Development and Validation of an Awareness Assessment Instrument of Safe Work for Laboratory Staff

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ABSTRACT

Background: Chemistry laboratories of universities are dangerous. However, there is no appropriate instrument to assess staffs’ awareness. The present study aims at developing a standardized instrument for awareness assessment of laboratory personnel on safe work.

Methods: The present study is a kind of developing instrument methodology. The study was implemented in two phases: (I) generating items based on the review of relevant literature and interviews, and (II) assessment of the content validity according to seven occupational health and laboratory sciences experts. The validity of the tool was determined based on content validity index (CVI) and content validity ratio (CVR).

Results: In the item generation phase, 53 items were developed in four areas including storage of chemical substances, usage of chemical substances, personal protection equipment, and general observations. The value of CVI was in the range of 0.75-0.91, while the CVR was in the range of 0.4 to 1. Based on these values, some items were omitted and, finally, the content validity for the 40-item questionnaire was established.

Conclusion: Since the content validity of this questionnaire was established, it can be used in future studies.

1. Introduction

Industrial developments made human to be exposed to chemical substances. Nowadays, use of chemical substances in our daily life is inevitable. Undoubtedly, use of chemical substances in many fields of life and economy has led to remarkable benefits, revolutionized the quality of life, caused individuals have been exposed to various chemical substances, especially in their workplaces [1]. The evidence and epidemiological studies show unsafe use of chemical substances has caused chemical accidents in the workplace and environmental catastrophes [2].

Some of these chemical substances have a lot of hygiene hazards for health, and exposure to them can have a different Harmful effect on the health of workers and personnel [3]. These hazards specifically relate to the production and use of chemical substances in various procedures [4]. Currently, the people are facing 85 thousand types of chemical substances. In addition, more than 500 to 1000 new chemical and recombinant substances are introduced each year, and the personnel’s lack of awareness about the characteristics of these substances is threatening their health and work safety [5]. The exposure to chemical substances is very diverse, and it occurs in a wide range of industrial and non-industrial workplaces in different dimensions – from small workshops to largescale industries.
In addition to factories and chemical industries, laboratories are among workplaces where the personnel are exposed to chemical substances and their hazards; and, given the diversity of the job and the workforce, laboratories are highly vulnerable workplaces; therefore, their safety demands a great deal of attention [6].

It is surprising to realize that university laboratories are more dangerous than industrial environments; because the educational organizations’ attention toward safety is negligible if not completely nonexistent [7, 8]. Conducted studies indicate that the majority of accidents that take place in laboratories are due to the lack of awareness of personnel about the correct method of using chemical substances [9].

As such, some researchers have pointed out the necessity of a study on this matter, and have taken some steps for the examination and assessment of such environments. For instance, Lestari et al. (2015) compiled a checklist about the conditions of laboratories [10]. Moreover, Mogopodi et al. (2015) examined the safety management in such laboratories [11]. Awareness about the laboratory safety is the first key element for changing the personnel’s behavior and preventing accidents in these work settings [12].

Nevertheless, no particular instrument for the awareness assessment of laboratory personnel has been proposed so far. As such, this study was implemented to develop an instrument for the awareness assessment of laboratory personnel about work safety.

2. Materials and Methods

This study was a type of developing tools which was implemented in two phases. The first phase was dedicated to creating items based on the review of relevant texts and also with laboratory experts, and in the second phase, evaluation of face and content validity of those items was done.

Initially, the research team determined that the questions should be provided in four separate areas including chemicals storage, application and use of chemicals, personal protection equipment, and general considerations.

To provide a complete list of required questions in each section, were tried to scrutinize all of the guides, instructions, and even scientific and legal resources in the country (Iran). To being comprehensive the list of questions, a remarkable number of sources were consulted. These sources include collections of occupational safety and health regulations for laboratories, safety books in chemistry and biochemistry laboratories, safety, health and environment academic book, comprehensive guidebooks to working with hazardous chemical substances, labor protection and health regulations, personal protection equipment regulations, journals and publications on safety, hygiene, and environmental protection, laboratory safety and protection, safety and laboratory engineering, and the GHS standard. The questions were extracted aforesaid sources, and a total of 55 questions were obtained by removing common items.

Next, the questionnaire was presented to the experts panel (n = 7), which was composed of specialists in the field of occupational safety and health and laboratory sciences.

Then, content validity was measured based on Lawshe method (1975).

According to his suggestion, the content validity was established of all questions with a minimum content validity ratio (CVR) of 0.99 and a minimum content validity index (CVI) of 0.75 was established. In order to calculate these indexes, the answers of the members were collected in the Likert scale (options included essential, beneficial but inessential, and inessential). Based on the number of votes assigned on the “essential” option the CVR of each question was calculated using Equation 1.

$$CVR = \frac{n_E - N}{2}$$  

1. $n_E$: The number of experts who selected “essential” option for each question.
2. $N$: The overall number of experts’ panel

Based on the number of individuals present in the group of experts, a certain range of values for the CVR will be acceptable. With a larger panel of experts, the acceptable CVR value will decrease; if the panel includes 7 members, the minimum acceptable CVR will be equal to 0.99.

The following criteria have been used to accept or reject questions:

1- The question was instantly accepted if the CVR was equal to or greater than 0.99. This would take place whenever all members of the panel of experts selected the “essential” item.

2- Accept the question if its CVR value is between 0 and 99. Provided that the average value of judgments is equal to or greater than 1.5. In order to calculate the average value of judgments for each question, based on Lawshe’s method, options will be replaced with numerical values. So that the “essential” with the number 2, the “necessary but inessential” with the number one, and the “inessential” with the zero value are replaced. This value of CVR shows that more than half the panel members have chosen the “essential” option while the remaining members have chosen the “beneficial” option.

3- A question was rejected when the value of CVR is below zero and the average value of judgment is smaller than 1.5.

A CVR value below zero indicates that less than half of all panel members have chosen the “essential” option and the average value of judgment is closer to the “inessential” option [13]. Items which were accepted in the previous phase, were also examined in terms of their CVI.

The content validity index reflects the comprehensiveness of the judgments about the validity or feasibility of a model,
test, or instrument. To assess the content validity index, all questions should be examined in terms of their simplicity, clarity, and relevance. Each area will be scored from 1 to 4. The CVI approaches 0.99 as the content validity increases. The content validity index (CVI) can be calculated using equation 2 [13].

\[
V_1 = \frac{\text{Total coefficients of simplicity}}{\text{Number of panel members}} + \frac{\text{Total coefficients of clarity}}{\text{Number of panel members}} + \frac{\text{Total coefficients of relevance}}{\text{Number of panel members}}
\]

3. Results and Discussion

In the item generation phase, 53 items were developed in four areas: storage of chemical substances, usage of chemical substances, personal protection equipment, and general observations. Then, content validity was analyzed according to Lawshe’s method and the opinions chosen by the panel of experts.

As it can be seen in Table 1, the CVI of all questions is acceptable and no questions were omitted in this phase. But the study of the content validity ratio showed that some of the questions were not accepted by the members of experts panel (Table 2). In this stage, content validity of 40 questions was established.

In Iran, assessment of personnel’s awareness about the basic principles of a profession and potential dangers is uncommon, and if such an assessment is carried out, there is rarely an appropriate instrument available. Rahimdzadeh et al. (2012) studied bakers’ awareness about the effects of using sodium bicarbonate in their breads. The instrument used in their study was a questionnaire whose validity and consistency is unclear [15]. In addition, Kashi and Pourkabiri (2013) attempted to study the effectiveness of training programs which attempt to raise students’ awareness about safety in organic chemistry laboratories. The study was conducted on 120 students using a 48-item questionnaire to assess students’ awareness about the safety of the organic chemistry laboratory [16]. However, there is no information regarding how to confirm the validity and reliability of this questionnaire. The present study was carried out to offer an appropriate methodology. In this study, using a scientific approach, a questionnaire was designed to measure the knowledge of the laboratory personnel about how to work safely with chemicals. For this purpose, first a list of items relevant to safety measures for working with chemical substances was prepared based on the literature, scientific resources, and laboratory safety guides; and, a 53-item questionnaire was designed which encompassed four areas i.e. storage of chemical substances, usage of chemical substances, personal protection equipment, and general observations. It appears that the method employed in the present study for the generation of the initial items is a reliable method as Hulla et al. (2015) used a similar method for the generation of knowledge standards for practitioners within the field of toxicology [17].

Other scholars such as Yaghmai (2003) have regarded the use of content validity procedures sufficient for the standardization of research instruments [18]. In this study, based on Lawshe’s method and using the validity and reliability ratio, the items were reviewed and revised down to 40 items. Therefore, the content validity of the developed instrument is established.
<table>
<thead>
<tr>
<th>Item</th>
<th>CVI</th>
<th>Accepted/Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where is the best place for the storage of containers with flammable substances?</td>
<td>0.89</td>
<td>Accepted</td>
</tr>
<tr>
<td>2. Where is the best place for the storage of containers of corrosive liquids (e.g. acids and alkaloids)?</td>
<td>0.86</td>
<td>Accepted</td>
</tr>
<tr>
<td>3. Compressed and oxidative gases should be kept away from which of the following materials?</td>
<td>0.82</td>
<td>Accepted</td>
</tr>
<tr>
<td>4. Oxidative acids should be kept away from which of the following substances?</td>
<td>0.80</td>
<td>Accepted</td>
</tr>
<tr>
<td>5. Acids should be kept away from which of the following substances?</td>
<td>0.78</td>
<td>Accepted</td>
</tr>
<tr>
<td>6. Where is the best place for the storage of non-reactive solids?</td>
<td>0.90</td>
<td>Accepted</td>
</tr>
<tr>
<td>7. Fine metal powders should be stored away from which of the following materials?</td>
<td>0.85</td>
<td>Accepted</td>
</tr>
<tr>
<td>8. How should capsules containing compressed gases be carried?</td>
<td>0.90</td>
<td>Accepted</td>
</tr>
<tr>
<td>9. What is the upper limit for filling the test tubes?</td>
<td>0.83</td>
<td>Accepted</td>
</tr>
<tr>
<td>10. Liquid oxygen should be kept away from which of the following substances?</td>
<td>0.85</td>
<td>Accepted</td>
</tr>
<tr>
<td>11. Reactive metals cannot be kept in which of the following liquids?</td>
<td>0.85</td>
<td>Accepted</td>
</tr>
<tr>
<td>12. Which one is the procedure for the dilution of acids and alkaloids?</td>
<td>0.89</td>
<td>Accepted</td>
</tr>
<tr>
<td>13. Which types of containers should not be used for the dilution of acids?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>14. While working with unstable chemical substances which state of matter should be used?</td>
<td>0.75</td>
<td>Accepted</td>
</tr>
<tr>
<td>15. How should oxidative agents be heated?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>16. Which of the following items are main concerns when working with ethers?</td>
<td>0.84</td>
<td>Accepted</td>
</tr>
<tr>
<td>17. Which of the following measures should be taken when washing glass containers of alkaloids?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>18. Fume hoods (which are used to limit the operator’s exposure to hazardous chemicals) are not necessary for working with which substances?</td>
<td>0.83</td>
<td>Accepted</td>
</tr>
<tr>
<td>19. Which steps should be taken before using new glass equipment for the first time?</td>
<td>0.86</td>
<td>Accepted</td>
</tr>
<tr>
<td>20. Which substance is appropriate for the neutralization of strong alkaloids which have leaked?</td>
<td>0.82</td>
<td>Accepted</td>
</tr>
<tr>
<td>21. Which substance is appropriate for the neutralization of strong acids which have leaked?</td>
<td>0.82</td>
<td>Accepted</td>
</tr>
<tr>
<td>22. Which gloves are appropriate for working with hot objects?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>23. Which gloves are appropriate for washing glass equipment or disinfecting them?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>24. Which gloves are not appropriate for working with organic solvents?</td>
<td>0.85</td>
<td>Accepted</td>
</tr>
<tr>
<td>25. Which gloves are appropriate for working with corrosive liquids (e.g. acids, alkaloids, etc.)?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>26. Which shoes are appropriate for working with corrosive liquids (e.g. acids, alkaloids, etc.)?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>27. Which protective apron is appropriate for working with corrosive liquids (e.g. acids, alkaloids, etc.)?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>28. For working with which of the following substances bullet filters are not necessarily required?</td>
<td>0.57</td>
<td>Accepted</td>
</tr>
<tr>
<td>29. What is the most typical way for the penetration of chemical substances into the body?</td>
<td>0.79</td>
<td>Accepted</td>
</tr>
<tr>
<td>30. The majority of typical accidents in laboratories are related to which of the following objects?</td>
<td>0.88</td>
<td>Accepted</td>
</tr>
<tr>
<td>31. Which of the following types of waste is considered as to be general and regular waste?</td>
<td>0.85</td>
<td>Accepted</td>
</tr>
<tr>
<td>32. Which of the following types of waste is considered as to be special waste?</td>
<td>0.85</td>
<td>Accepted</td>
</tr>
<tr>
<td>33. What is the first step for cleaning any substance which is spilled on the laboratory floor?</td>
<td>0.85</td>
<td>Accepted</td>
</tr>
<tr>
<td>34. What is indicated by the first sign on a label?</td>
<td>0.79</td>
<td>Accepted</td>
</tr>
<tr>
<td>35. In order to absorb and recollect the chemical substances which have leaked or spilled over, using which of the following items is essential after using the leakage kit?</td>
<td>0.84</td>
<td>Accepted</td>
</tr>
<tr>
<td>36. Which of the following meanings is indicated by this sign?</td>
<td>0.91</td>
<td>Accepted</td>
</tr>
<tr>
<td>37. Which of the following meanings is indicated by this sign?</td>
<td>0.91</td>
<td>Accepted</td>
</tr>
<tr>
<td>38. Which of the following meanings is indicated by this sign?</td>
<td>0.91</td>
<td>Accepted</td>
</tr>
<tr>
<td>39. Which of the following meanings is indicated by this sign?</td>
<td>0.90</td>
<td>Accepted</td>
</tr>
<tr>
<td>40. Which of the following meanings is indicated by this sign?</td>
<td>0.91</td>
<td>Accepted</td>
</tr>
</tbody>
</table>
Table 2: CVR Results

<table>
<thead>
<tr>
<th>Item</th>
<th>CVR</th>
<th>Average</th>
<th>Accepted/Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where is the best place for the storage of containers with flammable substances?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>2. Where is the best place for the storage of containers of corrosive liquids (e.g. acids and alkaloids)?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>3. Compressed and corrosive gases should be kept away from which of the following substances?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>4. Oxidative acids should be kept away from which of the following substances?</td>
<td>0.7</td>
<td>1.82</td>
<td>Accepted</td>
</tr>
<tr>
<td>5. Acids should be kept away from which of the following substances?</td>
<td>1</td>
<td>1.2</td>
<td>Accepted</td>
</tr>
<tr>
<td>6. Where is the best place for the storage of non-reactive solids?</td>
<td>0.43</td>
<td>1.53</td>
<td>Accepted</td>
</tr>
<tr>
<td>7. Fine metal powders should be stored away from which of the following materials?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>8. How should capsules containing compressed gases be carried?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>9. What is the upper limit for filling the test tubes?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>10. What materials should containers of oxidative agents be made of?</td>
<td>0.14</td>
<td>1.2</td>
<td>Rejected</td>
</tr>
<tr>
<td>11. Liquid oxygen should be kept away from which of the following substances?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>12. Reactive metals cannot be kept in which of the following liquids?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>13. What material should laboratory test tubes (Erlenmeyer flasks, beakers, etc.) be made of?</td>
<td>-0.14</td>
<td>-</td>
<td>Rejected</td>
</tr>
<tr>
<td>14. What is procedure for diluting acids and alkaloids?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>15. What should be used to the dilution of dense acids and alkaloids?</td>
<td>0.14</td>
<td>1.2</td>
<td>Rejected</td>
</tr>
<tr>
<td>16. Which types of containers should not be used for the dilution of acids?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>17. While working with unstable chemical substances which state of matter should be used?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>18. How should oxidative agents be heated?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>19. To which of the following categories do hydrates and oxidative agents belong?</td>
<td>-0.43</td>
<td>-</td>
<td>Rejected</td>
</tr>
<tr>
<td>20. Which of the following are main concern when working with ethers?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>21. Which of the following measures should be taken when washing glass containers of alkaloids?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>22. Fume hoods (which are used to limit the operator’s exposure to hazardous chemicals) are not necessary for working with which substances?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>23. Which steps should be taken before using new glass equipment for the first time?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>24. Which chemical substances can make their way to the blood circulation after touch?</td>
<td>-0.14</td>
<td>-</td>
<td>Rejected</td>
</tr>
<tr>
<td>25. Touching which of the following materials causes only local symptoms?</td>
<td>0.14</td>
<td>1.2</td>
<td>Rejected</td>
</tr>
<tr>
<td>26. Which substance is appropriate for the neutralization of strong alkaloids which have leaked?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>27. Which substance is appropriate for the neutralization of strong acids which have leaked?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>28. Which substance is not appropriate for rinsing chemical substances?</td>
<td>-0.14</td>
<td>-</td>
<td>Rejected</td>
</tr>
<tr>
<td>29. Which gloves are appropriate for working with hot objects?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
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<tr>
<td>30. Which gloves are appropriate for washing glass equipment or disinfecting them?</td>
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<td>1.8</td>
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<tr>
<td>31. Which gloves are not appropriate for working with organic solvents?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>32. Which gloves are appropriate for working with corrosive liquids (e.g. acids, alkaloids, etc.)?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>33. Which shoes are appropriate for working with corrosive liquids (e.g. acids, alkaloids, etc.)?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>34. Which protective apron is appropriate for working with corrosive liquids (e.g. acids, alkaloids, etc.)?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>35. What substance is used for ensuring the correct functioning of emergency showers?</td>
<td>0.42</td>
<td>1.47</td>
<td>Rejected</td>
</tr>
<tr>
<td>36. Which protective instrument should not be changed while working in the lab?</td>
<td>0.14</td>
<td>1.2</td>
<td>Rejected</td>
</tr>
<tr>
<td>37. For working with which of the following substances bullet filters are not necessarily required?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>38. Which of the following materials is most appropriate for the safety labels of substances present in the laboratory?</td>
<td>0.42</td>
<td>1.47</td>
<td>Rejected</td>
</tr>
<tr>
<td>39. Which chemical state is considered to be the most important one in the laboratory?</td>
<td>0.14</td>
<td>1.2</td>
<td>Rejected</td>
</tr>
<tr>
<td>40. What is the most typical way for the penetration of chemical substances into the body?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>41. The majority of typical accidents in laboratories are related to which of the following objects?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>42. Which of the following materials are stable in the air?</td>
<td>-0.14</td>
<td>-</td>
<td>Rejected</td>
</tr>
<tr>
<td>43. Which of the following types of waste is considered as to be general and regular waste?</td>
<td>0.43</td>
<td>1.53</td>
<td>Accepted</td>
</tr>
<tr>
<td>44. Which of the following types of waste is considered as to be special waste?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>45. On what basis is the toxicity of chemical substances determined?</td>
<td>0.14</td>
<td>1.2</td>
<td>Rejected</td>
</tr>
<tr>
<td>46. What is the first step for cleaning any substance which is spilled on the laboratory floor?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>47. What is indicated by the first sign on a label?</td>
<td>0.7</td>
<td>1.8</td>
<td>Accepted</td>
</tr>
<tr>
<td>48. In order to absorb and recollect the chemical substances which have leaked or spilled over, using which of the following items is essential after using the leakage kit?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>49. Which of the following meanings is indicated by this sign?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
<tr>
<td>50. Which of the following meanings is indicated by this sign?</td>
<td>1</td>
<td>2</td>
<td>Accepted</td>
</tr>
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<td>51. Which of the following meanings is indicated by this sign?</td>
<td>1</td>
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<td>52. Which of the following meanings is indicated by this sign?</td>
<td>1</td>
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<td>53. Which of the following meanings is indicated by this sign?</td>
<td>1</td>
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4. Conclusion

The developed instrument is reliable to be used for the assessment of the laboratory personnel’s awareness about work safety, and its results can be used for the following purposes:

1- Identification of performance weaknesses which can potentially result in accidents.
2- Determining the educational needs in different parts of laboratories.
3- Providing the necessary educational materials (e.g. guide books, brushes, workshops, etc.) for raising the personnel’s awareness.

Authors’ Contributions

F.Gh., conducted the field work and wrote the manuscript; Sh.A., designed the study, analyzed the data and wrote the manuscript; M.M., conducted the field work; J.B., conducted the field work; Sh.Gh. conducted the field work. All authors revised and approved the final manuscript.

Conflict of Interest

The authors report no conflict of interest.

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