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Assessment of Human Resources Cost in Scenarios for Improving Environmental Health Services Using Monte Carlo Simulation

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Abstract

Background: Financial limitation is a challenge in allocating human resources to provide environmental health services as a public health need. This study aimed to compare the cost of manpower for environmental health services in public health centers in the current situation and scenarios based on local needs.

Methods: A financial model including fixed and variable costs in providing human resources was used. Human resources costs in the current situation and scenarios based on the allocation of human resources considering local needs were analyzed and compared. The financial situation in the studied scenarios was analyzed using the Monte Carlo simulation.

Results: The workforce capacity was 25.38 to 80.06% less than local demands. Also, in 25% of the studied rural health centers, the workforce capacity was 13.8 to 39.03% less than local demands. In addition, in 75% of the rural health centers, the capacity of the environmental health workforce was 13-138% higher than local demands. Based on the traditional human resource support model, increasing the capacity of the environmental health workforce in the studied area would require hiring equal to 84% of the current workforce capacity, which would increase human resource management costs by 60%. However, applying a proportional distribution model of the environmental health workforce led to a 14.42% reduction in human resource costs.

Conclusion: Proportional distribution of the health workforce based on local demands is a necessity in human resource management to prevent occupational consequences such as burnout and administrative costs.

Keywords: Healthcare service, Human resource, Health management, Health economics
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Introduction

Improving health indicators is a critical objective for developing countries that have experienced industrial and economic growth in recent decades (1,2). In recent decades, the need for health services has increased significantly due to urbanization and population growth, requiring the employment of more human resources (3,4). Health services in developing countries are among the most complex and dynamic organizations, involving a significant number of human resources with diverse expertise, including treatment (physicians, nurses, etc.), health care (epidemiologists, environmental health, etc.), and diagnostic laboratory services (5,6-8). Therefore, traditional methods of workforce supply may not support demands and lead to a decrease in the quality of health services (9). Of course, depending on the type of service, the number of needed health workers is estimated based on different criteria. For example, the number of doctors or nurses needed in each area can be estimated based on the population ratio or per hospital bed, but the number

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of jobs, such as environmental health technicians, is estimated based on local characteristics and the size of the area covered (10). This traditional method of estimating the required health workforce can sometimes lead to a mismatch between the workforce and health demands and also increased costs (11).

Iran is a developing country that has tried to increase the level of access to health services in recent decades by increasing its health facilities in line with the United Nations Sustainable Development Goals (UNSDGs). Although only the third goal of the 17 goals proposed in the UNSDGs directly refers to good health (12), other proposed goals also include issues related to public health, such as safe water, sanitation, waste management, etc. (13). Therefore, an important part of the environmental health services provided in the health system structure of developing countries, including Iran, can be effective in achieving the UNSDGs (14). In recent decades, indicators related to public health services in Iran have improved due to the development of medical universities and economic development (15). More access to health centers resulting from the development of the health structure in Iran has been one of the reasons for the improvement of health indicators (16,17). Environmental health services are one of the types of health services provided by the government in all urban and rural areas, and even in nomadic populations (18,19). These services include water health control, supervision of sanitary wastewater disposal, supervision of solid waste control and management, and food hygiene control (20,21). The provision of these services is carried out by employing a network of urban and rural health centers and hiring environmental health experts for each health center. This structure has led to the improvement of environmental health indicators in Iranian cities, with the results of previous studies confirming a ratio of more than 99% in the indicators, including access to safe water, proper wastewater disposal, coverage of supervision of food preparation and distribution centers, and collection of solid waste in urban and rural areas.

The literature review shows that estimates of health care costs in recent decades have focused on the estimates of hospital admission costs and post-hospital care at home. For example, Stewart et al. (2002) estimated the direct and indirect costs of heart disease in the UK to be 1.9% of total NHS expenditure (22). Furthermore, most health economic estimates in the past literature have focused on the treatment of diseases, with less attention paid to the costs of other health services. For example, Simon et al. (2005) reported the costs associated with the treatment of eating disorders in millions of euros in various countries, including Germany, the United Kingdom, Australia, the Netherlands, Denmark, and the United States (23). On the other hand, previous studies evaluating the issue of environmental health services have often reported aspects of service quality and neglected the costs associated with these services. For example, there are studies evaluating the status of environmental health indicators in different cities in Iran (19,21).

Although human resources have an important impact on achieving sustainable development goals related to environmental health services, previous studies have only assessed the status of local indicators and compared them with ideal conditions (24,25). Therefore, the impact of human resources provision and its associated costs on achieving sustainable environmental health services is a knowledge gap. In addition, estimating the required manpower according to local variables is an important factor in providing sustainable environmental health services that has remained unanswered in previous studies. Accordingly, the main question of this study was to estimate the amount of change in human resource costs through human resource allocation based on local demands. This study aimed to assess the proportionality of the environmental health workforce with local health demands in a region in western Iran, which was distributed in a traditional method. Another aim of this study was to investigate the efficiency of the studied health workforces based on the health indicators of the Iranian Ministry of Health. The other aim of this study was to economically compare the current situation with a new model for the supply and distribution of the environmental health workforce to improve the efficiency of health services using the Monte Carlo simulation in the studied area.

Materials and Methods

Study area

This cross-sectional study was conducted in Tuyserkan, western Iran, in 2025 (Figure 1). The region includes a central city, two small towns, and 105 villages in an area of 42 km^2. The central city of the Tuyserkan region is located at 34.5532° N, 48.4420° E. The population of the Tuyserkan region consists of 104,000 people, 57.7% of whom live in rural areas.

Health structure of the studied area

The health structure of the Tuyserkan region includes 2 hospitals, 7 urban health centers, and 10 rural health centers. In addition, 43 health houses in this region provide health services such as vaccination, prenatal care, newborn health, infectious disease control, food hygiene, water hygiene, and public health care in rural areas. There are six emergency medical service bases in this region, four of which are located in rural areas. The health structure of the Tuyserkan region includes 800 workers in various specialties, including doctors, nurses, health experts, health technicians, and other health professionals.

Environmental health services in the study area

In the Tuyserkan region, 17 experts support environmental

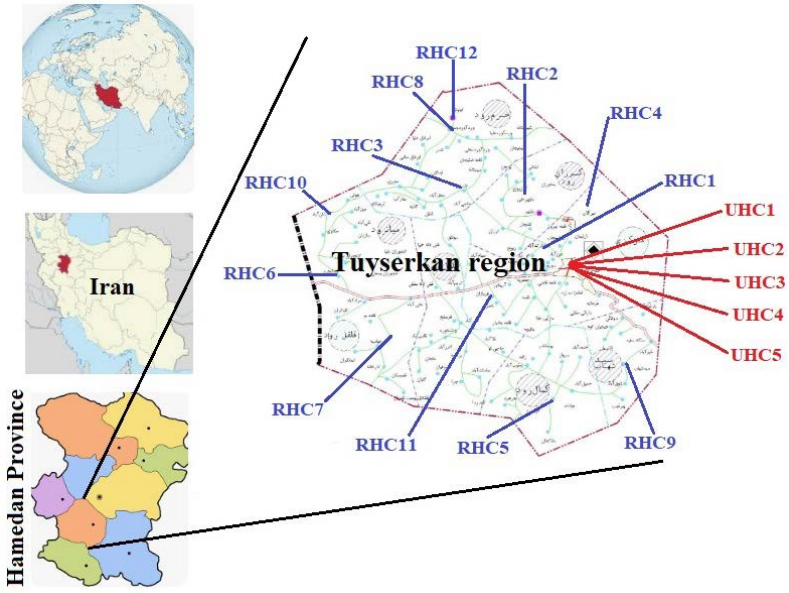


Figure 1. Location of rural health centers (RHC) and urban health centers (UHC) in the study area

health services. Five experts provide environmental health planning and management services in the health center, and twelve experts support environmental health services in urban and rural health centers. The distribution of workforces includes one environmental health expert in each urban health center and one environmental health expert for the two rural health centers. Environmental health services provided in the Tuyserkan region, based on the goals of the Iranian Ministry of Health, include monitoring environmental factors affecting health, such as food hygiene, water hygiene, wastewater management, solid waste management, and hygiene of public places such as schools.

Allocation of environmental health workforce and related costs

The financial analysis of human resources costs in this study was defined based on a conceptual model. This model was used to assess the current situation and alternative scenarios. The model consisted of a linear equation consisting of parameters affecting human resources costs, which are described in Table 1.

The human resources costs in this model were based on the estimated number of environmental health specialists due to local demands, which was based on the environmental health job descriptions in the study area and the time required to provide these services. The time required to provide environmental health services depends on variables including transportation, regional training costs, or specialized equipment for rural or contaminated areas, and was different for each health center. After determining the human resources required in each scenario, the human resources costs were estimated based on fixed salaries and other costs, which are described in Equation 2. In the current traditional method, the environmental health workforce was distributed based on the geographical division of rural and urban areas. However, the local environmental health demands were different in each urban or rural area. Therefore, the following model (Equation 1) was studied to modify the distribution of the environmental health workforce. Then, workforce supply costs were estimated using Equation 2. This method included the distribution of the workforce based on local demands. The details of the studied model and the available scenarios for the distribution of the environmental health workforce are shown in Table 1. All data were prepared based on data gathered from the health center of the studied county. Information on employed human resources and costs related to fixed salaries and variable bonuses was also gathered from official data registered in the local health system. The analysis of these calculations involved a static model because the scenarios studied were based on the optimal distribution of existing manpower, which had the same status in parameters such as manpower efficiency, skill, experience, and service complexity. Also, the environmental health needs in the study area were considered for one year, which eliminated the temporal variations in the need for health services.

$$\mathrm{Rwf} = \sum(\mathrm{Es}\times\mathrm{Tr}\times\mathrm{Sf})/(\mathrm{Wd}\times\mathrm{St}\times\mathrm{E}) \qquad \text{Eq.1}$$

$$\mathrm{Cwf} = \mathrm{Rwf}\times[(\mathrm{Sb}\times\mathrm{Oc})+\mathrm{Ac}] \qquad \text{Eq.2}$$

The human resource cost in the studied scenarios was estimated using the Monte Carlo simulation with 1000 iterations. Input parameters included the types of environmental health services, the time required for each service, the frequency of services per year, the number of working days per year, and the basic salary and other costs.

Table 1. Details of parameters and studied scenarios

Parameters	Rwf	Required workforce
	Es	Environmental health services types
	Tr	Average time required for each service
	Sf	Defined service frequency in a year
	Wd	Working days in a year
	St	Service time per day
	E	Net service time coefficient (0.85-0.95 in urban areas, 0.75-0.85 in rural areas)
	Cwf	Workforce cost
	Sb	Basic salary
	Oc	Options fee
	Ac	Additional costs
Scenarios	S1	Current situation
	S2	Hiring new workforces for high-demand centers
	S3	Providing additional workforces in high-demand centers by reducing working days in low-demand centers
	S4	Providing additional workforces in high-demand centers using S3 and part-time use of managerial workforces
	S5	Providing additional workforces in high-demand centers using S3, S4, and hiring new workforces for the remaining demand

Most of the parameters had a log-normal distribution. The quantity and cost data used in the equations were collected from official data in the studied area.

Results

The results showed that in the current situation, the distribution of the environmental health workforce in the studied health centers was uniform. In this situation, the calculation of the proportion of the environmental health workforce with local demands in the studied health centers using Equation 1 is shown in Table 2. The results showed that in 17.64% of the studied health centers, there was a proportion of workforce and environmental health demands, while in 47.05% of the studied health centers, there was an excess workforce, and in 35.29% of the studied health centers, there was a shortage of workforce.

The distribution of the environmental health workforce based on a uniform geographical division led to an imbalance between local demands and the required workforce. The results of the assessment of the ratio of environmental health services to local demands in each of the studied health centers are shown in Figure 2. The results showed that in 80% of urban health centers, local demands were significantly higher than the environmental health workforce capacity, while in 75% of rural health centers, local health needs were lower than the health workforce capacity of the center. The highest demand for environmental health services was observed in urban health center No. 2 (UC2), which indicated a need for four additional workforces. This imbalance reduced the efficiency and quality of environmental health services in the study area, such that service efficiency was less than 40% in six of the 17 studied centers. However, the working hours of the environmental health workforce at RHC10 were 2.5 times higher than the local demands for environmental health services.

The results of the analysis of the studied scenarios for improving the proportionality of environmental health services in the Tuyserkan region and workforce capacity are shown in Table 3. The results showed that the second scenario could add 241% to the capacity of the environmental health workforce in high-demand health centers. However, in the second scenario, the workforce was still not fully matched to the local demand for environmental health services. In the second scenario, the workforce capacity and organizational tasks were matched in 47.05% of the studied health centers, but in nine health centers, on average, human resource capacity was calculated to be 46.3% higher than the local environmental health demands.

The results of estimating the cost of human resources for the full provision of environmental health services in the studied scenarios are shown in Figure 3. The results showed that the cost of human resources for environmental health services in the studied area in the current traditional method was 3.9E+9 IRT/year. Also, the cost of increasing environmental health services to meet local demands in S2 was estimated to be 6.24E+9 IRT/year, which was 16.85% higher than the human resource cost in S5. Therefore, providing a workforce by considering proportional distribution of human resources with local demands (S4) reduces the costs of providing environmental health services in the studied area by 2.1E+9 IRT/year. Therefore, the second scenario resulted in higher costs because it was defined solely based on hiring new staff to cover the required environmental health services, but the fifth scenario, which was defined based on targeted allocation of staff based on local environmental health demands and reduction in recruitment, had lower staff costs. Given that

Table 2. Required and current environmental health workforce in each of the studied health centers

	Rural Health Centers												Urban Health Centers				
	RHC1	RHC2	RHC3	RHC4	RHC5	RHC6	RHC7	RHC8	RHC9	RHC10	RHC11	RHC12	UHC1	UHC2	UHC3	UHC4	UHC5
RWF	1.21	1.16	0.82	0.44	0.37	0.27	0.36	0.38	0.40	0.21	0.42	0.38	5.15	2.32	5.26	1.40	1.34
CS	1	1	0.5#	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2	1	1	1	1

*CS: The number of environmental health workers in the current situation.
0.5 represents a part-time employee at a health center (Health centers where environmental health experts work half the days of the week).

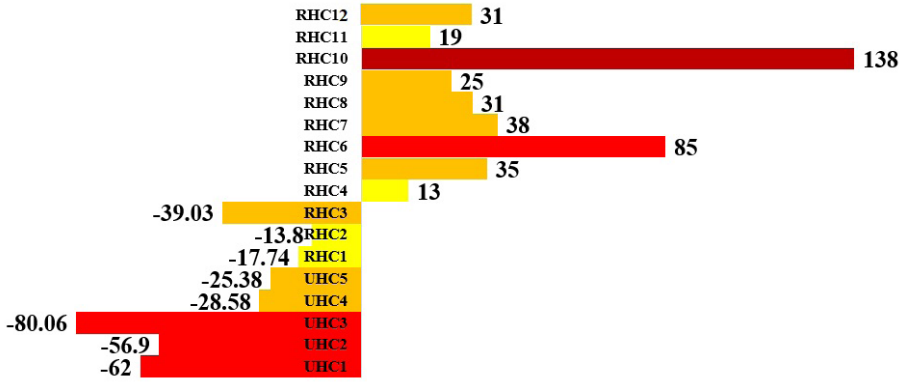


Figure 2. Proportion of environmental health workforce capacity to local demands in each studied health center (%)

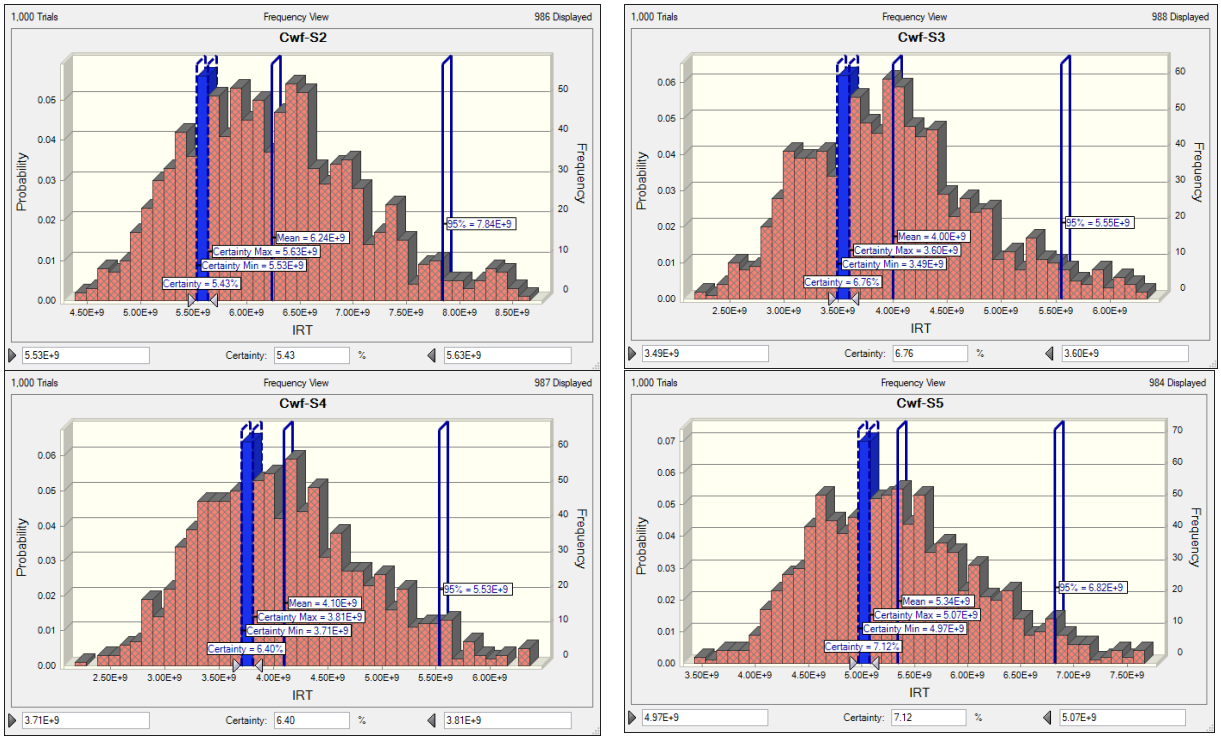


Figure 3. Monte Carlo simulation of estimating the annual cost of environmental health manpower in the studied scenarios

these scenarios were based on creating a balance between working hours and local demands of environmental health services, reducing the working hours of specialists in some centers where working hours were higher than local demands would not have a negative impact on the quality of environmental health services. So, in scenarios that provided the desired quality of environmental health services, staff distribution options considering local needs have an economic advantage.

Discussion

Health workforce development is one of the necessities to achieve the goals of improving health standards in developing countries (26), but limitations in financial

Table 3. Ratio of environmental health workforce capacity to local needs in the studied scenarios (%)

	Rural Health Centers												Urban Health Centers				
	RHC1	RHC2	RHC3	RHC4	RHC5	RHC6	RHC7	RHC8	RHC9	RHC10	RHC11	RHC12	UHC1	UHC2	UHC3	UHC4	UHC5
S1	-18	-14	-39	+13	+35	+85	+38	+31	+25	+138	+19	+31	-62	-57	-81	-29	-26
S2	+10	+15	+1	+13	+35	+85	+38	+31	+25	+138	+19	+31	-3	0	-5	-5	-1
S3	-5	0	-20	+13	-11	+22	-8	-13	+25	+57	+19	-13	-62	-57	-81	-5	-1
S4	-5	0	-20	+13	-11	+22	-8	-13	+25	+57	+19	-13	-42	-36	-62	-5	-1
S5	-5	0	-20	+13	-11	+22	-8	-13	+25	+57	+19	-13	-3	+7	-5	-5	-1

resources and expertise manpower are among the challenges of health workforce development (27,28). Therefore, increasing the efficiency of the health workforce has an important impact on controlling the limitations of health service provision in developing countries (12,26). However, the results showed that while the five health centers in the studied area were classified as high-demand centers due to the need for more than one environmental health workforce, the uniform distribution of the environmental health workforce reduced the productivity of the environmental health workforce in the studied area.

Therefore, workloads higher than the capacities of the workforce in some of the studied health centers as one of the occupational risk factors that can be a factor in reducing the quality of environmental health services (29). The workload higher than the working time is a known factor in occupational stress for the workforce (30). Increased job fatigue and dissatisfaction in the workplace due to job stress is one of the important reasons for reduced productivity, especially in developing countries (31,32). These conditions led to dissatisfaction of the environmental health workforce in high-demand centers. In addition, workloads less than the capacities and working time of personnel can be effective in reducing motivation in the workplace and a sense of inefficiency in the workforce. This feature, which was seen in the studied rural health centers, could be one of the reasons for the low quality of environmental health services in the studied region.

The results showed that the distribution of the environmental health workforce in the studied health centers was disproportionate to local demands. Therefore, corrective measures in human resource management are necessary. Increasing the workforce through new recruitment can be a solution for human resource development (33). However, in developing countries that face economic limitations, human resource development for providing health services is a challenge (34). In this situation, productivity can be considered as one of the critical factors in service development (35). The proportional distribution of the health workforce with the health services demand is an available option to control the imbalance of organizational tasks with the specialized workforce limitation.

The mismatch between the time available to environmental health professionals and local demands, as shown in Table 3, led to a decrease in the quality of services provided in urban health centers, which was confirmed by field observations in this study. For example, the proportion of health deficiencies, including the sale of unauthorized food in food preparation and distribution centers, was higher in urban areas, which was due to the reduced efficiency of environmental health professionals' supervision due to time constraints. Also, the frequency of visits of environmental health professionals to urban schools to provide health services was longer than in rural schools. On the other hand, although the quality of services in rural health centers was better, there was a waste of time for human resources due to fewer environmental health demands in rural areas.

Although the proportionality between local demands for environmental health services and workforce was improved in the third and fourth scenarios, the cost of human resource management was different in each of the available scenarios, as an important factor in selecting the optimal option. Environmental health workers in Iran are employed in a central health center, where the center's management defines the number of working days based on local needs in the sub-community rural and urban health centers. Also, according to current laws, managerial personnel can also provide specialized tasks. Therefore, the changes in working days defined in the studied scenarios, as well as the participation of managerial personnel in providing environmental health services, were in accordance with current labor laws.

Considering the importance of health services, including environmental health services, for developing countries in achieving the SDGs, factors that increase operational costs and reduce manpower efficiency should be controlled. One of the consequences of poor human resource management in health centers is burnout (36). In addition, labor waste due to inappropriate distribution of tasks is one of the common challenges in human resource management. The results of this study showed that in environmental health workforce management, burnout and time-wasting phenomena were significant, which can negatively affect the efficiency of the health system. While efficient human resource management is a necessity for the sustainability of the healthcare system (37), changing the approach to environmental health

workforce management should be a priority for local authorities. An adaptive approach to human resource management can facilitate the development of health services, as reported in the successful experience of China over the past seventy years (38). Although increasing the workforce can be an available option to increase the level of services (39), financial limitations in developing countries are local realities that must be considered (40). The results showed that by changing the distribution pattern of the environmental health workforce without the need to hire more experts, in addition to increasing the level of services, burnout can also be prevented. Rethinking the human resource management model is a necessity for developing countries because the disproportionate distribution of the health workforce has been reported in various countries, such as India (39), which is consistent with the results of this study and is an important factor in reducing the efficiency of the health system.

This study had strengths and limitations. Estimating the cost of human resources in different options for allocating human resources based on local needs was a strength of this study. However, the use of a static model was a limitation of this study. Although the model considered effective parameters such as the time required to provide environmental health services, the quantity of services required in each area, and the basic costs resulting from job characteristics such as work experience in a log-normal domain based on official data, the wide range of data due to the difference in human resource efficiency that is considered in a dynamic model was avoided. Also, the effect of financial parameters such as inflation in subsequent years and the increase in human resources was not considered, which is a limitation of this study. In addition, although the difference in salaries of existing specialist personnel based on work experience was considered in the evaluation of the studied model, this ratio was the same in the basic equations. These assumptions used in the model, which were the limitations of this study, were to facilitate the achievement of results and a comprehensive understanding of the economic conditions of environmental health services, which were assessed for the first time in this study. Considering the differences in local needs for environmental health services and allocating human resources based on them was one of the strengths of this study. Also, estimating human resources costs in different scenarios for allocating human resources was a strength of this study. However, not considering local and climatic conditions at the need time for environmental health services was a limitation of this study. Another limitation of this study was not considering the impact of non-governmental human resource capacity.

Conclusion

In this study, the status of environmental health human resource management in a region in western Iran, including seventeen urban and rural health centers, was studied. Also, the adequacy of the studied human resource capacity with local environmental health demands was assessed. The cost of human resource management in the available scenarios to meet local demands was estimated using the Monte Carlo simulation. The results showed that in seven of the seventeen studied centers, the human resource capacity was less than local demands (17.7-80.06%), and in three health centers, a relative adequacy of human resource capacity with local demands was observed. However, in seven rural health centers, the human resource capacity was significantly higher than local environmental health needs (25-138%). The annual human resource cost in the current situation was 3.9E+9 IRT (Iranian currency). In the traditional model, to achieve the adequacy of human resource capacity with local environmental health demands, 11 new workers were needed, which increased the annual human resource cost to 6.24E+9 IRT. However, the use of proportional distribution scenarios provided human resource support at an annual cost of 4.00E9 to 5.32E+9 IRT. Considering that financial limitations in developing countries, including Iran, are among the challenges in providing health services and developing human resources, the current method of allocating workforce to health centers is not optimal. The results of this study showed that not paying attention to the appropriate distribution of the workforce based on local environmental health demands, in addition to adverse financial consequences, leads to job consequences for healthcare workers, including burnout and job stress. Applying a workforce allocation model based on local environmental health demands is a necessity for developing countries, including Iran, to achieve health goals and reduce human resource costs. Therefore, the following are suggested to achieve a better situation:

- Defining the number of human resources for each region based on the diversity of services required in each location
- Paying attention to the time required for various types of environmental health services and the time available for human resources
- Calculating the wasted time, especially in rural areas, to access health service locations
- Targeting services after office hours (overtime hours) based on the proportion of human resources to the services required

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Competing interests

The author(s) declared no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

Ethical issues

This study was approved by the Ethics Committee of Hamadan University of Medical Sciences (Ethical code: IR.UMSHA.REC.1404.215).

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