12)60606-0.
Pearson, M., Zwi, A.B., Buckley, N.A., Manuweera, G., Fernando, R., Dawson, A.H., McDuie-Ra, D., 2015. Policymaking "under the radar": a case study of pesticide regulation to prevent intentional poisoning in Sri Lanka. Health Policy Plan 30, 56–67. http://dx.doi.org/10.1093/heapol/czt096.
Phillips, M.R., Yang, G., Zhang, Y., Wang, L., Ji, H., Zhou, M., 2002. Risk factors for suicide in China: a national case-control psychological autopsy study. Lancet 360, 1728–1736. http://dx.doi.org/10.1016/S0140-6736(02)11681-3.
PRISMA, 2009. PRISMA Checklist [WWW Document]. URL 〈http://prisma-statement.org/〉 (accessed 22 May 2016).
Reportlinker, 2012. Global Agrochemical Industry 2012–2017: Trend, Profit, and Forecast Analysis [WWW Document]. PR Newswire. URL: 〈http://www.prnewswire.com/news-releases/global-agrochemical-industry-2012-2017-trend-profit-and-forecast-analysis-162559196.html〉.
Research and Markets, 2015. Global Pesticide Market - By Regions and Vendors - Market Size, Demand Forecasts, Industry Trends and Updates, Supplier Market Shares 2014-2020 [WWW Document]. AG Prof.
Satar, S., Seydaoglu, G., Akpinar, A., Sebe, A., Karakoc, E., Gumusay, U., Yilmaz, M., Gokel, Y., 2009. Trends in acute adult poisoning in a ten-year period in Turkey: factors affecting the hazardous outcome. Bratisl. lekárske List 110, 404–411.
Shadnia, S., Sasanian, G., Allami, P., Hosseini, A., Ranjbar, A., Amini-Shirazi, N., Abdollahi, M., 2009. A retrospective 7-years study of aluminum phosphide poisoning in Tehran: opportunities for prevention. Hum. Exp. Toxicol. 28, 209–213. http://dx.doi.org/10.1177/0960327108097194.
Shahid, M., Hyder, A.A., 2008. Deliberate self-harm and suicide: a review from Pakistan. Int. J. Inj. Contr. Saf. Promot. 15, 233–241. http://dx.doi.org/10.1080/17457300802149811.
Soltaninejad, K., Faryadi, M., Sardari, F., 2007. Acute pesticide poisoning related deaths in Tehran during the period 2003–2004. J. Forensic Leg. Med. 14, 352–354. http://dx.doi.org/10.1016/j.jflm.2006.12.011.
Tahir, M.N., Akbar, A.H., Naseer, R., Khan, Q.O., Khan, F., Yaqub, I., 2014. Suicide and attempted suicide trends in Mianwali, Pakistan: social perspective. East. Mediterr. Heal. J. 19 (Suppl 3), S111–S114.
The World Bank, 2015. Population, total [WWW Document]. URL 〈http://data.worldbank.org/indicator/SP.POP.TOTL〉 (accessed 18 February 2016).
The World Bank, 2014. World Bank Indic. [WWW Doc.]. 〈http://wdi.worldbank.org/table/3.2〉 (accessed 22 May 2016).
The World Bank, 2013. Fact Sheet: The World Bank and Agriculture in Africa [WWW Document]. URL 〈http://www.fao.org/docrep/015/i2490e/i2490e01b.pdf〉 (accessed 22 May 2016).
Toe, A.M., Ouedraogo, M., Ouedraogo, R., Ilboudo, S., Guissou, P.I., 2013. Pilot study on agricultural pesticide poisoning in Burkina Faso. Interdiscip. Toxicol. 6, 185–191. http://dx.doi.org/10.2478/intox-2013-0027.
Tuan, N. Van, Dalman, C., Thiem, N.V., Nghi, T.V., Allebeck, P., 2009. Suicide attempts by poisoning in Hanoi, Vietnam: methods used, mental problems, and history of mental health care. Arch. Suicide Res. 13, 368–377. http://dx.doi.org/10.1080/13811110903266657.
United Nations, 2017. UN Population Data Search Engine [WWW Document]. URL 〈http://data.un.org/Default.aspx〉 (accessed 22 April 2017).
Vijayakumar, L., Jeyaseelan, L., Kumar, S., Mohanraj, R., Devika, S., Manikandan, S., 2013. A central storage facility to reduce pesticide suicides–a feasibility study from India. BMC Public Health 13, 850. http://dx.doi.org/10.1186/1471-2458-13-850.
World Health Organisation, 2015. Mortality Database: Cause of Death Query online [WWW Document]. URL 〈http://apps.who.int/healthinfo/statistics/mortality/causeofdeath_query/〉 (accessed 20 February 2016).
World Health Organisation, 2014. Preventing suicide: a global imperitive. Geneva.
World Health Organisation, 2016. Safer access to pesticides for suicide prevention: Experiences from community interventions. Geneva http://www.who.int/mental_health/suicide-prevention/pesticides_community_interventions/en/.
World Health Organisation, International Association for Suicide Prevention, 2006. Safer access to pesticides: community interventions. WHO. Geneva, Geneva.
Yip, P.S.F., Caine, E., Yousuf, S., Chang, S.-S., Wu, K.C.-C., Chen, Y.-Y., 2012. Means restriction for suicide prevention. Lancet 379, 2393–2399. http://dx.doi.org/10.1016/S0140-6736(12)60521-2.
Z'gambo, J., Siulapwa, Y., Michelo, C., 2016. Pattern of acute poisoning at two urban referral hospitals in Lusaka, Zambia. BMC Emerg. Med. 16, 2. http://dx.doi.org/10.1186/s12873-016-0068-3.
Zhang, J., Sun, L., Liu, Y., Zhang, J., 2014. The change in suicide rates between 2002 and 2011 in China. Suicide Life. Threat. Behav. 44, 560–568. http://dx.doi.org/10.1111/sltb.12090.