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Quantity and composition of produced dental solid waste in Isfahan, 2011

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ABSTRACT

Aims: The purpose of this study was to investigate the composition of dental waste coming from six dental health services in Isfahan, Iran.
Materials and Methods: From 45 public dental clinics in Isfahan, six public dental health services were selected (three dental clinics and three dental centers). Waste collection took place from October to December 2011. During this period, three samples were collected from each dental clinic and were divided to pre-determined groups manually.
Results: In dental centers, the amount of infectious, non-infectious and domestic-type waste accounting for 45.07%, 12.15% and 42.78%, respectively. Whereas in dental clinics the production rates of infectious, non-infectious and domestic-type waste accounting for 52.2%, 8.58% and 39.22%, respectively.
Conclusion: Overall, according to the results it can be said that integration of infectious and hazardous waste with general waste leads to the amount of infectious waste appears much greater than it actually is. The collection and disposal of amalgam and other hazardous dental solid waste should be regulated as soon as possible and to decrease the costs of dental waste management the uncontaminated recyclable items, which contained approximately 33% of total dental waste should be recycled or reused if possible.

Key words: Amalgam, dental clinics, dental solid waste, infectious waste, public dental services, solid waste management

INTRODUCTION

The importance of clinical waste management is a matter of concern that has been recognized for many years by the environmental health engineers and health care stakeholders. Now-a-days, one of the most important environmental issues is dental solid waste which despite of relatively small quantities has a great significance due to containing toxic and hazardous components such as pathological wastes, pharmaceutical and chemical residues, sharps and infectious wastes.[1] The majority of dental solid wastes usually disposed into municipal landfills without any recycling practices. Dumping of dental solid waste in domestic sites is detrimental to the environment and public health due to high contamination and hazardousness.[1,2] In general, the most important reasons of the mismanagement of medical waste are deficiency of proper legislation, economical problems, deficiency of qualified medical personnel, lack of consciousness and efficient management.[3]

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For developing an effective waste management approach, the most significant issues are waste generation source as well as the amount and composition of solid waste.[4,5] Due to the heterogeneous nature, determination of dental solid waste composition is not a simple subject; therefore, performing an accurate statistical analysis has special difficulties. However, by existing facilities and conducting a detailed study plan, this subject can be investigated appropriately. According to the features, risk potential and environmental significance, dental solid waste consists of three major groups: Infectious waste, non-infectious waste and domestic-type waste.[6]

Domestic-type wastes consist mainly of those wastes that are not containing harmful substances for human health, animals or the environment. This part of dental waste can be collected and disposed along with other typical urban waste. There is also possible to recycle them.[7] Non-infectious dental waste are those wastes that are not contaminated with blood or other body fluids and cannot disseminate disease, such as gloves, masks and barriers, which not contained any blood or saliva, empty amalgam capsules, mouth washing cups, empty drug containers, etc.[8-10] The non-recyclable fraction of these wastes can be putted into usual waste containers without any further health consideration.[2]

Chemical and toxic waste is a sub group of non-infectious waste includes waste contaminated with silver and mercury in dental amalgam, lead foils, disinfectants, metals and drug residues that these are believed to be in small quantities.[2] Amalgam waste contains 49% mercury and is also classified as hazardous waste. Amalgam is one of the most common materials in tooth restorations, which is used widely in dentistry. Due to the adverse effects of mercury on human health and environment, this element has caused a lot of concerns during the past decades.[6] Approximately 10,000 tons of mercury is extracted per year for anthropogenic applications in the world and has been estimated that about 3-4% of it is used globally in dentistry as a filling material.[11,12] According to previous studies, mercury of amalgam waste can enter the environment by disposal of the extracted teeth, amalgam particles disposed into the wastewater collection system during the dental operations, landfilling and sewage sludge incineration.[13-15] The remained amalgam should not be mixed or incinerated with other medical waste and must be shipped off to an appropriate authorized facility.[6,13,15]

Infectious waste is an important part of dental solid waste, which comprise 10-25% of total clinical wastes.[16] Infectious waste includes materials contaminated with blood or other infectious fluids of the mouth, sharps and amalgam.[4,6] Infectious waste such as swabs or dressings stained with blood and used sharps (needles, probes, etc.,) considered as hazardous waste due to the presence of pathogens[6,7,17] and will jeopardize healthcare staffs, environment and public health.[3,4,9] Even though hazardous waste represents a small proportion of total dental solid waste, proper management of dental waste is necessary in order to prevent environmental and public health difficulties.[4,6] There are numerous studies about the composition and quantity of dental waste in the world and Iran. For example, Al-Widyan *et al*. indicated that more than 80% of dental waste is made of combustible constituents that 60% were of paper origin and the remaining were built of plastic in Jordan.[1] Ozbek and Sanin found that the rubber gloves are the highest proportion of dental waste (35% by weight) and other components of the waste, including paper, glass and plastic.[2] According to study of Kizlary *et al*., (in Greece) the produced dental waste were divided into three sub groups and proportions of infectious, non-infectious and domestic type waste were 94.7%, 2% and 3.3%, respectively.[6,18]

Taghipour and Mosaferi, Nabizadeh *et al*., Nafez *et al*. and others have conducted some research about dental solid wastes management in Iran.[18-20] In the study conducted by Nabizadeh *et al*. was found that the average per capita waste production in general dental offices in Hamadan was 48.72 g/day. The maximum production rates were related to potentially infectious waste and domestic type waste with 7614.13 kg (51.93%) and 5595.83 kg (38.16%) respectively.[19] In the study performed by Nafez *et al*. in Qazvin, stated that there was a significant difference between the quantity of produced dental waste in private and general dental centers, but there was no significant difference between the produced dental wastes in these centers, qualitatively.[20]

In Iran, like in most of other developing countries, approximately the entire solid waste generated in dental health clinics are mixed with the municipal waste and disposed in the household landfills with the serious consequences on human health and the environment.[18] Considering the priority of dental solid waste characteristics and composition in its proper management,[3,4,19] as well as the scarcity of information about this waste in Iran, this study was conducted aimed at the determination of composition and generation rate of typical dental solid waste produced in different public dental clinics in Isfahan, Iran.

MATERIALS AND METHODS

Dental health services selection

The location of sampling and accomplishment of this descriptive cross-sectional study was metropolitan areas of Isfahan province. Isfahan city, the capital of Isfahan province with an area of 18,200 ha and 1,583,600 people.[21] There are 45 public urban dental clinics in Isfahan. For the present study, 6 clinics were selected through simple random sampling. Three of these clinics just have 1-3 dental units (dental clinics) and others have 8-12 dentists with different procedures (dental centers). In order to study the components of generated dental solid wastes and to examine the dental solid waste management at public dental clinics in Isfahan, three samples of solid waste were collected from these dental

clinics on working days during October, November and December of 2011. This period is marked by normal flow of dental work and was considered to be a representative sample for a municipal area, such as Isfahan. Statistical analysis (independent sample *t*-test) was performed with the SPSS 18 software for windows (IBM Corporation) on data achieved during this study.

The procedures performed in these clinics are pretty dissimilar from each other. The practices applied in the dental clinics are intraoral and extra oral examination, local anesthetization, tooth extraction, treatment and restoration of decayed teeth and other primary dental services. Dental clinics are actually a subset of urban health clinics, but dental centers just considered as dental services and other health services are not provided. Besides the primary services, dental centers provided more advanced dental services such as: treatment of periodontal diseases, fixed and removable prosthodontic treatments, implant surgery and other oral surgical procedures, crown and bridge restorations and root treatments.

Sampling of dental solid waste

Considering that there are numerous procedures applied in each of the six clinics at various times and this may considerably transform the composition of the dental solid waste, these three samplings were considered to be a representative sample and appropriate for the identification of the waste composition. Solid waste composition from each clinic was investigated after transferring to Laboratory of Solid Waste Management of the Environment Research Center of Isfahan University of Medical Sciences (IUMS). Every sample analysis was carried out throughout one to 2 days after collection.

Dentists and their assistants were vindicated about this research before the sampling. Dentists were educated to collect the total amount of waste they generated. The whole of produced dental solid waste from each center was collected by the end of each working day at about 4:00 pm. Furthermore, in order to investigate the current status of dental solid waste management in public dental health services, a questionnaire containing 25 questions was completed through interview and observation.

Separation and classification of waste components

Each sample of dental waste was investigated individually. Initially according to Kizlary *et al*.[6] the sample from each clinic was pulled apart into 22 components and then manually separated into predetermined sub-fractions. Eventually, the categorized fractions were weighed using a digital balance with accuracy of centigram. To achieve the amount of waste generation for each patient in each working day, the number of patients admitted and major clinical procedures also was recorded in selected dental health clinics.

An overall of 154.91 kg dental solid waste was gathered throughout the sampling period and was divided to pre-determined sub-groups and each sub-group was evaluated. By multiplying the average daily production rate of waste components in the number of working days in 2011 (290 days), annual production rate of various components of dental waste was determined. Then obtained values should be extended to the whole community (Isfahan city).

Finally due to the potential hazards of heavy metals contained in amalgam, the composition of residual amalgam in dental solid waste was investigated by using the inductively coupled plasma mass spectrometry method (Perkin Elmer 4300, USA).

RESULTS

The annual production rates of different components of generated dental wastes in public dental centers and dental clinics of Isfahan are shown in Tables 1 and 2, respectively. As can be observed in these tables, the total amount of waste generated annually in public dental centers and dental clinics of Isfahan is 117301.36 kg (74520.68-160072.26 for confidence interval [CI] 95%) and 22842.39 kg (14637.94-31044.84 for CI 95%) in 2011.

Thus, it was evaluated that more than 140 tonnes of dental waste is produced in Isfahan municipal dental health services annually.

The fraction of waste production in these dental services is presented in Figures 1 and 2. The maximum production rate

Table 1: Dental solid waste production in dental centers

Waste category	Average production rate (kg/year)	% by weight
Infectious and potentially infectious waste	**52867.72**	**45.07**
Blood and saliva contaminated gauzes and cotton rolls	6240.43	5.32
Latex and nylon gloves	37841.42	32.26
Saliva ejectors	6873.86	5.86
Sharps (dental tools, needles, syringes)	1372.42	1.17
Extracted teeth	539.59	0.46
Non-infectious waste	**14252.11**	**12.15**
Amalgam residues	199.41	0.17
X-ray films (lead foil and coating)	656.89	0.56
Impression materials (wax, alginate)	7988.22	6.81
Pharmaceutical waste	5407.60	4.61
Domestic-type waste	**50181.52**	**42.78**
Plastic	20457.36	17.44
Plasticized paper	10134.84	8.64
Paper and cardboard	16750.63	14.28
Food wastes	2099.70	1.79
Other	739.00	0.63
Total	**117301.36**	**100**

is related to infectious and potentially infectious wastes in both dental clinics and dental centers with 45.07% and 52.2%, respectively. The proportion of chemical and pharmaceutical wastes (non-infectious waste) was the lowest part of wastes with 12.15% and 8.58% in dental clinics and dental centers, respectively.

The average proportions of main heavy metals contain in amalgam alloys is shown in Figure 3. As can be observed in this figure the most significant part of amalgam is composed of mercury and silver. Table 3 represents the mean values and standard deviations of heavy metals that contained in amalgam.

DISCUSSION

According to the results of selected public dental clinics and using the number of referred patients to these centers, the total amount of each category of dental waste produced throughout the study were calculated. The average production rates of dental waste in dental clinics and dental centers were 142.17 g/patient/day and 160.84 g/patient/day, respectively. Whereas this amount was dissimilar in the rest of the world, for example in Xanthi, Greece 513 g/patient/day and for Qazvin, Iran 74 g/patient/day.[6,20] It seems that these differences in various studies are due to the classification of

Table 2: Dental solid waste production in dental clinics

Waste category	Average production rate (kg/year)	% by weight
Infectious and potentially infectious waste	**11923.72**	**52.2**
Blood and saliva contaminated gauzes and cotton rolls	1475.61	6.46
Latex and nylon gloves	9267.15	40.57
Saliva ejectors	769.78	3.37
Sharps (dental tools, needles, syringes)	155.32	0.68
Extracted teeth	255.83	1.12
Non-infectious waste	**1959.87**	**8.58**
Amalgam residues	15.98	0.07
X-ray films (lead foil and coating)	89.08	0.39
Impression materials (wax, alginate)	523.09	2.29
Pharmaceutical waste	1331.71	5.83
Domestic-type waste	**8958.78**	**39.22**
Plastic	2757.07	12.07
Plasticized paper	2574.33	11.27
Paper and cardboard	2983.21	13.06
Food wastes	541.36	2.37
Other	102.79	0.45
Total	**22842.39**	**100**

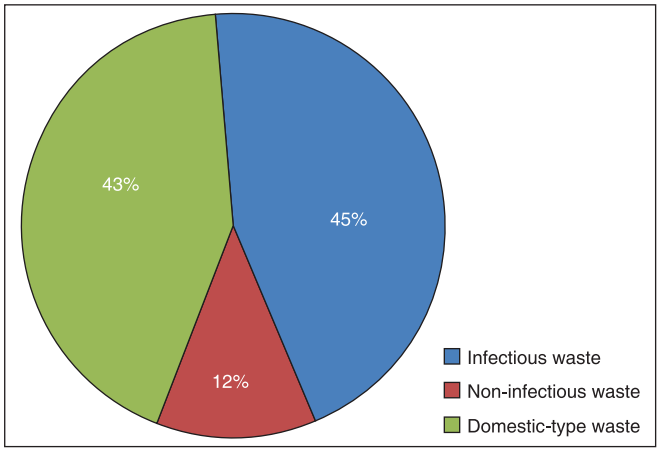

Figure 1: Classification and fraction of dental solid waste from the public dental health centers

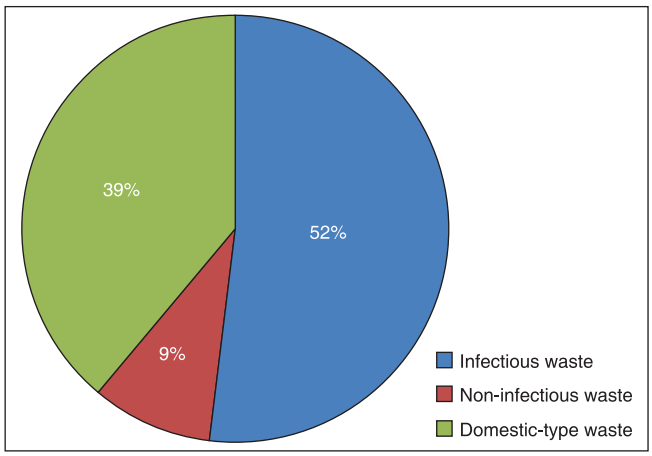

Figure 2: Classification and fraction of dental solid waste from the public dental health clinics

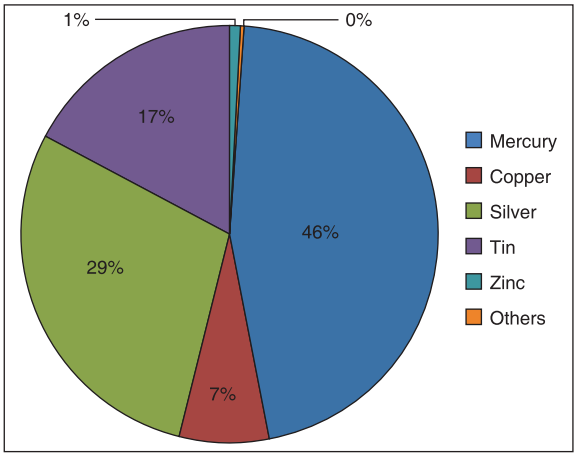

Figure 3: Major metal components of dental amalgam

Table 3: The mean values and standard deviations of heavy metals that contained in amalgam waste

Metal	Hg (%)	Cu (%)	Ag (%)	Sn (%)	Zn (mg/kg)	Ni (mg/kg)	Mo (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
Average	45.55	7.01	28.73	16.85	55.04	11.12	0.65	1.83	0.61	0.89
standard deviation	3.05	1.09	5.15	3.07	46.83	6.30	0.14	0.76	0.24	0.40

%: Weight percentage

dental wastes and study location. Statistical analysis revealed that there is a significant difference between the amount of produced dental waste in dental clinics and dental centers.

On average, about 28% of patients referring to dental centers required restoration using amalgam. Proportion of patients referring to examination and tooth extraction practices was approximately 47% and 15%, respectively. About 10% of referred patients needed more advanced procedures such as implant surgery, root treatments and other oral surgical procedures. The results of this study showed that more than 84% of public dental units do not have any plan for waste minimization and separation and classification of dental waste just conducted in 33% of public dental units. Statistical analysis revealed that there is no significant difference between the produced dental solid waste in dental clinics and dental centers, qualitatively.

Infectious waste

The production of infectious waste in the evaluated dental clinics ranged from 28.5% to 57.4% of the total amount of waste produced. Production rates of infectious waste in dental clinics and dental centers were 74.21 and 72.5 g/patient/d, respectively. The infectious waste category consists of blood and saliva contaminated gauzes and cotton rolls (12.37% and 11.8%), latex and polyvinyl chloride (PVC) gloves (77.72% and 71.57%), Saliva ejectors (6.45% and 13%), sharps (1.32% and 2.63%) and extracted teeth (2.14% and 1%) in dental clinics and dental centers, respectively. A comprehensive categorization of dental solid waste is provided in Tables 1 and 2. On investigation, the composition of dental solid waste, paper, plastics, latex gloves, masks and aprons were the four factions that exist in all clinics.

In accordance with Iranian health-care waste legislations, dental staffs should collect the needles in special enclosed containers (called Safety box) and placing it in the refuse bin. Nevertheless, it seems that these rules are not always adhered. The fraction of these constituents fluctuates among 0 and 4% in all the clinics for all of the sampling times; the overall average being 2.5% which over 72% of them were contaminated needles. Despite it was not expected to recover needles and sharps, sharp objects found in 9 samples included 14 anesthesia and 10 suture needles, eight endodontic files, five dental drills and seven scalpel blade. The main producer of discarded sharp instruments was dental centers; this would be due to the type of applied practices. The three waste fractions (needles, cartridges for anesthetic containment and extracted teeth) are related to teeth extraction practices in dental clinics.[6] In a tooth extraction operation, one up to three needles is typically required while in a tooth restoration one or no needles are applied.[6] Culturally, poor patients that refer to the public dental facilities prefer tooth extraction, rather than restoration which involves further time and expenditure.

It was also found that the highest amount of produced wastes in the municipal health clinics related to dental consumable items (such as latex gloves, protective covers, masks and gauzes) as reported in previous studies.[2,20] Glove production rates were 54.78 g/practice/d for the composite sample (all public centers), 57.67 and 51.88 g/patient/d for dental clinics and dental centers, respectively. The high production rate of gloves observed for dental clinics compared with dental centers may be due to that more dentist assistants cooperate with dentists in dental clinics.

Non-infectious waste

The production rates of chemical and pharmaceutical wastes (non-infectious waste) in dental clinics and dental centers were 12.2 and 19.54 g/patient/d. Chemical and pharmaceutical wastes included 0.8% and 1.4% (0.1 and 0.27 g/patient/d) amalgam residues, 4.5% and 4.6% (0.55 and 0.9 g/patient/d) radiographic films, 26.7% and 56% (3.25 and 10.95 g/patient/d) impression materials and 68% and 38% (8.3 and 7.42 g/patient/d) pharmaceutical wastes in dental clinics and dental centers, respectively. The important thing that observed about the chemical and pharmaceutical wastes is that in some dental health-care services intact or incompletely used containers of chemicals were placed into the trash accidentally.

Amalgam waste should be considered as toxic to living organisms and a hazardous part of dental solid waste that contains 49% mercury[6] and since mercury, silver, copper, zinc and other amalgam constituents are the most significant environmental contaminants this waste evaluated individually in our study. The generation rate of amalgam residues was 15.99 and 199.41 kg/year in dental clinics and dental centers, respectively. These amalgam production rates not included the amalgam constituent in the extracted teeth and the remaining amalgam in the capsules. The amalgam waste included 28.8% amalgam particles, 34.7% amalgam ampoules and 36.5% amalgam contaminated gauzes. The amount of amalgam waste discharged to the environment along with dental waste during 1 year was approximately 215 kg. This amount is apart from that discharged by wastewater originating from dental clinics. Although amalgam is collected and treated as hazardous waste in public dental centers, there are no regulations associated with amalgam management in Iran. However, amalgam waste must be collected and disposed separately and require control guidelines in the national regulations.

Finally, production rates of domestic-type waste were 55.76 and 68.8 g/patient/d, for dental clinics and dental centers, respectively. The domestic-type waste comprised 30.77% and 40.76% (17.16 and 28.02 g/patient/d) plastic, 28.73% and 20.2% (16.02 and 13.9 g/patient/d) plasticized paper, 33.3% and 33.4% (18.57 and 23 g/patient/d) paper and cardboard, 6.06% and 4.2% (3.38 and 2.88 g/patient/d) food wastes and

1.14% and 1.44% (0.63 and 1 g/patient/d) miscellaneous wastes in dental clinics and dental centers, respectively.

Domestic-type waste

The domestic-type waste mainly composed of plastic, paper and food wastes some of which are recyclable. As in previous studies conducted by other researchers.[4,6] In a study that carried out by Nabizadeh *et al*. on dental wastes composition in Hamadan, Iran the dental wastes were divided into 74 components. The highest amount of dental wastes was related to the infectious waste and domestic like wastes with 51.93% and 38.16%, respectively. The contribution of chemical, pharmaceutical and toxic waste had a total of 9.91%. The authors of this paper suggested that to improve the management of dental wastes, the waste minimization programs should be employed through using of materials with less hazards and smaller packaging.[19]

In a usual working day in public dental clinics in Isfahan generated 10.75 kg/d of dental solid waste, with 5.23 kg/d of this waste being infectious, 1.11 kg/d being chemical and pharmaceutical wastes (hazardous waste) and 4.41 kg/d domestic-type waste. The relevant amounts of sharps were 200 g/d and of amalgam waste 34.3 g/d [Tables 1 and 2]. The significant difference between the amounts of produced wastes in these dental clinics indicates that dental solid waste production rate differs significantly depending on the dental services.

Based on the population of the Isfahan in 2011, the production rate of dental waste during the research period on a per capita basis was approximately 0.09 g/person/day (on a 365 day/year basis). The existing records for household solid waste in Isfahan for 2011 was 568 g/person/day.[21] Although the dental solid wastes comprise only 0.016% of domestic solid waste in Isfahan, but this proportion was 0.007% in Xanthi, Greece.[6] Although this value seems insignificant compared with the amount of generated municipal solid waste in Isfahan, however considering special properties and hazardous potential of this wastes they need to be managed properly.

The largest producer of dental waste was dental centers. The significant difference between two groups of waste indicates that dental solid waste production differs significantly depending on the dental services.

The high production rate for dental centers was due to the large volume of removable appliances (e.g., dentures), which involve large quantities of gypsum, silicones, acrylics, mercaptans and other impression materials and relatively high weight of these materials.

This study indicated that latex and PVC gloves are the greatest portion of infectious dental wastes. The results of Ozbek and Sanin study illustrated that the most important constituent of these wastes was dental gloves which accounted for approximately 35% by weight of the waste.[2]

The larger production rate for extracted teeth and lower production rate for amalgam waste in dental clinics indicated that most clients of these clinics just refer for tooth extraction and most of the time the restoration practices implemented in dental centers. Indeed, these dental clinics are involved mainly in the oral examination and tooth extraction rather than tooth restoration.

Proposed management approach

Pollution prevention is the use of processes, procedures, materials, products or energy that avoids or reduces the formation of pollutants and wastes, at the source. The most important works which can be done in proper management of dental waste is prevention of mixing the dental wastes components with each other as well as using the equipment that produces less solid waste. Dental wastes components have different properties that each management approach should be based on these specifications. Thus, disposal of dental wastes to either blend and garbled doesn't seem very consistent and appropriate. Such waste must be collected separately and to be sterilized before disposal.

As indicated in the previous sections much of the generated waste in Isfahan dental centers constitute of domestic-type and infectious waste (up to 90%). Annually, about 59140.3 kg domestic-type waste is produced in Isfahan dental centers. Thus, with isolation of such waste from other parts of the dental waste and especially potentially infectious waste the volume of contaminated dental waste can be reduced by more than 42%. To decrease the waste quantity and management charges, paper, plastic and other uncontaminated components could be disposed or recycled as municipal solid waste.[2,4]

Another section of dental waste is potentially infectious waste that its annual production rate is 64791.5 kg in Isfahan dental centers. By segregation of these wastes from other wastes the total volume of generated dental waste is reduced by about 46% and more importantly, removal of this type of waste will significantly reduce the potential risk of dental waste.

The third category of dental waste is toxic waste or chemical and pharmaceutical waste which include 10% of total generated waste. This part contains toxic ingredients and chemicals while some of its components such as amalgam particles and lead foil of radiographic films are recyclable. Overall it can be said that this section of dental waste should be collected and disposed separately, specifically based on their characteristics and sometimes such as a hazardous material. In certain countries, such as Sweden has prohibited the use of amalgam in dental treatment. Moreover in the case of using amalgam, in order to reduce generation of additional amalgam in dental offices it's recommended using of capsule amalgam with the smaller capsules instead of powdered amalgam.[15] The other option is using the units equipped with amalgam filters for reduction of entrance the amalgam

to environment that unfortunately most of dental units within the country are without such facilities.

For proper management of dental wastes the waste minimization measures, waste segregation, recycling and reuse should be implemented as much as possible. Waste minimization measures can be performed through the use of materials and products with less hazardous potential and smaller packages.[6,19] Reduction of using the disposable materials as well as using the reusable materials and equipment can also be involved in reduction of dental waste generation.

Therefore, not only the training courses on waste reduction, recycling and waste segregation methods based on the waste characteristics must be implemented in the production source for dentists and dental staffs but also, the relevant organizations should provide certain rules and guidelines for collecting and disposal of this group of wastes. The authors suggested that for more appropriate management of dental wastes in dental clinics not only the waste generation rate should be minimized, but also after segregation of wastes at generation site amalgam and lead coatings should be collected separately and other waste components after sterilization should be disposed in a sanitary landfill.

CONCLUSION

Integration of infectious and hazardous waste with general waste leads to the amount of infectious waste appears much greater than it actually is. Then hazardous chemical and infectious wastes should be collected separately and particular disposal and recycling regulations should be used. The exception of this waste is management of amalgam waste that the collection and disposal of which is not regulated. To decrease costs and environmental impacts of dental solid waste the uncontaminated recyclable items especially plastic and paper fraction which contained approximately 33% of total dental waste should be recycled or reused. In public dental clinics needles are collected in special enclosed containers and placed into the trash in that form. Nevertheless, some syringes had uncovered needles, where they represent a serious damage to collecting workers, the public health and the environment. These results emphasize the demand for improving dental solid waste management, as well as waste reduction and recycling. It's expected that the results of this study encourage the dental health staffs to change their viewpoint about the existing dangerous waste material and therefore follow by the legal necessities and keep away from many harmful health and environmental impacts.

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