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[Research]

A theoretical framework for determining environmental costs, benefits, and the net welfare effects associated with hazardous waste management

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ABSTRACT

This paper reviews and presents a theoretical model to determine the costs, benefits, and welfare effects of hazardous wastes management. According to the Iranian law, environmental costs are assigned to waste producing firms. However, in practice, due to weak enforcement programs, firms do not pay any environmental costs. Using the basic principles and logic of welfare economics, we present a micro-level model for analyzing an industry that generates waste as a by-product of its production process. Firms in the industry choose the least cost method of disposal (either legal or illegal disposal). By utilizing various figures of presented models in partial equilibrium structure we found R'_1, R'_2 and R'_3 which are the net welfare effect of producing firms, the net welfare effect to firms supplying legal waste disposal services and the net welfare effect of the environmental damage, respectively. By analyzing the presented figures we concluded that government regulatory policy may ideally lower environmental costs via a subsidy program.

Keywords: *Hazardous waste, Legal and illegal disposal, Environmental cost and benefits, Subsidy program.*

INTRODUCTION

An important issue in drawing environmental policy is the assignment of costs for hazardous waste disposal. Iranian Environmental Protection Agency (IEPA), under provision of laws makes wastes generators (producing firms) pay all costs (private and environmental costs) associated with waste disposal (Saed and Tila, 2009). This provision also gives IEPA a broad power to enforce the law. In practice, however, due to weak enforcement programs, the Act does not fulfill the intention of law makers.

The liability policy of Environmental Protection Agency (EPA) and IEPA has a number of efficiency effects (E.P.A., 1998). On the positive side, the increase in the cost of managing wastes narrows the gap between the marginal private cost and marginal social cost of disposal, generating efficiency gains as the volume of waste disposal decreases. On the negative side, the policy decreases the relative cost of illegal disposal, causing an increase in the volume of illegal disposal, generating efficiency losses (Sullivan, 1997; Dewees, 1998).

There are no precise estimates of the magnitude of the illegal disposal of hazardous wastes, and the environmental costs associated with the problem may be substantial (E.P.A., 2008). The Environmental Protection Agency has estimated that $\frac{1}{7}$ of hazardous waste generators (producing firms) dispose their waste illegally (E.P.A., 2008). Such disposal can cause air, water and soil pollutions. Wastes are sometimes incinerated incompletely, causing air pollution. The dumping of wastes onto land can affect health through dermal exposure and ingestion, as may be the case for children playing in dioxin- contaminated soils. Land pollution can affect agriculture and silviculture through plant intake from contaminated soil, and can lead to the pollution of ground water.

While precise estimates of the environmental costs of illegal disposal are not available, there are estimates of the costs of restoring improper and illegal disposal sites. It has been estimated that, the clean-up costs for Love Canal, will exceed the cost of proper disposal by at least 750% (Magorian and Morall, 1999; Tieteberg, 1999).

The objective of this paper is to review and present an economic model of hazardous disposal, and determine the costs, benefits, and the net welfare effects associated with hazardous waste management. Since marginal cost pricing of illegal disposal is impractical, efficiency losses in one or more of the three markets (for legal, illegal disposal, and the victims) are inevitable.

Method

Using the basic principles and logic of welfare economics, we present a micro-level model for a Partial Equilibrium Analysis. This model considers an industry that generates waste as a by-product of its production process. Firms in the industry choose the least cost method of disposal (either legal or illegal disposal). Public policy determines the prices of both legal and illegal disposal: legal disposal may be subsidized, and the expected cost (price) of illegal is determined by the enforcement effort (Steven and William, 1993; Tietenberg, 1999; Layard and Walter, 2007).

Consider first the determination of the cost of legal disposal. This market is illustrated by Fig.1. Let C_p represents the marginal private cost of waste disposal, C_n is the sum of imputed liability cost, C_s is the marginal environmental cost of disposal, and H (D) is the derived demand curve for disposal (the marginal environmental benefit of legal disposal).

Point X is the market equilibrium if only the marginal private cost of waste disposal is covered by the waste generator. The equilibrium price and quantity are then P'' and D''_w respectively. But if the full marginal environmental cost is covered by waste generating firm along with the marginal private cost, (by regulatory waste disposal business through liability rules) then market equilibrium occurs at point E with equilibrium price P' and quantity D'_w.

An intermediate situation can also arise in the market for legal waste disposal as shown in Fig.1. It is possible that the waste generating firms will pay all of the marginal privet costs of waste disposal but only a fraction of the marginal environmental cost. This possibility is represented by the C_n schedule shown in Fig.1. The market equilibrium now occurs at point G with an equilibrium price of P and equilibrium quantity of D_w. It is assumed that point X represents the initial equilibrium, and that point G describes the equilibrium point in the legal disposal market created by government policy (subsidy).

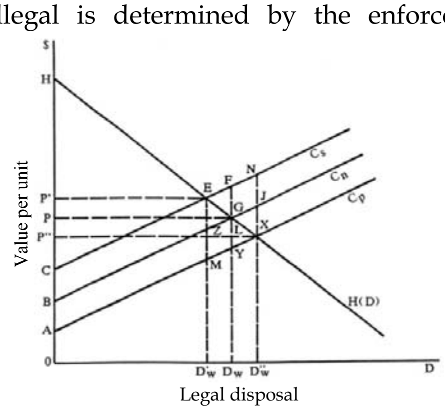


Fig 1: Legal disposal market

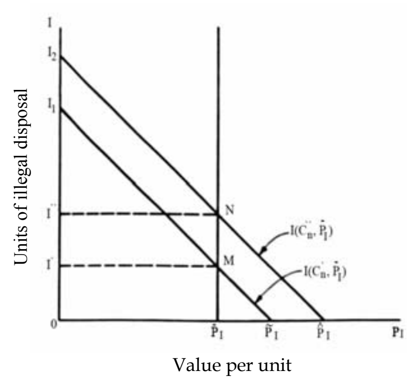


Fig 2: Illegal disposal market

Illegal market is illustrated by Fig.2. It hypothesized that waste generators have demand for illegal as well as legal waste disposal. This implies, moreover, that these waste generating firms receive benefits from having access to illegal disposal. The demand for illegal waste disposal depends on two factors:

1- The policy cost of illegal waste disposal and the policy cost of legal disposal, paid by the waste generators, C_n-C_p. The policy cost of illegal waste disposal is determined by governmental programs. Increasing the policy cost of legal waste disposal paid by the waste generators causes the demand for illegal waste disposal to shift to the right.

2- P, the policy cost of illegal waste disposal, is assumed to be constant in this situation. Increasing cost of legal waste disposal generator means that the demand for illegal waste disposal increases I' to I".

Illegal waste disposal activities also imply the possibility of environmental damage which is associated with marginal environmental costs as well. Discussion and measurement of these costs are based on Fig., 3. The marginal environmental cost of illegal disposal consists of two components. The first one is the volume of illegal disposal. In Fig., 3, there are two volumes: I' associated with P" in Fig., 1, and I" associated with P in Fig., 1.

The second component is the cost of the resources required to make the external effect, harmless to third parties (victims) affected by illegal disposal. These costs are assumed to be a single value per unit, that is, the per unit cost is assumed to be $\psi\ C_s$, where ψ measures illegal disposal costs, as a fraction of legal disposal costs, ψ can be greater than one. The exact relationship between $\psi\ C_s$ and P_I (price of illegal waste disposal) is not known on a priority basis.

Environmental cost per unit

Fig 3: Environmental cost in the illegal market

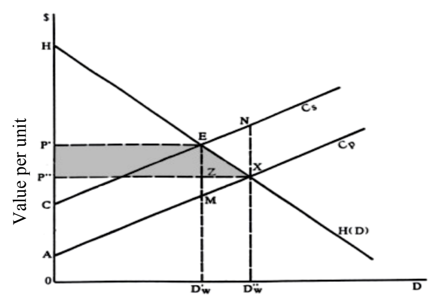
RESULTS

As noticed, the price increase for legal disposal (from P" to P' by government regulatory action) may cause a welfare loss (consumer surplus) equal to the area P"P'EX (Fig; 4). This area can be determined by the following expressions 1, 2 and 3:

$$EX\,P''\,P' = EZ\,P''\,P' + EXZ \quad (1)$$

$$EZ\,P''\,P' = O\,D'_w\,EP' - O\,D'_w\,ZP'' = H(D'_w) \times D'_w - P'' \times D'_w \quad (2)$$

$$EXZ = D''_w\,D'_w\,EX - D''_w\,D'_w\,ZX = \int_{D'_w}^{D''_w} H_{(D)}\,d_D - P''(D''_w - D'_w) \quad (3)$$



Legal disposal

Fig 4: Benefit received by firms in the legal market with no subsidy program

This price increase encourages waste generating firms to discard their waste illegally, hence, demand for illegal market increases from I' to I"(Fig., 5). When the demand for illegal disposal is $I(C'_n, \bar{P}_I)$, total benefit for the waste generating firms is equal to area OI'M$\tilde{P}_{I'}$, while the total cost of illegal disposal is equal to area OI'M $\bar{P}_I$. Therefore a net benefit is equal $\bar{P}_I$M$\tilde{P}_I$. But if demand is $I(C''_n, \bar{P}_I)$, then total benefit is OI"N$\tilde{\bar{P}}_I$and total cost is OI"N$\bar{P}_I$. This implies a net benefit of $\bar{P}_I$N$\tilde{\bar{P}}_I$. Thus, increasing demand for illegal waste disposal from I' to I" implies that, the waste generating firms receive an increase in net benefit equal to the area $\tilde{P}_I$MN$\tilde{\bar{P}}_I$ (Fig., 5). This area can be determined by expression 4:

$$\tilde{P}_I MN \tilde{\bar{P}}_I = \int_{\bar{P}_I}^{P_I} I(C_s, \bar{P}_I)\,d\bar{P}_I - \int_{\bar{P}_I}^{P_I} I(C_p, \bar{P}_I)\,d\bar{P}_I \quad (4)$$

The net welfare effect of changing waste disposal from legal to illegal waste disposal may be formulated by using figures 6 and 7, in expression 5:

$$R'_1 = -\{[H(D'_w) \times D'_w - P'' \times D'_w] + [\int_{D'_w}^{D''_w} H_{(D)}\, d_D - P''(D''_w - D'_w)]\} + [\int_{\bar{P}_I}^{\hat{P}_I} I(C_s, \bar{P}_I)\, d\bar{P}_I - \int_{\bar{P}_I}^{\hat{P}_I} I(C_p, \bar{P}_I)\, d\bar{P}_I] \quad (5)$$

When price of legal disposal is at P", benefits (in terms of producer surplus) received by his firms is equal to the area XAP" (Fig., 6). But, if the full marginal environmental cost is covered by waste generating firms along with the marginal private cost, then price of legal disposal goes up to P', hence, benefits received by legal disposal service firms is equal to the area ECP′ in Fig.7. Therefore, the net welfare effect to firms supplying legal waste disposal services is (expressions 6, 7 and 8):

$$R'_2 = -ECP' + XAP'' \quad (6)$$

$$R'_2 = -EP'OD'_w + ECOD'_w + ZP''OD'_w - MAOD'_w + XZD'_wD''_w - XMD'_wD''_w \quad (7)$$

Or

$$R'_2 = -(C_s(D'_w) \times D'_w) + \int_0^{D'_w} C_s(D)\, dD + (P'' \times D'_w) - \int_0^{D'_w} C_p(D)\, dD + (P''(D''_w - D'_w)) - \int_{D'_w}^{D''_w} C_p(D)\, dD \quad (8)$$

Base on Fig.1, when legal waste disposal activity is equal to D''_w , the associated level of environmental cost is equal to the area ACNX (expression 9). Assigning the full environmental cost of legal disposal to waste generator firms, may result in a reduction in environmental cost equal to ACEM (expression 10); with an overall cost reduction equal to the area MENX (expression 11).

$$ACNX = OCND''_w - OAXD''_w \quad (9)$$

$$ACEM = OCED'_w - OAMD'_w \quad (10)$$

The net welfare effect of illegal waste disposal because of price rise from P" to P in the legal market is shown by I'I"AB in Fig., 9. The area of I'I"AB may be calculated by knowing marginal private cost equation and marginal environmental cost equation (expressions 12, 13 and 14).

$$MENX = \int_{D'_w}^{D''_w} [C_s(D) - C_p(D)]\, d_D \quad (11)$$

$$I'I''AB = \psi C_s[I(C_s, \bar{P}_I) - I(C_p, \bar{P}_I)] \quad (12)$$

$$R'_3 = MENX - I'I''AB \quad (13)$$

$$R'_3 = \int_{D'_w}^{D''_w} [C_s(D) - C_p(D)]\, d_D - \psi C_s[I(C_s, \bar{P}_I) - I(C_p, \bar{P}_I)] \quad (14)$$

In order to avoid the environmental cost, some environmental economists support a subsidy at a rate based on the value of ψ Cs. Suppose this subsidy levied at point G in Fig. 10. Theoretically, this subsidy should reduce the environmental costs in legal market by the area YFNX. This subsidy might also reduce the environmental cost in illegal market by area I"'I"A'B showed in Fig. 9.

The area of FNXY (Fig., 10) and the net welfare effect of illegal waste disposal on the extra units occurred from price rise from P" to P in the legal market are shown in the Fig.10 and by I'I"AB in Fig.9.

From Fig.10, we have (expression15):

$$FNXY = \int_{D_w}^{D''_w} [C_s(D) - C_p(D)]\, d_D \quad (15)$$

From Fig. 2 and 10 (expression16):

$$I'I''AB = \psi C_s[I(C''n, \bar{P}_I) - I(C'n, \bar{P}_I)] \quad (16)$$

Where ψ Cs represents the externality cost per unit of illegal waste $[I(C''n, \bar{P}_I) - I(C'n, \bar{P}_I)]$ represents the change in the demand for illegal disposal for a fixed unit price of illegal disposal ($\bar{P}_I$).

Substituting expressions 15 and 16 in expression 17 (i.e. the net welfare effect of the environmental damage) yields expression 18.

$$R_3 = FNXY - I'I''AB \quad (17)$$

$$R_3 = \int_{D_w}^{D''_w} [C_s(D) - C_p(D)]\, d_D - \psi C_s[I(C''n, \bar{P}_I) - I(C'n, \bar{P}_I)] \quad (18)$$

DISCUSSION

This paper gives a short review about a micro-level model to analyze an industry that generates waste as by-product of its production process. It was demonstrated that, when price of waste disposal in the legal market is raised from P" to P, the legal amount of disposal is at its lowest level D'_w (Fig.1). In a laissez - faire situation, this leads to a loss in consumer's surplus (generating firm being as consumer of waste disposal service) equals the area P"P'EX. This also leads to waste generators to increase their demand for illegal disposal, results increase in net benefit equals the area $\bar{P}_I MN \hat{P}_I$ (Fig. 2). Illegal waste disposal also implies the possibility of damage which is associated with marginal environmental costs. The welfare loss of disposal on extra units occurring because of the price rise from P" to P in the legal market is equal to the area I'I"AB (Fig.3). In the absence of an environmental cost assignment policy, the environmental cost associated with legal disposal is equal to ACNX. Assigning the environmental cost of legal disposal to waste generators via provision of law, could result in a reduction in environmental cost equal to ACEM; with an overall cost reduction equal to the area MENX. This assignment also encourages illegal waste disposal, leading to an environmental damage equal to area I'I"AB. In order to minimize this cost, some countries adapted a sharing liability policy or a subsidy program.

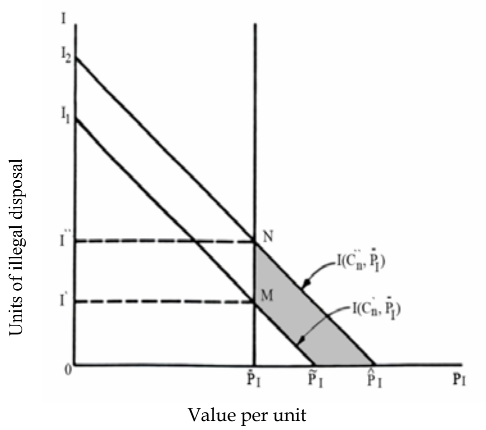


Fig 5. Benefit received by waste generating firms in illegal market

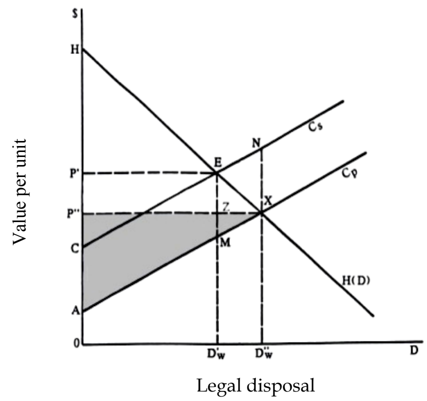


Fig 6. Benefit received by waste disposal service firms before regulation

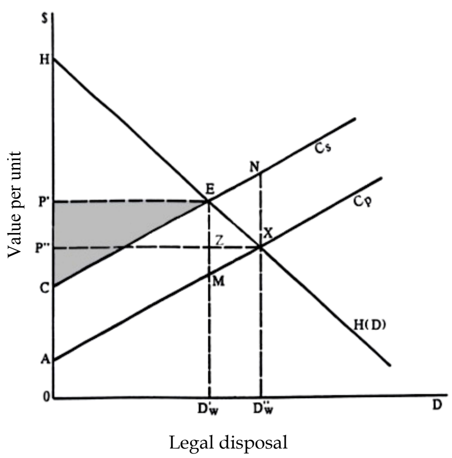


Fig 7. Benefit received by waste disposal service firms after regulation

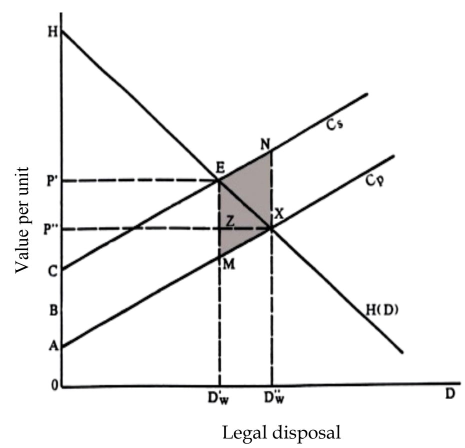


Fig 8. Environmental cost in the legal market without subsidy

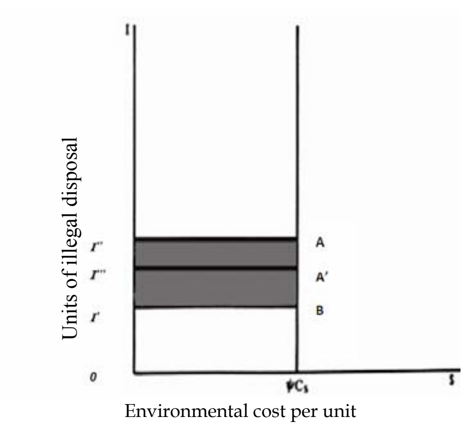


Fig 9. Environmental cost as the result of regulation without subsidy

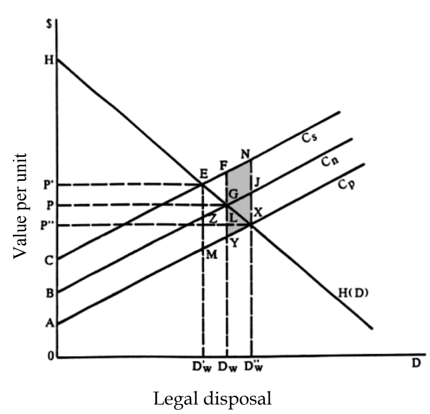


Fig 10. Environmental cost in the legal market with subsidy

Menhaj (1994) found that any policy raising the cost of legal waste disposal is likely to induce at least some illegal waste disposal. If it does then optimal liability for legal waste disposal is likely to be less than the full liability. A lower value for the optimal liability share may require a subsidy of waste generators by government. In assigning subsidy, some should consider the value of ψC_s (Menhaj, 1994).

One implication of this model is that, authorities have to be concerned by devising policies to reduce the impact of hazardous waste disposal on communities composed predominantly of low-income families. The evidence from Kiel and Zabel (2001) supports the idea. They investigate the cost effectiveness of Superfund for cleaning up the abandoned hazardous waste sites. By using the hedonic approach to the two Superfund sites in Woburn, they found that, the benefits from cleaning these sites are greater than the present value of the estimated costs. Thus, the cleanup of these two sites results in positive net benefits to society (Kiel and Zabel, 2001).

In this context, Ronald et al (2002) studied the question of environmental equity for the metropolitan New York City region. For this purpose, they investigated the socioeconomic status, particularly racial/ethnic population bear a disproportionate of hosting undesirable environments. They found that, racial/ethnic demo-graphics, in particular the Hispanic percentage of a tract's population are significantly associated with the presence of potentially environmentally adverse effects (Ronald et al, 2002). Smith et al (1998) identified the main types of economic impacts that may be associated with hazardous waste management sites. They provided rough estimates of these sites potential magnitude based upon data for existing sites. They also described ways in which adverse impacts have been prevented, or mitigated, or compensated in communities that have addressed these issues (Smith et al, 1998).

Regarding illegal waste disposal, there are no precise estimates of the magnitude of the hazardous waste. However, the environmental costs associated with the problem may be substantial. Dumping of wastes into sewer systems and surface water can pollute water resources. The dumping of waste onto land can affect health through dermal exposure and ingestion. Since there are not available data for these damages and most of the damages are qualitative, the assessment of these costs is difficult. That is, why the precise estimates of the environmental costs of illegal disposal are not available (Magorian and Morel, 2005).On the other hand, there are estimates of the costs of restoring improper and illegal disposal sites. The U.S office of Technology Assessment estimates that costs will total $100 billion to restore illegal and improper disposal sites (O.T.A., 2007).

In 1998, Morris made a comparison between the existing environmental laws in some leading industrial countries. He found that, the United State of America has more success in managing hazardous waste, because of rigorous laws and enforcement policies. He then concluded that, America possesses better comprehensive laws relative to other industrialized nations. As Morris and other investigators noticed, if provision of laws is supported by precise enforcement programs as well as not supported by government aids (i.e. subsidy), the problem with environment damage is a continuous process (Morris et al, 1998).

For the type of waste generated by the metal disposal cost at Casmalia Resources (in Santa Barbara County, California, U.S.A) Sullivan estimates $17 per barrel; the corresponding figure for BKK corporation (in west Covina, California, U.S.A), the author estimates about $25.These correspond to the private costs of disposal; allowing for some external cost of legal disposal. The marginal environmental cost of legal disposal from this analysis is about $30. However, the author’s estimate for the marginal environmental cost of illegal disposal is about $255 (Sullivan, 1997).

Ultimately, the usefulness of this model in public policy debates rests on subsequent empirical estimation of the demand and supply functions for hazardous waste disposal, the environmental costs associated with handling this hazardous waste, and the appropriate welfare gains and losses of affected parties. Therefore, value of the characteristics such as; price elasticity of demand for waste disposal, elasticity of C_p, elasticity of P_I, multiplier for illegal-disposal cost(ψ), marginal environmental cost of disposal are key to the issue. By having the values of these parameters and using a simple programming language, one could approximately calculate the area $\widetilde{P}_1MN\widehat{P}_1$ (Fig., 5), area YFNX (Fig., 9), area I'I"AB (Fig., 10), and area MENX (Fig., 8). Using these calculated figures, we may be able to estimate the value of R'_1, R'_2, R'_3 and R.

The value of the enforcement budget that affects the price of illegal disposal is important in this context. There is perhaps enough policy interest in direct means of reducing illegal disposal, however further research on this aspect of the problem is needed. Policy makers may want to know, for example, if it is cheaper to subsidize legal disposal as a means of reducing illegal disposal than it is to spend more money on law enforcement for that purpose.

The analysis described in this paper could be used by Iranian policy makers to determine the appropriate liability policy and subsidy for hazardous waste management. For practical application the policy makers need:

- Having legal disposal sites; through establishment of certain special locations, to handle and discard hazardous wastes technically and legally. These places can provide maximum care for having relatively safe and clean environment.
- Passing new legislations which provide IEPA with a broad power, different outlook more departments, duties and staffs.
- Having comprehensive pieces of legislation for administrating the business of hazardous wastes. For instance, RCRA type of act should be the role model for countries like Iran having growing population, over consumption behavior, and rich natural and mineral resources.
- Monitoring and enforcing the law rigorously is the key to success of each piece of legislation. Unfortunately Iranian legislations are carried out with weak enforcement programs. The cause of weaknesses could be several issues. The most important one, however, is the financial issue. Therefore, financial enforcement and budgeting for enforcing the environmental laws ought to be on the priority list in the national budget.

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ارائه الگوهای نظری برای تعیین هزینه‌ها و منافع محیط زیستی جهت مدیریت پسماندهای ویژه

م. ع. عبدلی، ب. توکلی و م. ح. منهاج

چکیده

این مقاله ارائه کننده الگویی نظری برای تعیین هزینه ها و منافع محیط زیستی به منظور مدیریت پسماندهای ویژه است. در ایران، طبق قانون هزینه های محیط زیستی مربوط به این نوع از پسماندها برعهده تولید کنندگان است، اما در عمل به دلیل نقص و ضعف در اجرا و نظارت صحیح قانون ، صاحبان صنایع به ندرت این هزینه ها را تقبل می کنند. در این مطالعه با استفاده از اصول اساسی علم اقتصاد و منطق اقتصادی، مدل هایی ارائه شده که منافع گروه های ذینفع جامعه را تحلیل می کند. صاحبان صنایع معمولا ارزان ترین روش (دفع غیر قانونی) را برای دفع این نوع پسماند انتخاب می کنند. با بکارگیری الگو های متفاوت برگرفته از الگوی ارائه شده، R'_1 ، R'_2 و R'_3 تعیین شدند که به ترتیب عبارت از اثر خالص رفاه برای تولید کنندگان پسماند ویژه، اثر خالص رفاه بر موسسات خدمات دفع و اثر خالص بر گروه های آسیب پذیر مراکز دفع غیر قانونی می باشند. تحلیل ها و بحث بر روی نمودارها بر اثر سیاست های حمایتی دولت (پرداخت یارانه) نشان داد که سیاست های انظباطی (در چهارچوب قوانین جامع مصوب) می تواند هزینه‌های محیط زیستی را کمتر نماید.