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Investigation and Evaluation of Air Pollution Risk Management in Hospital Incineration (Case Study: Hospital Incineration Plant of Tehran)

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Abstract. In this paper we investigate and evaluate environmental risk management in hospital incineration plant of Tehran and provide solutions to control and reduce environmental risks. Statistical computations indicated that environmental aspects with risk priority of more than 18.4 are at very high risk level. According to our results, 26.55% of environmental aspects are at low risk level, 19.8% are at medium risk level, 15.79% are at high risk level, and 39.9% are at very high risk level. For the last two (high risk level and very high risk level), reformative measures and risk management has been defined.

Keywords: Air pollution, risk management, hospital incineration, tehran.

1. Introduction

The growth of industry and development of modern medical services has given rise to some concerns about waste transmission, burial and recycling (Kay). As certain wastes are hazardous to the environment and human beings, broad investigations have been made all over the world and different standards have been designed for production, separation, transmission, burial and recycling of special wastes, particularly for biological and environmental analysis [2]-[26]. Investigations have demonstrated that certain wastes may endanger the health of people, particularly children [5]-[32], animals, environment, ground waters [16]-[23], air [20], and even plants [2]-[22]. The quality of water resources is especially important in arid regions such as Tehran. Each cubic meter of hospital waste may pollute 50 cubic meter of water. If necessary measures are not taken to control hospital wastes, water resources of Tehran will be at the risk of pollution. Although no activity can be absolutely free of pollution, efficient solutions should be provided to reduce and control pollutions caused by such activities.

The above facts reveal the importance of investigation about the impacts of industrial wastes. Hospitals use a great deal of chemicals, which may pollute surface waters if necessary measures are not taken. In this research, we investigate the effects of hospital waste on surface water resources in Tehran Province. We chose Tehran because it has the highest hospital concentration in Iran. Moreover, Tehran should be given more attention as it has a great population and is located in an environmentally critical situation. Our main objectives in this study are to identify chemical properties of hospital wastes in Tehran Province from the viewpoint of surface water quality criteria, introduce the most important effects of hospital waste on surface water resources, analyze negative impacts of hospital waste in Tehran Province on surface water resources and, finally, provide an efficient solution to locate hospitals.

2. Review of Literature

According to definition of Resource Conservation and Recovery Act (RCRA), hazardous waste is a combination of wastes which may cause a considerable prevalence of mortality due to quality, density, physical

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and chemical properties, and infection [4]-[31]. This occurs when the waste is not well treated, stored, transmitted and disposed (United Nations Environmental Protection Agency 2005). Also, according to report of Basel Convention (BASEK), hazardous wastes have such properties as radioactivity, infectiousness, explosiveness, and toxicity [28], [29]. Therefore, the wastes of medical centers, hospitals, and dental centers are among hazardous wastes due to having pathogens [2]-[13]. Hazardous medical wastes have been categorized into two groups: A) Infections and potentially infectious wastes and B) Non-infectious hazardous wastes [17]. According to WHO definition, infectious waste is some kind of waste which contains pathogens enough for causing disease in sensitive hosts [21]. Infectious wastes include blood and its products, pathologic wastes, tissues contaminated by microbial cultivation environments, syringe, used sharp tools, nasal discharge, phlegm and excrements of patients, and other waste materials produced in emergency ward, surgery room, and hospitalization places. According to regulations, there are four main types of medical waste: 1) infectious waste 2) sharp waste 3) chemical and pharmaceutical waste 4) ordinary waste (Islamic Republic of Iran EPA 2007).

The amount of waste produced in hospitals of Iran varies depending on the type of hospital and the services it provides. According to investigations made in different cities of Iran, however, the amount of waste in hospitals of Ahvaz, Tehran, Sanandaj, Tabriz, Rasht and Arak is respectively 2.54 kg/bed/day [18], [19], 2.87-4.4 kg/bed/day [6], [7], 1.92 kg/bed/day [9], 3.486 kg/bed/day [27], 4.438 kg/bed/day [1], and 2.9 kg/bed/day [6], [7]. Infectious waste constitutes 10.5-29.5% (up to 34.5% in some cases) of this amount. According to WHO report [32], the amount of daily waste produced in university hospitals is 4.1-8.7 kg/bed, in public hospitals is 2.1-4.2 kg/bed, and in regional hospitals is 0.5-1.8 kg/bed.

The ever-increasing growth of population has led to the increased consumption and waste production. Mass production and consumption, as an outcome of industrial revolution and modern technology, has transformed the life of people [31], [32]. Not only it has increased waste production, but also it has changed the nature of wastes and increased their quantity. In addition, a huge volume of different kinds of urban waste and thousands to tons of hazardous hospital and industrial waste has entered the environment giving rise to many problems. Waste production is one of the most important threats to the global health and to the environment. Besides, waste disposal and destruction has become a serious threat to urban environment. Tables 1 & 2 show hospital incineration equipment and their functions:

Table 1: The functions of air pollution control equipment in urban incinerator

Name	Function
Settling basin	A big basin next to combustion chamber which removes particles bigger than ash.
Barrier collectors	Plates of wet or dry brick or metal which are usually next to heat chamber. These plates remove particles with diameter of 50 mm or more by reducing their speed or by centrifugal force.
Detergents	Ash particles are removed by water drops. There are a variety of methods depending on the type of equipment.
Silicon separator	It separates dry ash particles by centrifugal force. In this method, particles are collected when contacting the wall.
Electrostatic precipitator	Ash particles are charged by electrodes and are collected by plates in a high voltage field. These particles discharge in collector plates and stick together. With a light knock on the plates, the particles fall down.
Bag filters	Gases produced by combustion are cleaned by these filters which are made of a variety of materials.

3. Research Method

To study air pollution parameters including NO2, SO2, CO, NO and O3, we selected chimneys nos. 1, 8, 12, 15 and 22 located at unit surface for sampling. We precisely located sampling place using EPA1 method. Next, we measured outflow speed and chimney diameter and spotted three points on the chimney in the distances of 17, 49.7 and 82.2 cm from chimney diameter. We fixed prop of the device at each of the points so that assessment values were accurately recorded on the display. Then we investigated pure air standard in the north, east, south and west of the site. First, we performed surrounding air particles (PM10) by portable photometer (model DUST TRAK) based on light assessment and standard BS-EN 12341. Aerosol photometer measured the amount of

light emitted from particles which are proportional to their density. The amount of light emitted from particles is a function of the size, shape and indexes of light. The amount and intensity of emitted light was shown in DUST TRAK display for the compounds of particles and aerosols. The obtained result is a function of the size of particles in unit densities. Particles emit less than 1 micron. In this method, we first calibrated the device and placed it in an appropriate position, a little above ground surface (1.5 m from the surface). Then we adjusted the flow and performed sampling for the specified duration. Considering the device capability, we measured the maximum, minimum and average of air particles in the volume unit. After measuring the particles, we measured internal air gases. To assess the gases NO2, SO2, CO, NO and O3, we used BABUC/A device which had replaceable electrochemical sensor. We transferred the parameters to the system based on voltage change, which were displayed in standard unit. Moreover, we measured hydrocarbon compounds using PHOCHEK5000 based on PID with 2% accuracy. Based on the results of data analysis and environmental study, we identified and assessed environmental risks by FMEA method. In the next paragraphs we present risk management solutions based on risk level. There are various methods for identification and assessment of environmental risks, each with certain advantages and disadvantages. In this study, considering the limitation in time and budget and for more concentration on qualitative results, we used FMEA method for evaluating environmental risks. Equation 1 determines the degree of risk.

Table 2: Comparison of different kinds of air pollution control equipment in urban incinerator

Collectors	Approximate space percentage	Approximate functionality percentage	Water quantity for collector	Waster pressure drop	Relative coefficient of execution cost
Settling basin	60	0-30	2-3	0.5-1	0.25
Multi-cyclones	20	30-80	Without water	3-4	1
60-Inch Cyclone	30	30-70	Without water	1-2	0.5
Detergents	30	80-96	4-8	6-8	2.5
Electrostatic precipitator	100	90-97	Without water	0.5-1	75
Bag filters	100	97-99.9	Without water	5-7	25

• Gallon/min per 1,000 cubic font/min
• Sometimes gases are cooled down before settlement by detergents or water spray

In this paper we investigate and evaluate environmental risk management in hospital incineration plant of Tehran and provide solutions to control and reduce environmental risks.

Table 3: Probability of environmental consequences in hospital incineration

Category	Rank	Description
Frequently	4	Occurs frequently during process.
Probable (medium)	3	Occurs several times during process.
Occasionally (low)	2	Occurs from time to time during process.
Rarely	1	Rarely occurs during the lifetime or hospital activities.

Tables 3-5 present the levels of severity, occurrence probability and detection probability. Table 6 determines the risk degrees.

4. Results

As you can see in Figure 1 below, the results obtained from measurement of gases emitting from the chimneys indicated that the amount of CO and other gases is less than standard limit and within acceptable range.

As you can see in Table 7 and Figure 2, the results of measurement of particles indicated that the amount of particles exceeds standard limit in northern and eastern sides of the site and is acceptable in other stations. The results obtained from assessment of aerosols indicated that the amount of aerosols exceeds the standard limit announced by Environment Organization.

Table 4: Severity of environmental consequences in hospital incineration

Category	Rank	Description
Disastrous	4	Irreparable destruction of resources; the lack of effective measures for its reduction and control; broad emission of pollution inside and outside the hospital; and frequent complaints from the concerned parties
Critical	3	Reparable destruction of resources with measures taken to control it; emission of pollutants inside the hospital; effectiveness of the event within organization; and consumption of natural resources
Medium	2	Consumption of natural resources with a little saving and production of pollutants in a part of the hospital
Low	1	Consumption of natural resources and production of inconsiderable amount of pollutants; effect on the surrounding environment of the hospital

Effect severity × occurrence probability × detection probability – risk degree

Table 5: Probability of detecting environmental consequences in hospital incineration

Category	Rank	Description
Undetectable	3	No system has been executed; there is no awareness about the environment; there is a lack of coordination with respect to environmental parameters; it is fully based on personal views.
Detectable with 50% probability	2	Environmental aspects have been identified and evaluated, but there is a lack of execution; evaluation is not reviewed but there is some control over the environment.
Detectable	1	Monitoring system works effectively; environmental control mechanism works well in the hospital and is fully able to detect and notify pollution.

Table 6: Determination of the degree and level of environmental risk in hospital incineration

Risk Degree	Risk Level
6-12	Average
12-18	High
18-24	Very high

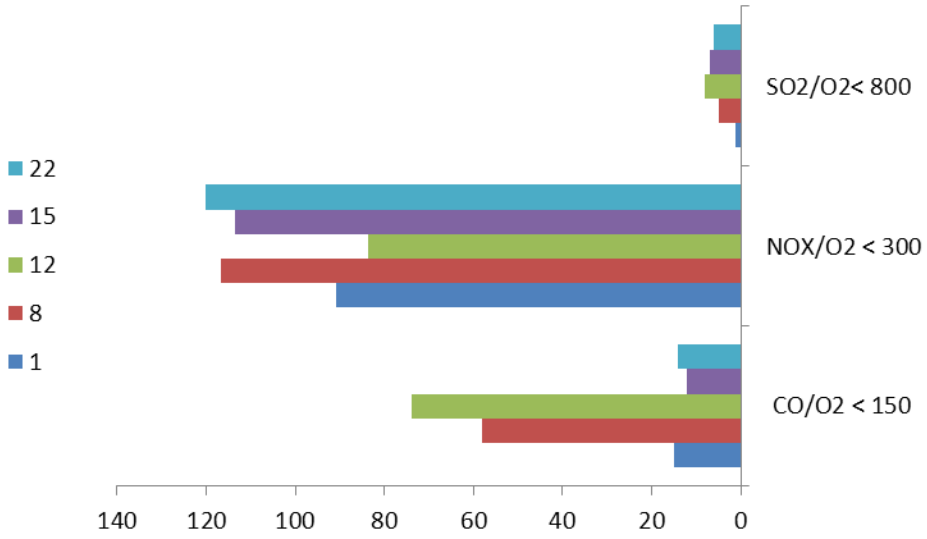

Fig. 1: Results obtained from measurement of gases emitting from chimneys

Table 7: Results of Assessment of Particles (PM10) based on pure air standards

Situation	Time (min)	Suction volume (m3)	Volume (m3/h)
Northern part	15	0.0255	0.102
Eastern part	15	0.0255	0.102
Southern part	15	0.0255	0.102
Western part	15	0.0255	0.102

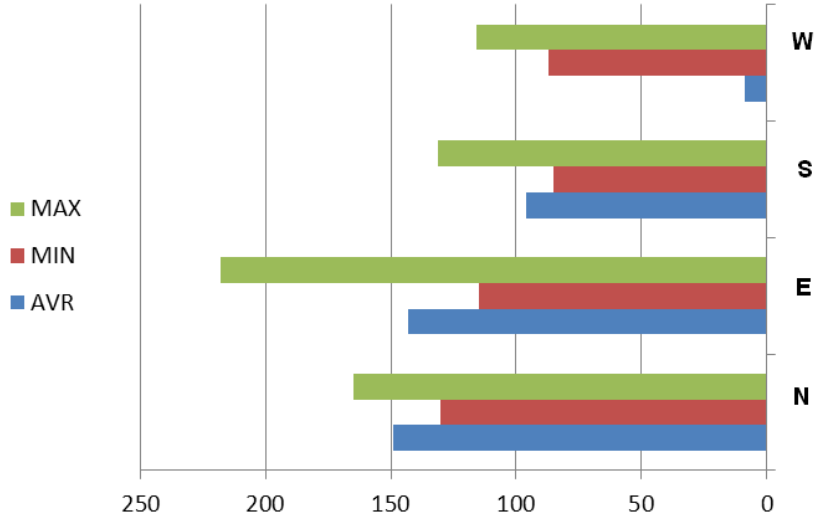

Fig. 2: Results of Assessment of Particles (PM10) based on pure air standards

Table 8: Assessment of environmental risks

Name of equipment	Intensity	Occurrence probability	Pollution range or recycling possibility	RPN	Risk Level
Settling basin	3	2	1	6	L
Solution	Incineration and recycling may be useful provided the materials are not chlorinated (chlorination is caused by gradual decay of pipe.)				
Barrier collectors	3	2	2	12	M
Solution	One of the methods is sodium hydroxide wash. This method is usually performed before incineration.				
Detergents	1	2	2	10	M
Solution	Neutralization by limestone in fluoride-calcium mud and sludge and calcium nitrate is an efficient method.				
Silicone separator	3	3	5	45	H2
Solution	It has a lower amount compared to coal. Separation and removal of certain substances from waste, which contain high levels of lead and cadmium, reduces toxicity of ash.				
Electrostatic precipitator	3	3	1	9	M
Solution	Chlorination of pond in order to control odorous oxidized compounds and bacteria. Fabric filters can displace more than 90% of organic materials.				
Bag filters	3	3	2	18	H1
Solution	These can be controlled by using calcium compounds. Advanced acid-gas scrubbers are able to control more than 90% of these compounds.				
Settling basin	3	3	2	18	H1
Solution	Advanced acid-gas scrubbers are able to control more than 60% of these compounds. Bag filters can absorb 90% of them.				

The assessment of environmental aspects in hospital incineration plant of Tehran indicated that certain activities exhibit a high risk level. According to our results, 26.55% of environmental aspects are in low risk level, 19.8% are in average risk level, 15.79% are in high risk level, and 39.9% are in very high risk level. Considering appropriate solutions to reduce the existing risks, we computed risk priority figure once again. As you can see in Table 8, almost all parameters under study are in acceptable range.

5. Conclusion

According to our results, 26.55% of environmental aspects are at low risk level, 19.8% are at medium risk level, 15.79% are at high risk level, and 39.9% are at very high risk level. By analyzing failure modes and its effects on the environment, we can identify the affected environment, estimate risk quantity and compare it with the existing criteria, and determine risk reduction measures. As a qualitative method, the analysis of failure modes and its effects on the environment is an efficient method in the development of products and identification of structures and important environmental aspects during product cycle or process. Since man plays the main role in sustainable development, efficient solutions need to be found to eliminate and reduce pollutants. Also, some methods must be used to prevent excessive waste and consumption of resources in line with environmental risks. Compliance with industrial standards, application of environmental policies, and the use of efficient managerial methods are among the measures which ensure the reduction of harmful impacts of industrial activities. Considering applicable standards with the highest risk priority of 189 and the lowest risk priority of 6, we can conclude that hospital incineration plant of Tehran, with highest priority risk of 26 and lowest priority risk of 5, enjoys a safe control system and relatively good environmental conditions. However, control measures must be taken in cases where the equipment is at very high risk.

6. Recommendations

In general, the following measures have to be taken in order to reduce air pollution risks:

1. **Appropriate Location:** Incineration plant must be located in an area with reasonable distance from pollution sensitive regions. Based on topographical conditions, incineration plant must be located in an appropriate area to enable broad emission of gases so that they do not remain in air.
2. **Chimney Height:** Chimney must be tall enough to enable the thinning of gases and particles before settling on the ground. Tall chimneys play an important role in the thinning of gases and reduction of pollution. Brink and Croker's experimental models are used to design chimneys.
    a. Chimney must be at least 2.5 times taller than the buildings nearby, in order to allow for turbulence.
    b. The gases emitting from chimneys with the height of less than 60 m and diameter of less than 1.5 m come back to the ground and increase pollution density.
    c. Speed of gases emitting from chimney must be more than 60 foot/sec so that they go up speedily.
    d. Tall chimneys reduce density of pollutants in ground surface. This density has a negative relationship with chimney height.
3. **Selection of appropriate waste to be fed by incinerator:** As far as possible, those kinds of wastes capable of being destructed by appropriate technologies should be separated. An example is separation of plastic which helps to control carbon dioxide. Another example is separation of batteries and thermometers in order to prevent the emission of heavy metals such as mercury.
4. **Installation of air pollution control equipment to reduce gases and particles:** Different kinds of equipment should be used to control air pollution caused by emission of gases and particles.
5. Monitoring the incinerator in order to control air pollutants caused by incineration, including NO, NO2, SO2, PM10, VOCs, TSP and HCI.
6. Weekly monitoring program to control heavy metals such as Mo, Ni, Pb, Ti, V, As, Cd, Co, Cr, Cu, Hg, polycyclic aromatic hydrocarbons, dioxins and furans (PCDDs/Fs), and BTEX organic compounds (gasoline, toluene, ethyl benzene and xylene.

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