Original Article
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Medical Journal of the Islamic Republic of Iran (MJIRI)
Iran University of Medical Sciences

Trends in health burden of untreated water and insanitary environments in Iran, 1990-2010: Findings from the global burden of disease study 2010

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Received: 10 October 2015 Accepted: 25 September 2016 Published: 15 October 2016

Abstract

Background: Water, sanitation and hygiene have a very important role in public health. Poor sanitation is the cause of water contamination, which causes many types of diseases. The aim of this paper was to present the attributable death and disability adjusted life year (DALYs) of untreated water and insanitary environments from 1990 to 2010 in Iran.

Methods: In the Global Burden of Disease 2010 study, using the comparative risk assessment, the proportion of death and DALYs attributable to untreated water source and insanitary environment has been calculated in 1990 to 2010. The certain outcomes were intestinal infectious diseases for both untreated water source and insanitary environments**.** Estimated attributable deaths and DALYs were reported with 95% uncertainty interval (UI).

Results: DALY number for untreated water source and insanitary environments was 5838 (95% UI: 198-14837) in 1990, which decreased to 326 (95% UI: 9-863) in 2010 and the percent of decrease was 94.42%. In addition, DALY rate was 5667 (95% UI: 192-14402) DALY per 100,000 in 1990, which decreased to 453 (95% UI: 13-1199) DALY per 100,000 in 2010 and the percent of the reduction was 92.01%. The greatest percentage of decrease in the attributed number of deaths was also found in the late neonatal age group (95.45%).

Conclusion: A significant decrease has occurred in a number of DALYs and deaths between 1990 and 2010, which was attributed to the development of new water systems and environmental sanitations in Iran.

Keywords: Water, Insanitary Environments, Disability Adjusted Life Year, Burden of Diseases, Iran.

Cite this article as: Ebrahimi A, Mahdavi M, Ghasemian A, Poursafa P, Sharifi F, Mohammadi R, Nejatifar M, Amin MM, Asayesh H, Safiri S, Ansari H, Qorbani M. Trends in health burden of untreated water and insanitary environments in Iran, 1990-2010: Findings from the global burden of disease study 2010. *Med J Islam Repub Iran* 2016 (15 October). Vol. 30:424.

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Introduction

Water is crucial for all aspects of life. Failure to ensure drinking-water safety may expose the community to the risk of outbreaks of intestinal and other infectious diseases. Water-borne diseases are caused by ingestion of contaminated water with pathogens contained in human or animal excreta. The disease burden of unsafe water, sanitation and hygiene (WSH) was first estimated at a global level in 1990 (1). More recently, the impact of WSH on the disease has been reassessed in a more comprehensive way (2), which estimated that almost one tenth of the global burden of disease could be attributed to water, sanitation and hygiene. Poor sanitation is the cause of water contamination, which causes many types of diseases. If sewage treatment is not appropriate, water related diseases would spread to the human environments.

Diseases associated with untreated water, poor sanitation and hygienic conditions comprise on average 6-7% of the annual mortality in developing countries (3). Some researches suggest that WSH interventions are effective and capable of delivering large health benefits to target populations (4,5). Prüss et al. estimated the disease burden from water, sanitation and hygiene to be 4.0% of all deaths and 5.7% of the total disease burden occurring worldwide, taking into account diarrheal diseases, schistosomiasis, trachoma, ascariasis, trichuriasis, and hookworm disease. (6). Most water-borne diseases cause diarrheal illness. Access to safe drinking water, basic sanitation and proper hygiene could not only prevent diarrheal diseases by nearly 90% (7) but may also lead to improved health, poverty reduction and socio-economic development.

Owing to the increased attention to the impact of environmental pollutants on human health, the environmental health risk assessment has gradually become a necessary approach before risk control and risk management (8,9). Therefore, with regards to the environmental pollution effect on health, the adoption of quantifiable indicators, such as the disability adjusted life year (DALYs), is necessary for the assessment of health impact caused by environmental contaminants (10).

DALYs has been widely used since 1990s to assess global or regional burden of diseases. Many environmental pollutants are hazardous to human health, so DALYs is recognized as an indicator to quantify the health impact of these pollutants related to disease burden (11). DALYs measure the population impact of specific health conditions, accounting for both premature death and morbidity. In addition, environmental risk factors play an important role in the burden of disease, both globally and nationally (12). As a disease burden indicator, DALYs combines the estimation of time lived with disability and time lost due to premature mortality with adjustment by a set of social preference values (13). WHO and World Bank developed DALYs to quantify the disease burden and injury on human populations in the Global Burden of Disease (GBD) study (14).

One of the most important advantages of using the DALYs is its aggregation of different impacts on the quality and quantity of life and its focus on actual outcomes rather than potential risks, so it supports rational public health priority setting. DALYs can be used to define tolerable burden of disease and the related risk (15). Exposure to contaminants may also cause health loss; DALYs was used to quantify the impacts of this environmental pollution (16-19). The aim of this paper was to present the global assessment of untreated water and insanitary environment attributable death and DALYs by sex and age from 1990 to 2010 for Iran. The impact of the development of water and wastewater treatment plants, water distribution systems and sewerage collection systems on burden of disease and the amount of DALYs number were also investigated over this period in Iran.

Methods

The GBD study in 2010 was a comprehensive effort with a standard basis and structure of collecting data, modeling, and processing estimations, which are explained elsewhere (3,20-26). The data and methods used for a wide set of risk factors to compute global and regional comparative risk assessment of death and disease burden attributable to particular defined risk factors such as untreated water and sanitation are also described in detail (3).

There were five main steps for estimation of disease burden due to risk factors according to the basic approach of the GBD study in 2010. In the first step, risk–outcome pairs were selected to enter the analysis based on the criteria for causal association. The definition of untreated water source was "proportion of households using an unimproved water source (unprotected wells or springs, vendor-provided water, tanker trucks, surface water, and other unspecified sources)", and insanitary environment was defined as "proportion of households using unimproved sanitation (traditional latrines, open latrines without squatting slabs, bucket latrines, hanging latrines, open defecation or no facilities, and other unspecified facilities). The certain outcomes were intestinal infectious diseases for both unimproved water source and unimproved sanitation (3).

Second, the distribution of exposure to each risk factor was estimated by means of doing a systematic search to identify published and unpublished data sources. Population surveys and censuses were the main data sources for untreated water source as well as unimproved sanitation (3). Statistical models were developed to use the existing data for exposures in countries for several years and for sex and different age groups to generate a complete and comprehensive dataset of exposure distributions. The exposure estimation method for unimproved water source and unimproved sanitation was Spatiotemporal Gaussian process regression (27-29). Extensive ranges of covariates originating from covariates in databases generated at the Institute for Health Metrics and Evaluation (IHME) for the GBD 2010 were defined, and the analysis considered important study characteristics to estimate the distribution of exposure to risk factors (3).

In the third step, effect size per unit of exposure for each risk-outcome pair was assessed. The source of relative risk to provide effect sizes for untreated water source and insanitary environment was based on new meta-analysis. The epidemiological evidence for the effects of water and sanitation was revised by reviewing the relation between water, sanitation and hygiene and diarrhea, regarding previous reviews (17,29,30,32) and a meta-regression was done for studies, which was designed to adjust for intervention and baseline group characteristics (3).

Using the theoretical-minimum-risk exposure distributions for alternative comparison was the next step. For untreated water source and unimproved sanitation, the theoretical-minimum-risk exposure distributions were as follows: "All households use a safe water source (household connection, a public tap or standpipe, a tube well or borehole, a protected well or spring, or rainwater collection), and "All households use improved sanitation (public sewers, septic systems, flush or pour-flush facilities, ventilated improved latrines, simple pit latrines with squatting slabs, and composting toilets)", respectively.

Finally, mortality and disease burden attributable to risk factors (population attributable fraction) were calculated through comparing the current distribution of exposure to the theoretical minimum risk exposure distribution for each year, sex, age group and cause. Uncertainty in the estimates was also assessed by simulation analysis to take 1000 draws from the posterior distribution of exposure, relative risk, and each related outcome for each country, year, sex and age. At the end, the mean deaths and DALYs caused by each risk factor and the mean rank for the risk factors in the ranking list were calculated (3). Uncertainty in the exposure estimates, relative risks, theoretical minimum risk distributions and uncertainty in the relevant outcome rates were distributed into the final estimates.

Results

There was a significant decline in DALYs number and DALYs rate attributable to untreatedwater and insanitary environment from 1990 to 2010. The highest percentage of decrease was demonstrated in the late neonatal age group. The number of DALYs decreased (94.42%) from 5,838 (95% UI: 198-14,837) in 1990 to 326 (9-863) in 2010. In addition, the rate of DALYs declined (92.01%) from 5,667 (95% UI: 192-14,402) per 100,000 in 1990 to 453 (13-1,199) per 100,000 in 2010. There was also 75.0% reduction in the age-standardized DALYs rate per 100,000 population over this period (Table 1).

The greatest percentage of decrease in the attributed number of deaths was also found in the late neonatal age group (95.45%), which was 66 (95% UI: 2-169) in 1990 and declined to 3 (95% UI: 0-9) in 2010. The age standardized death rate per 100,000 population decreased 100% as well as death rate in some age groups such as 1-4 years and 50-69 years (Table 2).

Years life lost (YLLs) number and years lived with disability (YLLs) rate decreased over this period in all age groups due to upgrading water supply systems and environmental sanitation. The highest decrease was also observed in the age group of late neonatal. The number of YLLs declined (95.43%) from 5,694 (95% UI: 191-14,553) in 1990 to 260 (7-744) in 2010, and the rate of YLLs decreased (93.47%) from 5,527 (95% UI: 185-14,126) per 100,000 in 1990 to 361 (10 -1,034) per 100,000 in 2010. Furthermore, the decrease in the age standardized YLLs rate per 100,000 population was 84.09% (Table 3).

The highest percentage of decrease in YLDs number and YLDs rate due to untreated water and insanitary environment was found in the age group of 5-14 years, 59.98% and 41.67%, respectively. The remarkable point was that the number of YLDs increased in the age group of 15-49 years and higher, while the rate of YLDs decreased in all age groups. The age stand-

Table 1. DALYs Rate and Number Attributed to Unimproved Water and Sanitation in Iran in 1990 and 2010

Ages	Number of DALYs			Rates of DALYs (per 100,000)		
	1990	2010	%Δ[1]	1990	2010	%Δ[1]
Early Neonatal	2,706[95-6,951]	221[6-625]	-91.83	7,799[274-20,032]	913[23-2,586]	-88.29
Late Neonatal	5,838[198-14,837]	326[9-863]	-94.42	5,667[192-14,402]	453[13-1,199]	-92.01
Post Neonatal	44,026[1,341-106,742]	3,855[109-10,009]	-91.24	2,661[81-6,451]	335[10-870]	-87.41
1 to 4	27,186[964-62,117]	5,178[131-12,475]	-80.95	370[13-845]	106[3-255]	-71.35
Under 5	79,756[2,588-182,498]	9,581[264-22,877]	-87.99	873[28-1,997]	156[4-373]	-82.13
5-14 years	6,223[187-14,744]	2,025[53-5,125]	-67.46	39[1-93]	19[0-47]	-51.28
15-49 years	5,056[162-12,193]	5,625[158-13,651]	11.25	21[1-51]	12[0-30]	-42.86
50-69 years	1,887[80-4,280]	1,187[34-2,765]	-37.1	38[2-85]	14[0-32]	-63.16
70+ years	810[29-1,814]	693[20-1,587]	-14.44	86[3-192]	26[1-60]	-69.77
All Ages	93,731[3,116-210,689]	19,111[509-44,603]	-79.61	171[6-384]	26[1-60]	-84.8
Age-standardized	-------------------	--------------------	-----------	108[4-243]	27[1-63]	-75

DALY: Disability adjusted life year, [1] Between 1990 and 2010

Table 2. Deaths Rate and Number Attributed to Unimproved Water and Sanitation in Iran in 1990 and 2010

Ages	Number of Deaths			Rates of Deaths(per 100,000)		
	1990	2010	%Δ[1]	1990	2010	%Δ[1]
Early Neonatal	31[1-80]	2[0-7]	-93.55	89[3-230]	10[0-27]	-88.76
Late Neonatal	66[2-169]	3[0-9]	-95.45	64[2-164]	4[0-12]	-93.75
Post Neonatal	487[15-1,183]	33[1-88]	-93.22	29[1-71]	3[0-8]	-89.66
1 to 4	224[7-548]	21[1-55]	-90.63	3[0-7]	0[0-1]	-100
Under 5	808[25-1,844]	59[2-152]	-92.7	9[0-20]	1[0-2]	-88.89
5-14 years	57[2-142]	17[0-48]	-70.18	0[0-1]	0[0-0]	..
15-49 years	52[2-137]	51[1-142]	-1.92	0[0-1]	0[0-0]	..
50-69 years	49[2-114]	17[0-41]	-65.31	1[0-2]	0[0-0]	-100
70+ years	53[2-121]	37[1-89]	-30.19	6[0-13]	1[0-3]	-83.33
All Ages	1,019[33-2,284]	180[5-438]	-82.34	2[0-4]	0[0-1]	-100
Age-standardized	-------------------	--------------------	-----------	1[0-3]	0[0-1]	-100

[1] Between 1990 and 2010

Table 3. YLLs Rate and Number Attributed to Unimproved Water and Sanitation in Iran in 1990 and 2010

Ages	Number of YLLs			Rates of YLLs(per 100,000)		
	1990	2010	%Δ[1]	1990	2010	%Δ[1]
Early Neonatal	2,658[92-6,876]	199[5-567]	-92.51	7,661[265-19,816]	822[21-2,347]	-89.27
Late Neonatal	5,694[191-14,553]	260[7-744]	-95.43	5,527[185-14,126]	361[10-1,034]	-93.47
Post Neonatal	41,787[1,259-101,490]	2,823[88-7,597]	-93.24	2,525[76-6,133]	246[8-661]	-90.26
1 to 4	18,801[626-45,955]	1,727[44-4,620]	-90.81	256[9,-25]	35[1-94]	-86.33
Under 5	68,941[2,129-157,387]	5,008[143-12,948]	-92.74	754[23-1,722]	82[2-211]	-89.12
5-14 years	4,383[139-10,995]	1,289[27-3,675]	-70.59	28[1-69]	12[0-34]	-57.14
15-49 years	3,018[116-7,963]	2,929[68-8,138]	-2.95	13[0-33]	6[0-18]	-53.85
50-69 years	1,248[51-2,905]	454[11-1,134]	-63.62	25[1-58]	5[0-13]	-80
70+ years	651[22-1,509]	382[10-904]	-41.32	69[2-160]	14[0-34]	-79.71
All Ages	78,242[2,488-176,979]	10,062[273-25,471]	-87.14	143[5-323]	14[0-34]	-90.21
Age-standardized	-------------------	--------------------	-----------	88[3-196]	14[0-36]	-84.09

YLL: Years life lost, [1] Between 1990 and 2010

Table 4. YLDs Rate and Number Attributed to Unimproved Water and Sanitation in Iran in 1990 and 2010

Ages	Number of YLDs			Rates of YLDs(per 100,000)		
	1990	2010	%Δ[1]	1990	2010	%Δ[1]
Early Neonatal	48[2-115]	22[1-56]	-54.17	138[5-330]	91[3-234]	-34.06
Late Neonatal	144[5-367]	66[2-172]	-54.17	140[5-356]	92[3-239]	-34.29
Post Neonatal	2,239[82-5,539]	1,032[28-2,601]	-53.91	135[5-335]	90[2-226]	-33.33
1 to 4	8,385[287-20,403]	3,451[96-8,438]	-58.84	114[4-278]	71[2-172]	-37.72
Under 5	10,816[365-25,808]	4,572[133-11,332]	-57.73	118[4-282]	74[2-185]	-37.29
5-14 years	1,839[65-4,321]	736[23-1,888]	-59.98	12[0-27]	7[0-17]	-41.67
15-49 years	2,038[79-4,551]	2,696[83-6,662]	32.29	9[0-19]	6[0-15]	-33.33
50-69 years	639[25-1,444]	734[22-1,810]	14.87	13[1-29]	8[0-21]	-38.46
70+ years	158[6-361]	311[9-776]	96.84	17[1-38]	12[0-29]	-29.41
All Ages	15,490[553-36,631]	9,049[275-22,109]	-41.58	28[1-67]	12[0-30]	-57.14
Age-standardized	-------------------	--------------------	-----------	20[1-47]	13[0-32]	-35

YLD: Years lived with disability, [1] Between 1990 and 2010

ardized YLDs rate per 100,000 population also decreased 35.00% (Table 4).

Table 5 demonstrates the percentage of DALYs, deaths, YLLs and YLDs attributed to untreated water and unimproved sanitation to total DALYs, deaths, YLLs and YLDs in Iran, which decreased significantly from 1990 to 2010.

Discussion

Recent World Health Organization (WHO) estimates for children (0–14 years) put the annual global diarrheal death toll at over 1.8 million far in excess of the toll for tuberculosis (81,000), malaria (844,000) and HIV/AIDS (302,000) put together (WHO 2008a). In addition, it has been estimated that 50% (range 39–61%) of the malnutrition (i.e. under nutrition), burden of disease alone is attributable to the environment, mainly because of insufficient or substandard water supply systems and poor environmental sanitation provision (33). WHO estimates of diarrheal mortality were changed to DALYs using standard formulas from the global burden of disease study (34). According to Table 1, a significant decease has occurred in the number and rate of DALYs between 1990 and 2010 due to the development of new water systems and environmental sanitations of urban and rural areas in Iran. However, the number of DALYs increased 11.25% in 15-49 age group. Annette Prüss et al. estimated the disease burden from water, sanitation and hygiene to be 4.0% of all deaths and 5.7%

Table 5. The Percentage of Total DALYs, Deaths, YLLs and YLDs due to Unimproved Water and Sanitation in Iran from 1990 to 2010

In all ages, all causes and both genders	1990	2010
DALYs	0.43[0.01-0.99]	0.1[0-0.22]
Deaths	0.32[0.01-0.73]	0.05[0-0.13]
YLLs	0.49[0.02-1.14]	0.1[0-0.24]
YLDs	0.27[0.01-0.61]	0.1[0-0.24]

DALY:Disability adjusted life year; YLL: Years life lost; YLD: Years lived with disability

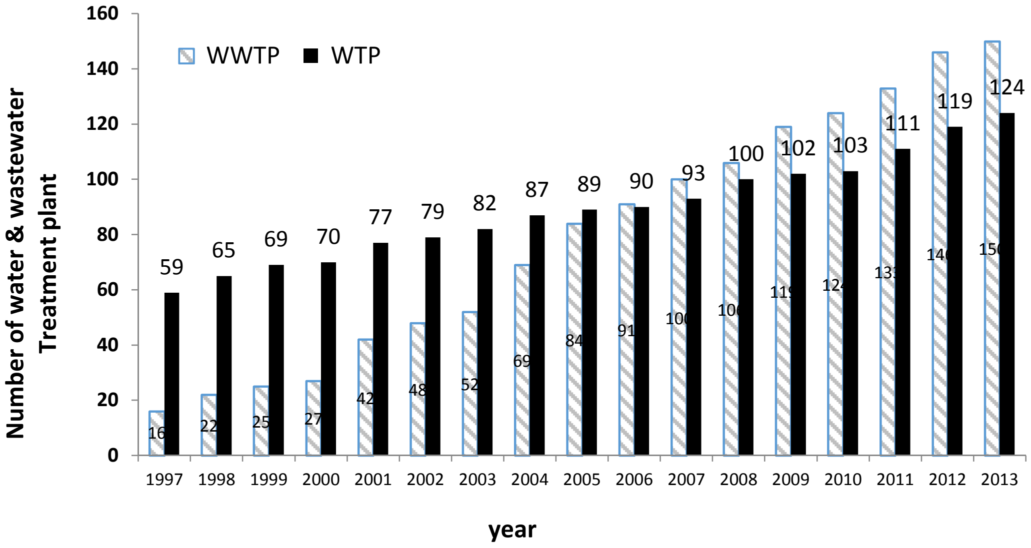

Fig.1. The Number of Constructed Water and Wastewater Treatment Plants in Iran from 1997 to 2013

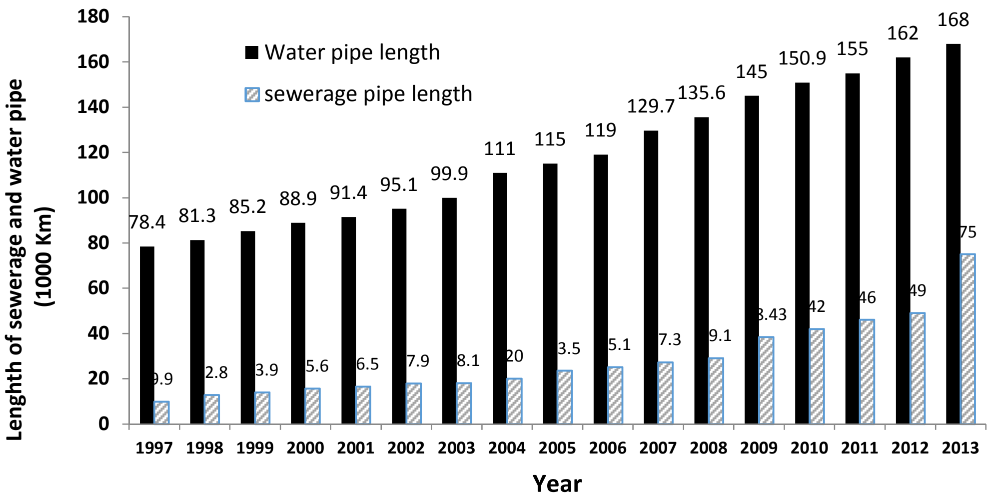

Fig. 2. Development of Sewerage Pipeline and Water Distribution Systems Length from 1997 to 2013

of the total disease burden (in DALYs) worldwide taking into account diarrheal diseases, schistosomiasis, trachoma, ascariasis, trichuriasis and hookworm disease (6).

According to the results of Table 2, deaths rate and number attributed to water supply development and environmental sanitation decreased from 1990 to 2010. One of the reasons for this reduction may be due to the development of water and wastewater treatment plants by water and wastewater company in Iran. Figure 1 shows the progress in construction of water and wastewater treatment plants in Iran. Up to 1997, this country had only 16 wastewater treatment plants (WWTPs), so most of the wastewater discharged to the environment and water bodies without any treatment. At 2013, this number reached to 150 WWTPs, so too much proportion of the wastewater was treated. Consequently, pollution of water bodies and reservoir waters decreased (Table 2).

Quality of consuming water is another important parameter in reduction of DALYs that have been considered in the period of 1997-2010. In 1997, only in a few big province centers, such as Tehran, Isfahan, Mashhad, Tabriz and Shiraz, the municipal drinking water resources were treated by conventional water treatment (coagulation, flocculation, slow/rapid sand filters and chlorination). In other regions, the manual chlorination was probably the only treatment technology for potable waters. However, in 2010, the number of cities with water treatment plant was raised to 124 plants (Fig. 1). In these cities, conventional treatment applied for water treatment. Even in some rural communities, a central water treatment plant is constructed and operated for delivery of finished water to cover populations. DALYs or disease incidence rates can be used as a measure for disease burden associated with known levels of risk for a direct comparison between different risk-reduction strategies . Another reason for the reduction in DALYs number is attributed to the development of water distribution systems and sewerage pipelines. These two parameters have a very important role in prevalence of some diseases that are transmitted by water consumption and pollution. In 1997, only a few had access to fresh and treated water (Fig. 2), but in 2013 about 168,000 Km pipeline delivered treated water to people. In addition, in 1997, Iran had only 9,900 meter sewerage, but in 2013 it reached to 75,000 Km. sewerage systems have a very important role in the reduction of communicable diseases by water (like cholera); and this has been approved by many studies (35,36).

Health care during pregnancy, birth and infancy plays an important role in reducing illness and complications due to childbirth. Polluted water, poor environmental sanitation and hygiene accounted for 62,800 deaths and 2.81 million DALYs in China in 2008. Most (83%) of the attributable disease burden and most (97%) of the deaths occurred in young children. Diarrheal disease accounted for 98% of the attributable DALYs. According to Elizabeth J Carlton et al., unsafe water, poor sanitation and hygiene are particularly detrimental to the health of young children, as they account for 61,200 deaths and 2.33 million DALYs in children under five, predominantly attributable to diarrheal diseases. Geographically, the disease burden attributable to polluted water, poor sanitation and hygiene are concentrated in China's poorest, inland provinces. Diarrheal disease accounted for 98% of the attributable DALYs. Soil-transmitted helminthiases were the second leading cause of attributable DALYs: An estimated 287 million such infections occurred in China in 2008, accounting for 29,800 DALYs (37).

Table 3 demonstrates that YLL rate and number attributed to developed water systems and sanitation decreased in all age groups. The highest and lowest reduction of number of YLL and rates of YLL occurred in the late neonatal and 15-49 year age groups, respectively.

According to Table 4, YLD number attributed to enhanced water systems, and sanitation dropped from early neonatal to 5-14 years but increased from 15 until >70 years.

This study has some limitations as the same as the limitations in the GBD study 2010, which are described elsewhere (3,20-27). The limitations in data sources had an effect on the exposure estimations of risk factors such as unimproved water and sanitation in Iran. Iran General Census of Population and Housing 2006, as a nationally representative collected data, which is provided by International Integrated Public Use Micro data Series (IPUMS), was the main source for unimproved water and sanitation estimates in Iran. The data sources that were not considered for water pollution estimates included population-based epidemiological studies, as well as national and sub-national health surveys. Due to the lack of access to data sources used for untreated water and insanitary environment estimates in Iran along with the extensive uncertainties, there was a substantial limitation to reach accurate estimates. Because of the incomplete or missing data on risk factor exposure, models were used to provide a complete and comprehensive dataset of exposure distribution. Estimation of exposure was made by statistical models, which used the predictors relevant to the exposure.

Considering the GBD limitations and the importance of measuring the burden of diseases, injuries and risk factors in Iran, a national systematic study titled National and Sub-national Burden of Disease (NASBOD) study was carried out in Iran to estimate the burden of diseases, injuries, and risk factors at national and sub-national levels from 1990 to 2013. The NASBOD study used a standardized protocol of data collection and estimation methods, providing comprehensive information to estimate health status at provincial level over a long period. Evaluating diseases and risk factor distributions at sub-national level would be the main source to identify the public health priorities and interventions among sub-national people and to inform policy makers in planning public health strategies (38).

National and sub-national Environmental Burden of Disease as a sub-component of NASBOD study can estimate the trends in the prevalence and health burden of unimproved water and sanitation at the national and sub-national levels between 1990 and 2013 (39). The results can help us provide the most effective strategies for policy making in Iran.

Conclusion

A significant decrease has occurred in the number of DALYs and deaths in Iran between 1990 and 2010 due to the development of new water distribution systems, waste water collection systems, instruction of water and wastewater treatment plants and subsequently environmental sanitations in Iran.

Acknowledgements

In terms of the publication of the present data, permission was granted from Professor Christopher J.L. Murray, the director of IHME, to the Non-Communicable Diseases Research Center, Endocrinology, and Metabolism Population Sciences Institute of Tehran University of Medical Sciences.

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