

# Interventions that facilitate sustainable development by preventing toxic exposure to chemicals: an overview of systematic reviews

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## ABSTRACT

**Objective.** To identify interventions that 1) facilitate sustainable development by preventing toxic exposure to chemicals, including pesticides, and 2) have a positive impact on health.

**Methods.** This overview utilized systematic review methods to synthesize evidence from multiple systematic reviews and economic evaluations. A comprehensive search was conducted based on a predefined protocol, including clear inclusion criteria. To be classified as “sustainable” interventions needed to aim (explicitly or implicitly) to 1) have a positive impact on at least two key dimensions of the United Nations integrated framework for sustainable development and 2) include measures of health impact.

**Results.** Thirteen systematic reviews and two economic evaluations met the inclusion criteria. The interventions that were most likely to have a positive impact on health included 1) legislation to ban Endosulfan pesticide to prevent fatal poisonings; 2) testing of drinking water for contamination with arsenic, and dissemination of the results to households; and 3) implementation of organic farming / diet to reduce exposure to pesticides. However, the cost-effectiveness of these three interventions and their impact(s) on health inequalities is not known. Strict enforcement of interventions to reduce lead in houses with children was cost-beneficial. Education and dust control interventions performed by cleaning professionals to reduce blood lead levels in children were ineffective.

**Conclusions.** What is needed now is careful implementation of the interventions whose impacts are likely to be positive. Ineffective interventions need to be replaced with more effective and cost-effective interventions. Finally, more and better-quality research on the prevention of toxic exposure to chemicals is needed to better support policy development.

## Key words

Sustainable development; environmental exposure; chemical compounds; pesticides; health; review; Americas.

Sustainable development is generally thought of as development that balances

social, environmental, and economic objectives or needs. It has been defined as “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (1, p. 41). Prior to the 2012 United Nations (UN) Conference on Sustainable Development held in Rio de Janeiro (commonly referred to as “Rio+20”), the UN System Task Team working on the Post-2015 UN Development Agenda proposed

an integrated framework for sustainable development that would realize the “future we want for all” (2, p. 24). The framework includes the core values of human rights, equality, and sustainability, plus four key dimensions: 1) inclusive social development; 2) inclusive economic development; 3) environmental sustainability; and 4) peace and security. Health is both an outcome of and precondition for all four dimensions of sustainable development.

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Toxic exposure to chemicals, including those in the living environment, can threaten human health. Preventing this exposure is part of the “inclusive social development” dimension of the integrated framework for sustainable development. The known global health burden due to chemicals is considerable. In total for 2004, worldwide, 4.9 million deaths (8.3% of total deaths) and 86 million disability-adjusted life years (DALYs) (5.7% of total DALYs) were attributable to environmental exposure and management of selected chemicals. Of total DALYs for 2004, 70% were attributable to air pollution mixtures, 11% to chemicals in acute poisoning, 11% to long-term effect(s) of single chemicals, and 8% to chemicals in occupational exposures. These results underestimate the total burden of chemicals, as the burden from most chemicals has not yet been assessed (3).

Potential toxic exposure to chemicals from threats to health and national or international security (e.g., chemical weapons or acts of terrorism, or chemical incidents affecting or displacing large populations or contaminating sources of food and/or water, and/or disturbing trade and tourism) can also affect “peace and security.” In addition, the manufacture and use of chemicals can have adverse environmental impacts and is therefore relevant to “environmental sustainability.” Toxic exposure to chemicals in the workplace has implications for the “inclusive economic development” dimension, including impacts on decent work and productive employment. Both environmental and work-related impacts are also determinants of health and therefore have both a direct and indirect impact on health. Toxic exposure to chemicals could also contribute to health inequalities and compromise inclusive economic development, as the risk of being exposed is disproportionately concentrated in populations already in a situation of increased socioeconomic vulnerability (4, 5).

This overview of the systematic review and economic evaluation literature (along with three other, related overviews) was developed by the Pan American Health Organization (PAHO) to inform the development of the new Sustainable Development Goals (SDGs), including but not limited to the provision of evidence for its member states on the possible health impact(s) of policies and

programs in non-health sectors (e.g., agriculture, environment, international development, economic).

The objective of this overview is to use the best available evidence to answer the following question: “What are the interventions that facilitate sustainable development by preventing toxic exposure to chemicals, including pesticides, and have a positive impact on health?” Sub-questions include: 1) “What is their impact on health inequalities?”; 2) “What evidence is there for their cost-effectiveness?”; and 3) “Which dimensions of the integrated framework are affected by the intervention, and how?”

This overview focused on policies and interventions to prevent and manage chemical incidents or emergencies of national or international concern, as covered by the World Health Organization (WHO) International Health Regulations (IHR) 2005 (6). It also aimed to include interventions to prevent and manage toxic exposure to industrial and agricultural chemicals (including pesticides) during their production, and use, including in self-poisoning to commit suicide.

## MATERIALS AND METHODS

This overview 1) used systematic review methodology to locate and evaluate published systematic reviews of interventions and 2) adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (7). A systematic review protocol was written and registered prior to undertaking the searches (8).

### Inclusion criteria for studies

Studies were selected based on the inclusion criteria described below.

**Types of studies.** Studies included systematic reviews of studies of effectiveness, including reviews of randomized controlled trials (individuals or clusters); quasi-randomized controlled trials; controlled before-and-after studies; interrupted time series; and analytic observational studies (cohort, case-control, cross-sectional studies). Economic evaluations (cost-effectiveness, cost-utility, and/or cost-benefit) and systematic reviews of economic evaluations were included.

**Types of participants.** Study participants included individuals, groups, communities, countries, or regions. Studies from both developed and developing countries were included.

**Types of interventions.** Interventions included programs, policies, strategies, legislation, regulation, and courses of action aimed at promoting sustainable development by preventing toxic exposure to chemicals. All relevant interventions related to global public health security (as defined by the core public health capacities of the IHR 2005) with measured (or intended) impact on health were included (6). Interventions at the community or national level that were not within the scope of the IHR 2005 were also included when they included prevention of toxic exposure to industrial and agricultural chemicals (e.g., occupational exposure), including their use in suicide. Only population-level prevention interventions were included (e.g., policy, regulation). Individual-level interventions were excluded (e.g., local-level education and psychosocial interventions). Interventions aimed at reducing air pollution in general were not included. Naturally occurring chemicals (e.g., arsenic and fluoride in water and natural toxins) were not included unless their levels had increased to toxic levels due to industrial or agricultural processes. To be classified as “sustainable” interventions needed to aim (explicitly or implicitly) to have a positive impact on at least two dimensions of the integrated framework (e.g., environmental sustainability and inclusive social development (which includes health) or inclusive economic development and peace and security (but where impact on health was also measured)).

**Types of comparisons.** Comparisons included “no intervention,” “another intervention,” or “current practice.”

**Types of outcome measures.** Primary outcomes included 1) health measures at the level of the individual, group, community, country, region, and/or globally, including disease incidence, prevalence, and burden; mortality (including suicide); morbidity; symptoms and signs of disease; health service use; health-related costs; and health inequalities, including by gender, age, life stage, socioeconomic status, area of residence, etc.; 2) measures

of chemical incident severity or frequency, such as number of chemical incidents and number of individuals affected by the incident; and 3) measures that show reduced risk of toxic exposure to chemicals.

Publications in English, Portuguese, or Spanish and published in the last 17 years (from 1997 to the day of the search) were included. Both grey and peer-reviewed literature were sought and included.

### Sources of systematic reviews and economic evaluations

A comprehensive search of 16 databases and eight websites was conducted. The databases searched for systematic reviews were PubMed; EMBASE®; CINAHL; ASSIA; PsycINFO; ScienceDirect; LILACS; SciELO; GreenFILE; The Cochrane Library (including Cochrane Reviews, the Database of Abstracts of Reviews of Effects (DARE), and the Health Technology Assessment Database (HTA)); The Campbell Library; and Health-Evidence™.

The websites that were searched included specialized sources for systematic reviews and other websites: Effective Public Health Practice Project, Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre), International Initiative for Impact Evaluation (“3ie”), the Sax Institute

Evidence Check Library (for rapid reviews), WHO (including the library database (WHOLIS) and the Institutional Repository for Information Sharing (IRIS)), Google, WHO International Programme on Chemical Safety (IPCS), and United Nations Environment Programme (UNEP) Chemicals and Waste. The reference list of included systematic reviews was also searched.

For economic evaluations, two specialized databases were searched: EconLit (American Economic Association abstracting database) and the NHS Economic Evaluation Database (NHS EED).

### Search strategy

Searches were conducted from 19 to 21 June 2014. Databases were searched using key words from Table 1, searched for in the title and abstract, except when noted otherwise. Key word areas were joined using ‘AND’. Searches were limited to human research with a publication date between 1 January 1997 and the day of the search. A sample search strategy for EMBASE using the Ovid interface (Ovid Technologies, New York, NY, United States) is shown in Table 1. Results were downloaded into the EndNote reference management program (version X7) (Thomson Reuters, New York, NY) and duplicates removed.

### Screening, data collection, and analysis

Searches were conducted and screened according to the selection criteria by one review author (MH). The full text of any potentially relevant papers was retrieved for closer examination. The inclusion criteria were applied to the papers independently by two reviewers (MH and RC for English language papers; MH and AS for Spanish; and AS and LG for Portuguese papers). Disagreements regarding eligibility of studies were resolved by discussion and consensus. All studies that initially appeared to meet the inclusion criteria but on inspection of the full-text paper did not were listed in a table (“Characteristics of excluded systematic reviews”) with the reasons for their exclusion. One reviewer (MH) extracted all relevant data from the included reports using a standard form. A second reviewer (RC) verified the extracted data. Differences were resolved by discussion and consensus. Data/information extracted from systematic reviews included objectives, inclusion criteria for the systematic review, date of search, number of studies included, country or region of included studies, details of interventions studied, the integrated framework for sustainable development dimensions targeted by the individual studies (implicitly or explicitly), summary of findings in relation to health, impact on any of the key

**TABLE 1. Key word areas and sample search strings used to identify studies for an overview of systematic reviews of interventions to prevent toxic exposure to chemicals, 1997–2014**

Key word area	Details
Chemical emergency or incident; toxic exposure to chemicals, including pesticides	<i>chemic* OR CBRN OR pesticide* OR insecticide* OR rodenticide* OR paraquat or organophosphate* OR organophosphorus OR agrochemical* OR arsenic OR asbestos OR benzene OR cadmium OR dioxin* OR lead OR mercury OR Chemical Hazard Release [MeSH Terms] OR Chemical safety [MeSH Terms]</i>
Interventions	<i>program OR policy OR policies OR strategy OR legislation OR law* OR intervention OR technique OR regulation OR procurement OR incentive OR prevention OR surveillance OR monitor*</i>
Outcomes	<i>disease OR injury OR burden OR incidence OR prevalence OR mortality OR morbidity OR suicide* OR health* OR severity OR frequency OR quality OR risk</i>
Sample search string for EMBASE (Ovid interface)	
1. ( <i>chemic* or CBRN or pesticide* or insecticide* or rodenticide* or paraquat or organophosphate* or organophosphorus or agrochemical* or arsenic or asbestos or benzene or cadmium or dioxin* or lead or mercury</i> ).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	
2. ( <i>program or policy or policies or strategy or legislation or law* or intervention or technique or regulation or procurement or incentive or prevention or surveillance or monitor*</i> ).mp.	
3. ( <i>systematic-review or meta-analysis</i> ).mp.	
4. 1 and 2 and 3	
5. ( <i>disease or injury or burden or incidence or prevalence or mortality or morbidity or suicide* or health* or severity or frequency or quality or risk</i> ).mp.	
6. 4 and 5	
7. limit 6 to ( <i>human and yr=“1997–Current”</i> )	

**Source:** Prepared by the authors based on the literature search process.

dimensions of sustainable development, impact on health inequalities, impact on secondary outcomes, impact on human rights, limitations of the systematic review, research gaps, and critical success factors for the interventions.

Findings from the included publications and their methodological quality were synthesized using tables and a narrative summary. Meta-analysis was not possible because included studies were heterogeneous in terms of the type of intervention studied and outcomes measured.

### Assessment of methodological quality

The methodological quality of included systematic reviews was assessed independently by two reviewers using

AMSTAR: A MeaSurement Tool to Assess Reviews (9). For this overview, reviews that achieved AMSTAR scores of 8 to 11 were considered “high-quality;” scores of 4 to 7 “medium-quality;” and scores of 0 to 3 “low-quality.” These cutoffs are commonly used in Cochrane Collaboration overviews. The review quality assessment was used to interpret the results of reviews when synthesized in this overview and in the formulation of conclusions.

## RESULTS

### Search results

Thirteen systematic reviews (from 14 articles) (10–23) and two economic evaluations (24, 25) met the inclusion criteria. The selection process for systematic reviews

and the number of papers found at each stage are shown in Figure 1. The reasons for the exclusion of 40 papers at the full-text stage are shown in [Supplementary Material File 1 \(Table A1a\)](#). The selection process for economic evaluations and the number of papers found at each stage are also shown in Figure 1. Four papers were excluded at the full-text stage because they were not economic evaluations ([Supplementary Material File 1, Table A1b](#)). For one of the economic evaluations (25), a supporting paper (published version of the working paper) (26) was found and used for additional information.

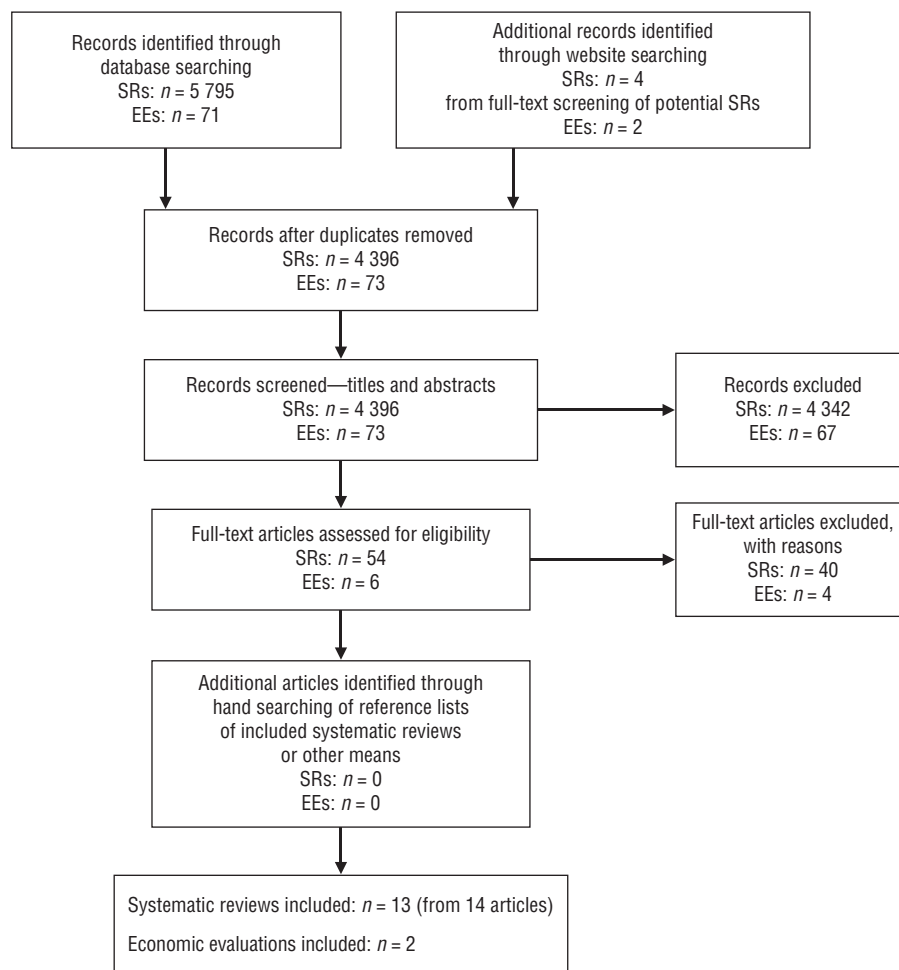
### Characteristics of included studies and quality assessment

The types of interventions studied and their potential connection with the four key dimensions of the integrated framework for sustainable development are shown in Table 2. Further details about the characteristics of the included systematic reviews and economic evaluations can be found in [Supplementary Material Files 2 and 3](#) respectively. AMSTAR scores ranged from 0 to 10, with four systematic reviews rated as “high-quality” (scores between 8 and 11) (15, 16, 19, 23); two rated as “medium-quality” (scores between 4 and 7) (10, 22); and seven rated as “low-quality” (scores between 0 and 3) (11–13, 17, 18, 20, 21). The results of the seven systematic reviews in the latter group are not included in the main findings because their low quality limits the ability to make conclusions about the effectiveness of the interventions they studied. AMSTAR scores for all systematic reviews are shown in [Supplementary Material File 2 \(Table A2a\)](#).

### Effectiveness

In terms of the impact on health, legislation to ban Endosulfan pesticide to prevent fatal poisonings (either intentional or unintentional) (19) was the most promising intervention included in this overview (Table 3). Two other interventions were promising in terms of their potential impact on health due to a reduction in exposure to toxic chemicals (pesticides) or health risk factors (arsenic levels in urine). These included 1) testing of drinking water for contamination with arsenic and dissemination of the results to households (15) and 2) the implementation of organic farming / diet to reduce exposure to

**FIGURE 1. Flow diagram of the number of records identified, included, and excluded in the search for systematic reviews (SRs) and economic evaluations (EEs) of interventions to prevent toxic exposure to chemicals, 1997–2014**



Source: Prepared by the authors based on the study selection process; flow diagram adapted from (7).



**TABLE 2. Interventions to prevent toxic exposure to chemicals that were studied and their potential effects<sup>a</sup> on the key dimensions of the integrated framework, 1997–2014<sup>b</sup>**

Intervention	Number of SRs <sup>c</sup> and EEs <sup>d</sup>	Key dimensions affected				Potential effects
		Econ <sup>e</sup>	Env <sup>f</sup>	Social <sup>g</sup>	P&S <sup>h</sup>	
Household interventions to reduce lead in houses with children: • Education combined with cleaning equipment or supplies • Dust control performed by cleaning professionals • Lead hazard control • Strict enforcement strategy	4 SRs (10, 11, 20, 23); 1 EE (24)	✓	✓	✓	✓	Elevated blood lead concentrations in children can affect cognition (IQ) and thus future productivity (Econ) and health, development, and behavior (Social). Effects on violence (P&S) are also possible. Changes to the levels of lead in the house (e.g., in paint) can affect indoor air (Env).
Policy options for computer monitor disposal to prevent air emissions of lead	1 EE (25)	✓	✓	✓	✓	Lead air emissions lead to higher blood lead concentrations. In children, these can affect cognition (IQ) and thus future productivity (Econ) and health, development, and behavior (Social). Health in adults is also affected. Effects on violence (P&S) are also possible. There is also risk of contamination of soil and water by disposal in uncontrolled solid waste disposal sites, landfills, or recycling areas (Env).
Household interventions to reduce other (non-lead) chemical hazards—radon, volatile organic compounds, pesticides, smoke, and particulate matter	1 SR (11)	✓	✓	✓	X	Exposure to indoor chemical agents has been associated with neurotoxicity and developmental disorders, asthma and other respiratory illnesses, and cancer (Social, Econ). Indoor emissions from burning solid waste also affect Env, as black carbon has a warming effect on climate.
Drinking water tested for contamination (arsenic, feces) and results disseminated to households	1 SR (15)	X	X	✓	✓	Contamination of drinking water is a serious human health hazard (Social) and affects health security and human rights (P&S).
Organic farming / diet to reduce exposure to pesticides	1 SR (22)	✓	✓	✓	✓	Organic farming benefits Env and possibly health (Social). It can also benefit producers (Econ). It is more labor intensive (increased employment), and may also decrease food insecurity (P&S).
Interventions to reduce pesticide overexposure and poisoning: • Safety training • Applicator training and licensure • Field re-entry restrictions • Use of personal protective equipment (PPE) • Use of isolation techniques such as closed tractor cabs • Pesticide handling (mixing, loading, or storage) techniques or procedures • Bio-monitoring programs	1 SR (13)	✓	✓	✓	X	Pesticide use can affect Env; the community's— particularly children's and workers'—health (Social); and potentially workplace productivity (if the worker suffers health problems) (Econ).
Legislation to ban or restrict access to pesticides to prevent suicide	3 SRs (17, 19, 21)	✓	✓	✓	✓	Legislation to ban or restrict access to pesticides and other chemicals could have positive effects on Env; the health of workers, their families, and agricultural communities (Social); and, potentially, the family income of workers (if they die as a result of their work) (Econ). It may also improve health security by decreasing the availability of the toxin in the food chain, and by eliminating transboundary transportation of the chemicals (P&S).
Local public health teams to prevent morbidity and mortality and providing timely and appropriate interventions in organized emergency disaster response to acute nonnatural environmental hazards	1 SR (12)	✓	✓	✓	✓	Acute nonnatural environmental hazards or incidents can displace people, affecting P&S and health (Social). They also disturb the production and/or transport and distribution of goods, and require additional resources (for the response) (Econ). In addition, releases may affect the quality of air, soil, and water bodies (Env).
Chemical (or other) terrorism prevention	1 SR (16)	X	✓	✓	✓	Chemical terrorism affects Env and P&S and can lead to death and injury (Social).
Animals as sentinels of chemical terrorism agents	1 SR (18)	X	✓	✓	✓	Chemical terrorism affects Env and P&S and can lead to death and injury (Social).

**Source:** Prepared by the authors based on overview of systematic reviews.

<sup>a</sup> Negative or positive.

<sup>b</sup> X means no known effect; checkmark means possible impact/connection.

<sup>c</sup> SR: systematic review.

<sup>d</sup> EE: economic evaluation.

<sup>e</sup> Econ: inclusive economic development.

<sup>f</sup> Env: environmental sustainability.

<sup>g</sup> Social: inclusive social development.

<sup>h</sup> P&S: peace and security.

pesticides (22). Insufficient evidence or no evidence of impact on health was found for soil abatement and combination interventions to reduce lead in households with children (23) and in the prevention of chemical or other types of terrorism (16). Two interventions were found to be ineffective: 1) education combined with the

use of cleaning equipment or supplies to reduce lead in households with children (10, 23) and 2) dust control performed by cleaning professionals to reduce lead in households with children (10, 23). The impact of these interventions on health inequalities is not known as none of the included systematic reviews reported it.

**Cost-effectiveness.** A strict enforcement strategy for interventions to reduce lead in households with children was found to be cost-beneficial, but the evidence of its effectiveness came from a retrospective cohort study rather than a systematic review (24). Policy options for increasing proper disposal of computer

**TABLE 3. Interventions studied,<sup>a</sup> quality of the evidence, and results (impact on health and cost-effectiveness), 1997–2014**

Intervention	Type <sup>b</sup> and name of countries	Quality of evidence	Impact on health	Cost-effectiveness
Interventions to reduce lead in houses with children: • Education combined with cleaning equipment or supplies • Dust control performed by cleaning professionals • Soil abatement	Developed (United States, Australia)	1 high-quality SR (including 14 RCTs <sup>c</sup> ) and 1 medium-quality SR (including 4 RCTs)	Household educational or dust control interventions are ineffective in reducing blood lead levels in children. Insufficient evidence to draw conclusions about the effectiveness of soil abatement or combination interventions (10, 23)	— <sup>d</sup>
Strict enforcement strategy	Developed (United States)	1 EE; evidence of effectiveness came from a retrospective cohort study	—	Strict enforcement prevented additional cases of elevated blood lead concentration ( $\geq 10 \mu\text{g/dL}$ ), resulting in US\$ 45 360 savings from decreased medical and education costs and increased productivity for protected children (24)
Policy options for computer monitor disposal to prevent air emissions of lead	Developed (United States)	1 EE; evidence of effectiveness came from sales and survey data	—	For the stock of monitors disposed of in the United States in 1998, policies restricting or banning some popular disposal options would increase disposal costs from about US\$ 1 per monitor to between US\$ 3 and US\$ 20 per monitor. In all cases the costs of the policies exceed the value of the avoided health effects of cathode ray tube disposal (25)
Drinking water tested for contamination with arsenic and results disseminated to households	Developing (Bangladesh)	1 high-quality SR (including 3 cohort studies and 1 randomized trial—all with moderate to high risk of bias)	Evidence is equivocal. The strongest evidence was for source switching, with 4 studies reporting higher rates of switching (26%–52%) in households previously drinking from contaminated wells (3 at statistically significant levels). One study measured health effects and reported a significant reduction of urinary arsenic among those using unsafe wells at baseline of 109 versus 6.2 m/L, standardized mean difference of 20.42 (CI <sup>e</sup> : 20.45 to 20.35) between groups, favoring those who had been informed that their wells were unsafe (15)	—
Organic farming / diet to reduce exposure to pesticides	Developed (United States, Europe)	1 medium-quality SR (including 17 controlled studies in humans and 223 studies of nutrient and contaminant levels in foods—fair quality)	No evidence of impact on health but may reduce exposure to pesticide residues and antibiotic-resistant bacteria. Conventional produce has a 30% higher risk for pesticide contamination than organic produce (risk difference, 30% (CI: 37% to –23%)). Organic chicken and pork may reduce exposure to antibiotic-resistant bacteria (22)	—
Legislation to ban Endosulfan pesticide to prevent fatal poisonings (includes suicide)	Developing (Sri Lanka)	1 high-quality SR (evidence for this intervention came from 1 interrupted time series study)	Legislation to ban Endosulfan pesticide increased the level of fatal poisonings immediately after the introduction with an effect size of 2.20 (CI: 0.97 to 3.43) but led to a decrease in the trend of poisonings over time with an effect size of –2.15 (CI: –2.64 to –1.66) (19)	—
Chemical (or other) terrorism prevention	Developed (Israel, Spain, United States)	1 high-quality SR (including 7 interrupted time series or intervention studies with comparison)	No studies looked specifically at chemical terrorism. There is almost a complete absence of high-quality scientific evaluation evidence on counter-terrorism strategies. What evidence there is does not indicate consistently positive results—some counter-terrorism interventions show no evidence of reducing terrorism and may even increase the likelihood of terrorism and terrorism-related harm (16)	—

**Source:** Prepared by the authors based on overview of systematic reviews.

<sup>a</sup> Only interventions with economic evaluations (EEs) and/or medium- or high-quality systematic reviews (SRs) are included here.

<sup>b</sup> Developing or developed.

<sup>c</sup> RCT: randomized controlled trial.

<sup>d</sup> Not known (i.e., no included EEs or SRs addressed the question).

<sup>e</sup> CI: 95% confidence interval.

monitors to prevent air emissions of lead were not found to be cost-beneficial, but the evidence of effectiveness for these analyses came from sales data, surveys, and assumptions and is thus weak (25).

### Integrated framework dimensions affected by the interventions

Given the study inclusion criteria, all interventions reported on here aimed to have a positive impact on inclusive social development (which includes health). Most interventions also aimed to have a positive impact on environmental sustainability, peace and security, and inclusive economic development. However, only one of the systematic reviews reported outcomes relevant to dimensions other than the social dimension (16). Lum et al. found that some counter-terrorism interventions may even increase the likelihood of terrorism and terrorism-related harm (16). Given that no chemical terrorism prevention studies were found for this systematic review, it is not possible to know whether that finding also applies to chemical terrorism.

## DISCUSSION

Three interventions were identified as being promising in terms of their potential impact on health. These included 1) legislation to ban Endosulfan pesticide to prevent fatal poisonings (based on one high-quality systematic review); 2) testing of drinking water for contamination with arsenic and dissemination of the results to households (based on one high-quality systematic review); and 3) the use of organic farming / diet to reduce exposure to pesticides (based on one medium-quality systematic review). Their cost-effectiveness is not known.

Education and dust control interventions performed by cleaning professionals to reduce blood lead levels in children were found to be ineffective (based on one medium- and one high-quality systematic review). A strict enforcement strategy for interventions to reduce lead in households with children was found to be cost-beneficial (based on one economic evaluation).

The fact that regulation is an effective policy for reducing the risks of lead exposure is not new. One of the most successful interventions to reduce the

public health risk of lead exposure was the elimination of lead in gasoline, as blood lead levels dropped systematically and significantly after the intervention (27).

### Strengths and limitations

A key strength of this overview was the use of high-quality systematic review methodology that included the consideration of the scientific quality of the selected studies when formulating conclusions. A meta-analysis was not possible due to the heterogeneity of the intervention types and populations studied in the included systematic reviews. As a result, publication bias could not be assessed quantitatively in this overview, and no clear methods are available for assessing publication bias qualitatively (28).

A significant limitation of this overview was the low quality of the systematic reviews found on the prevention of toxic exposure to chemicals, with seven of the 13 included systematic reviews judged as “low-quality” based on the AMSTAR criteria (11–13, 17, 18, 20, 21).

### Implications for policy

The strongest evidence found in this overview was for interventions designed to reduce lead in households with children—the systematic reviews that covered them were of medium to high quality, based on the AMSTAR criteria, and the included research used the strongest study design available (randomized controlled trials) (10, 23). This did not help clarify the way forward in terms of policy-making, however, because the outcomes were negative: the evidence clearly indicated that household dust control interventions are ineffective in reducing blood lead levels in children (10, 23). The authors of the systematic reviews suggest that while reduction in lead-contaminated house dust may be needed to reduce or prevent childhood lead exposure, it is not sufficient. It may be necessary to eliminate the source of the lead exposure by removing or eliminating lead-based paint and other residential lead hazards as well as sources outside the home (23). This finding is supported by the cost-benefit analysis that showed that a strict enforcement strategy was effective and saved money (most likely due to the removal of the lead-based paint) (24, 29). These results

suggest the need for additional testing of lead hazard control interventions because the studies done to date are insufficient to allow conclusions to be drawn (23).

### Sectors involved

An original aim of this overview was to determine which sectors the health sector should engage with in order to prevent toxic exposure to chemicals. However, this question could not be answered as none of the included reviews specified the sectors involved in implementation of the interventions studied. To enable discussion and policy development related to this issue, the reviewers deduced which sectors were involved based on their experience in policy development and knowledge of the area of prevention of toxic exposure to chemicals (Table 4). The relevant sectors vary according to the intervention and most commonly include the health and environment sectors.

### Implications for research

More research is needed on the interventions for which no systematic reviews or economic evaluations were found. These include 1) regulatory or policy interventions to prevent chemical releases arising from technological incidents or natural disasters; 2) regulations on chemicals in the IHR; 3) various international agreements on chemical safety (e.g., the Rotterdam or Basel Conventions) (30, 31); and 4) regulatory or policy interventions to reduce the toxicity of pesticides. This may require more primary studies, but until a systematic review is attempted it is difficult to know. Better-quality systematic reviews are also required for the interventions for which only low-quality reviews were available. Furthermore, the impact on health inequalities needs to be assessed in both primary studies and systematic reviews for all potential interventions.

Based on the systematic reviews, more primary studies are needed on 1) soil abatement and other lead hazard control interventions; 2) community-level interventions on dissemination of water contamination data; 3) regulatory interventions to reduce toxic exposure to pesticides; and 4) interventions for the prevention, detection, and response to chemical terrorism. Given the quality of the literature on the prevention of toxic exposure

**TABLE 4. Potential sectors involved in interventions to prevent toxic exposure to chemicals, 1997–2014**

Intervention	Health	Environment	Housing	Agriculture	International development <sup>a</sup>	Other
Household interventions to reduce lead in houses with children: • Education combined with cleaning equipment or supplies • Dust control performed by cleaning professionals • Lead hazard control • Strict enforcement strategy	✓	✓	✓			Education
Policy options for computer monitor disposal to prevent air emissions of lead	✓	✓			✓	Police/Justice Multilateral agreements to prevent export and/or import of electronic waste
Drinking water tested for contamination (arsenic, feces) and results disseminated to households	✓	✓	✓		✓	Secretary or department or Agency of Internal Affairs; development bank (national or international)
Organic farming / diet to reduce exposure to pesticides	✓	✓		✓		Economic; national or international development bank
Suicide prevention (legislation to ban or restrict access to pesticides)	✓	✓		✓		External Affairs (for regional and subregional economic agreements)
Chemical (or other) terrorism prevention						Defense; Homeland Security; Finance; Aviation; Diplomacy

**Source:** Prepared by the authors based on their experience in policy development and knowledge of the area.

<sup>a</sup> This sector includes both government and nongovernment organizations that tackle issues such as economic, health, and environmental development on an international scale.

to chemicals, better-quality research is needed, including stronger study designs, the use of suitable comparison groups, and agreed-upon outcome measures.

## Conclusions

What is needed now is careful implementation of the interventions most likely to have positive impacts, based on the evidence, such as legislation to ban Endosulfan. On the other hand, interventions found to be ineffective, such as education and dust control performed by cleaning professionals to reduce blood lead levels

in children, need to be replaced with more effective and cost-effective interventions. The potential impact on health inequalities must be considered and measured in future primary studies and systematic reviews. It is clear that more and better-quality research on the prevention of toxic exposure to chemicals is needed to better support policy development. Given the high burden of disease due to toxic exposure to chemicals, and its potential impact on other key dimensions of the UN's integrated framework for sustainable development, it is important that this research be carried out as soon as possible.

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## RESUMEN

### Intervenciones que facilitan el desarrollo sostenible al prevenir la exposición tóxica a los productos químicos: síntesis de revisiones sistemáticas

**Objetivo.** Señalar aquellas intervenciones que: 1) faciliten el desarrollo sostenible al prevenir la exposición tóxica a los productos químicos, incluidos los plaguicidas; y 2) tengan una repercusión positiva sobre la salud.

**Métodos.** Mediante la metodología de revisión sistemática se sintetizaron los datos probatorios de varias revisiones sistemáticas y evaluaciones económicas. Se realizó una búsqueda exhaustiva siguiendo un protocolo predefinido con criterios de inclusión concretos. Para considerarse “sostenibles”, las intervenciones debían perseguir los siguientes objetivos (explícitos o implícitos): 1) influir de forma positiva sobre al menos dos dimensiones clave del marco integrado de las Naciones Unidas para el Desarrollo Sostenible; y 2) incluir medidas que repercutan en la salud.

**Resultados.** Cumplieron los criterios de inclusión 13 revisiones sistemáticas y dos evaluaciones económicas. Las intervenciones con mayores probabilidades de influir positivamente en la salud son: 1) la prohibición por ley de los plaguicidas de endosulfán para prevenir las muertes por intoxicación; 2) los análisis del agua potable para detectar la contaminación por arsénico y la comunicación de los resultados a los hogares; y 3) la implantación de la agricultura o la alimentación orgánicas para reducir la exposición a los plaguicidas. Sin embargo, no se conoce la rentabilidad de estas tres intervenciones ni su repercusión sobre las desigualdades en la salud. La aplicación estricta de las intervenciones para reducir el plomo en los hogares con niños resultó rentable. Por el contrario, fueron ineficaces las intervenciones educativas y de desempolvado, a cargo de profesionales de la limpieza, para reducir los niveles de plomo en la sangre de los niños.

**Conclusiones.** Es conveniente aplicar correctamente las intervenciones que tienen mayor probabilidad de generar repercusiones positivas, en tanto que las intervenciones ineficaces deben sustituirse por otras más eficaces y rentables. Se necesitan más investigaciones y de mejor calidad sobre la prevención de la exposición tóxica a los productos químicos, para mejorar las bases sobre las cuales sustentar las correspondientes políticas.

### Palabras clave

Desarrollo sostenible; exposición a riesgos ambientales; compuestos químicos; plaguicidas; salud; revisión; Américas.