APPLICATION OF HAZARD RATING SYSTEM FOR PESTICIDES USED IN A WATERSHED OF ISTANBUL, TURKEY

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ABSTRACT
The paper refers to the application of toxicity, human health, and persistency (THP) hazard rating system for the aim of determining the overall relative risk levels of pesticides. The agricultural land within the outer long-range protection zone of a drinking watershed of Istanbul is selected as the target area which is mainly devoted to grain and vegetable production. Two pests are chosen for the application of the ranking system which has been slightly modified by the addition of a consumption factor calculated by the authors. All the substitute pesticides available are ranked from best to worst with orders of magnitude difference among themselves. At the end of the field survey and the application of the ranking system, it is clearly seen that those pesticides that are preferred to be applied in the area against the two pests are the ones with comparatively higher overall risk levels. However, they are favoured because of their lower prices. Such a ranking system may be used as a simple and valuable tool that puts forth rather significant findings in the selection of the most environmentally friendly substitute against a certain pest, especially in developing countries still facing misuse and/or unconscious use of pesticides.

Keywords: Hazard rating, Istanbul, Pesticide, Relative risk level, THP

INTRODUCTION
Pesticides are consumed on agricultural land to protect crops and plantation from probable pests, diseases and weeds that might decrease productivity. It is well known that pesticides, besides their benefit to production, are considered as important diffuse sources of pollutants. Misuse and/or unconscious use of pesticides lead to contamination of both land and water. Therefore, selection of the most appropriate pesticide against a certain pest in an agricultural land needs to be determined prior to application regarding both environmental and agricultural aspects.

Pesticides with similar and/or identical agricultural characteristics bear different properties in terms of environmental impacts. In some pesticides, the difference becomes even more significant. Therefore, it is possible to choose a less harmful substitute to environment while obtaining the same agricultural efficiency. The decision on selection of the appropriate pesticide requires a ranking system (Yazgan and Tanik, 2002).

There are several ranking systems used for comparison of relative hazard levels of chemical substances. Many scientists have referred that it is impossible to develop a single hazard ranking system covering almost all harmful aspects of pesticides, and they have advised not to use such a hazard rating. Others have realised these difficulties, but have considered that it is necessary for decisions to be made and that some guidance on priorities is needed. Such guidance may not necessarily be related to remedial action, but simply aimed at an effort on a careful detailed study of the problems resulting from the existence of a specific substance in environment. In case of using pesticides in agricultural land to cope with pests, such a ranking system would be beneficial in determining the most environmentally friendly alternative among its substitutes. It is important to note here that the regional and local conditions like topographical situation and soil characteristics of the area of concern and the external conditions prevailing at site like the climatic conditions together with the availability and cost of pesticides also affect the selection process.

In this study, the ranking procedure for selection of appropriate pesticides for environmentally acceptable crop production will be described on a case study. The agricultural land selected as the target area is located within the boundaries of a watershed in the Greater Metropolis Istanbul, Turkey, where the ranking system is applied for all the alternative pesticides that may be used for two specific pests and plant disease, and the relative risk levels of each similar pesticide is presented. The main target of the study is to present the findings of the ranking study to both the farmers and local authorities of the region by emphasising on the significance of such a pre-determination process that is especially a valuable tool for a developing country.

HAZARD RATING SYSTEM (THP) -FOR SPECIFIC WATER POLLUTANTS
The system used in the study is toxicity, human health, and persistency (THP) Hazard Rating System developed by Organisation for Economic Co-operation and Development in 1982. It has been developed for specific water pollutants such as pesticides to compare and rate their hazard degrees in the environment. The purpose of the system is to provide a quantitative method of categorisation and ranking of pollutants that might even deteriorate the receiving water quality as well as land according to the hazard which they pose to humans, wildlife and the overall ecosystem. It is expressed as a THP rating system that is based on measurable factors of toxicity, hazard and persistence to give an overall numerical rating. This quantitative rating is enriched by a magnification factor (+) which indicates that the compound is

bioaccumulated, and by an indicator "c" for carcinogenic compounds to emphasise on their carcinogenic effect (DHRSWP, 1982)

It is proposed that the rating should be on a logarithmic scale related to the concentration at which the specific water pollutant causes damage in the aquatic environment, is a hazard to human health, or, if it is persistent, to the rate of degradation of the substance in the environment except bioaccumulation which is difficult to quantify. The THP rating system will be a composite of 3 numbers separated by a colon and followed by a symbol indicating those substances, which are bioaccumulated. Table 1 states the components of the THP system, and each of the components will be briefly described.

Table 1. THP system (DHRSWP, 1982)

LC_{50}	T (toxicity)	LD_{50}	H (hazard to human health)	$T_{½}$	P (persistance)
10^{0} g/l	0	10^{0} g/kg	0	0-1 days	0
10^{-1} g/l	1	10^{-1} g/kg	1	2-10 days	1
10^{-2} g/l	2	10^{-2} g/kg	2	11-100 days	2
10^{-3} g/l	3	10^{-3} g/kg	3	100-1000 days	3
10^{-4} g/l	4	10^{-4} g/kg	4		
10^{-5} g/l	5	10^{-5} g/kg	5		
10^{-6} g/l	6	10^{-6} g/kg	6		
10^{-7} g/l	7	10^{-7} g/kg	7		

Toxicity to the aquatic environment

This value is based on the lowest concentration at which the specific water pollutant has an adverse effect on the aquatic environment. The rating proposed is numerically equal to the negative logarithm to the base 10 of the concentration expressed in g/l. This concentration is the 4-day, lethal concentration value, LC_{50}. Clearly, the long-term chronic, and/or sub-chronic impact of pollutants are of high importance to humans, either as a result of direct exposure by ingestion or as a result of ingesting bioaccumulated pollutants in food.

Hazard to human health by oral intake

LD_{50} value, expressed as grams of substance per kg weight of the test animal (g/kg), which is the oral intake amount for male rats, is used for defining the hazard of the pesticide to human health.

Persistence rating

It is based on the probable half-life of the substance in aquatic environment and is numerically equal to the logarithm of the half-life expressed in days with an upper limit of 3.

Bioaccumulation rating

A substance is called bioaccumulated, if its concentration increases when it is transferred from an environment or a body into other living organism, by means of food chain. Since it is difficult to express bioaccumulation quantitatively, a plus symbol (+) is used to indicate bioaccumulation in the proposed scheme.

Overall rating

The proposed overall rating is thus consisted of three separate numbers and in the case of bioaccumulated substances a symbol. These relate to the toxicity to the aquatic environment, T, the hazard to human health by oral intake, H, and the persistence, P. The rating should be easy to understand in that the greater the value of the three component numbers, the greater the potential hazard arising from the presence of a particular concentration of substance. Relatively non-hazardous substances would have a rating of 0:0:0 while a persistent substance which has adverse effects at a concentration of 1 g/1 would have a rating beginning with 6 and ending with 3.

APPLICATION OF THP SYSTEM TO BUYUKCEKMECE WATERSHED

Greater Metropolitan Istanbul is known as one of the highly crowded cities of the world. It has a population above 10 million and its drinking water demand is supplied mainly from reservoirs situated on both sides of the continents, Europe and Asia. The location of the main drinking water reservoirs of the Metropolis is shown in Figure 1. In almost all the watersheds of these reservoirs agricultural activities still prevail even though, the metropolis is the highly industrialised region of the country, where approximately half of the industries are located in the Metropolis and its vicinity. Strong protective measures and actions are taken against the point sources of pollutants which are dominant pollutants of the reservoirs for the time being; however, non-point sources of pollutants are, nowadays, becoming the dominating pollutants. Agricultural pollutants are the major sources of non-point sources of pollutants in the area which necessitates the careful selection of pesticides and fertilisers in order to damage the aquatic environment less. As drinking water reservoirs are sensitive environments where utmost care must be paid to the application of pesticides in agricultural land that usually take place in the outer long-range protection zones of the watershed. Detailed survey on the impact of agricultural pollutants of each major drinking watershed of the metropolis has been referred in Tanik et. al (1999), and trends in pesticide use including an updated survey of the common pesticides use in each watershed are mentioned in Tanik et. al. (2001). Buyukcekmece reservoir shown in the Figure is one of the largest drinking water reservoirs of Istanbul in terms of its surface area supplies 10 % of the city's drinking water demand. Land use distribution and pesticide consumption values of Buyukcekmece watershed area are given in Table 2.

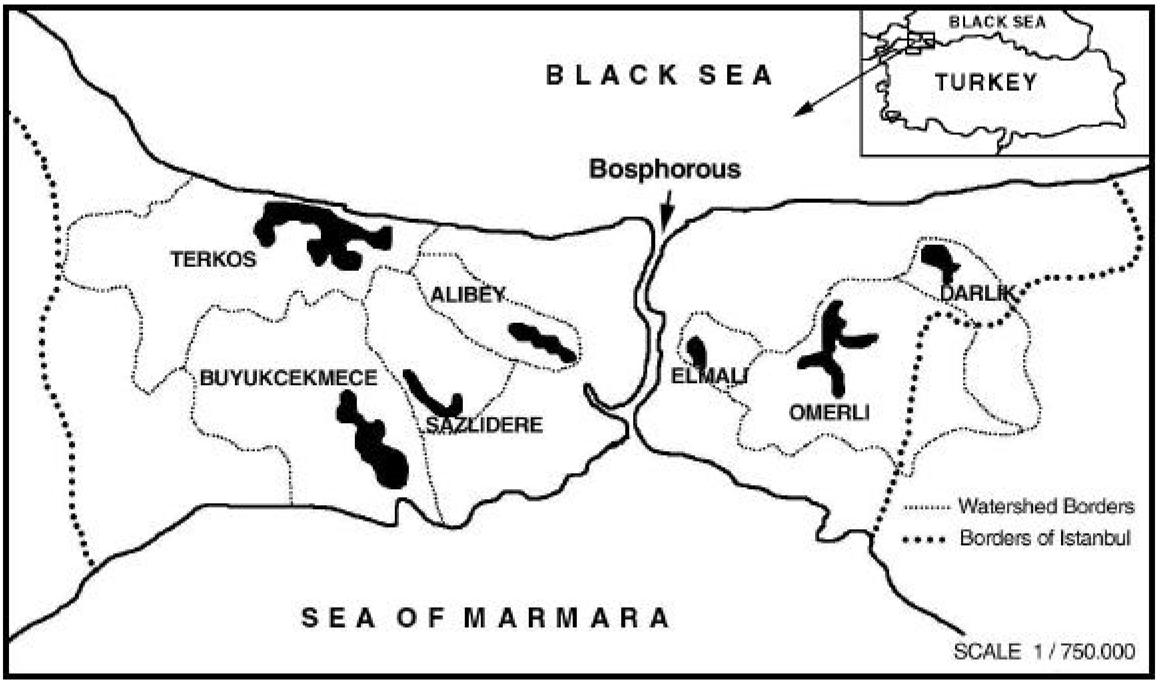

Figure 1. *The location of the main drinking water reservoirs of Istanbul*

Table 2. Land use distribution and pesticide consumption values in Buyukcekmece watershed area (Yazgan, 2002)

Parameter, units	Value
Total watershed area, km^2	621
Reservoir area, km^2	28.5
Forests & meadows, %	21
Agricultural land, %	65
Residential areas, %	12
Number of pesticides used	59
Pesticide consumption, (kg-l / year)	42343
Agricultural field, (ha)	38870
Pesticide consumption per hectare of agricultural areas, (kg-l/ha)	1.1
Pesticide loading per volume of reservoir, (mg/m^3)*	233

assuming that all the applied amount reach the reservoir without any loss in quantity and quality on its transportation pathway

The area is selected as the target area for the application of the THP system. The agricultural land covers almost two-thirds of the total watershed area with a high pesticide consumption rate. The major agricultural activities are grain and vegetable production. THP values of two groups of pesticides with similar agricultural effect are calculated and listed in Tables 3 and 4. While, the first group of pesticides are fungicides that are used against for *tilletia caries* and *tilletia foetida* causing stinking smut of wheat, second group are insecticides for white fly of vegetables (*Trialeurodes vapororiorum*).

In order to achieve a quantitative risk level for these pesticides, a risk estimation approach is developed by authors. It's known that, environmental risk of a hazardous compound is defined as the probability of threat posed by environmental hazard. In most of the environmental risk analysis for hazardous substances, adverse experiences faced after the application of chemicals such as detected concentrations, incidence of poisoning etc. are used to calculate the risk (Kates, 1981; Richardson, 1988; Kolluru, 1996). In this study, pre-application risk analysis is developed by using the known and available properties of pesticides and the amount released to environment. This method is an apparently straightforward approach for estimating environmental risk that aid to comparing the application dose of pesticides with values that are known to result in lethal effects and persistency. In complex assessments involving many factors, such as climatic conditions, soil properties or pesticide mobility, this approach can be used to set priorities for more detailed analysis. A rating system similar to THP has been developed in this study in order to calculate the pesticide consumption factors as stated in Table 5 that will then be used in the calculation of relative risk levels. In the determination of consumption factors ranking, the general consumption values and the effect of probable risks are taken into account.

Table 3. Calculated THP values for pesticides used against stinking smut of wheat (Tomlin, 1998; Extoxnet, 2003)

Pesticides	LC_{50}, mg/l	LD_{50}, mg/kg	Persistency, day	THP rating
Bitertanol	0,55	5000	30	4:3:2
Carbendazim	10000	15000	60	0:3:2
Carboxin	2	3820	1	3:3:0
Difenoconazole	0,8	1453	145	4:3:2
Diniconazole	1,58	474	14	3:4:2
Fenpiclonil	0,8	5000	0,03	4:3:0
Flutriafol	61	1140	*	2:3:2
Mancozeb	1,1	5000	5	3:3:1
Maneb	0,9	5000	25	4:3:1
Quintozene	0,1	5000	120	4:3:2
Tebuconazole	6,4	1700	7	3:3:1
Tiriticonazole	10	2000	360	2:3:2
Triadimenole	17,4	700	270	2:4:2

** not available, P value is arbitrarily selected as 2.*

Table 4. Calculated THP values for pesticides used for white fly of vegetables (Tomlin, 1998; Extoxnet, 2003)

Pesticides	LC_{50}, mg/l	LD_{50}, mg/kg	Persistency, day	THP rating
Amitraz	1,3	800	1	3:1:0
Bifenthrin	0,00015	2000	123	7:0:3
Cypermethrin	0,0002	300	23	6:1:2
Chlorpyrifos ethyl	0,009	1630	60	5:1:3
Deltamethrin	0,001	128	7	6:1:2
Endosulfan	0,0015	18	35	6:2:3
Formathion	50	365	1	2:1:2
Pirimiphos methyl	1,4	2050	*	1:0:2
Permethrin	0,009	4000	30	6:0:2

* not available, P value is arbitrarily selected as 2.

Table 5. Calculation of consumption factor for two groups of pesticides

Consumption factor	Consumed dose for application onto the seed, mg (Fungicide)	Consumed dose for application onto the plant (Insecticide)
1	< 2,5	> 20
2	2,5 – 4,9	20 – 39
3	5,0 – 7,4	40 – 59
4	7,5 – 9,9	60 – 79
5	10,0 – 12,4	80 – 99
6	12,4 <	100 <

Two groups of pesticides in a comparatively increasing order of relative risk levels together with the details of the approach are given in Tables 6 and 7. The consumed doses (C) are calculated by multiplying recommended application dose (A) and active ingredient portion (B) of each pesticide and by dividing 1000. Consumption factors (D) are calculated by using Table 5. Overall THP (E) values are obtained by adding values of three components of THP system to get a single value in order to calculate the relative risk level (F).

Table 6. Relative risk levels of pesticides used against stinking smut of wheat

	(A)	(B)	(C)	(D)	(E)	(F)
Pesticides	Recommended application dose, (g/100 kg seed)	Active ingredient, %	Consumed dose, mg/100 kg seed ((A×B)/1000)	Consumption factor	Overall THP value (T+H+P)	Relative risk level (D×E)
Flutriafol	150	2,5	0,4	1	5	5
Tebuconazole	150	2	0,3	1	7	7
Fenpiclonil	150	2,5	0,4	1	7	7
Tiriticonazole	150	2,5	0,4	1	7	7
Diniconazole	150	1	0,2	1	9	9
Difenoconazole	100	2	0,2	1	9	9
Bitertanol	150	10	1,5	1	9	9
Quintozene	200	18	3,6	2	9	18
Carbendazim	150	50	7,5	4	5	20
Mancozeb	150	60	9,0	4	7	28
Carboxin	150	75	11,3	5	6	30
Triadimenole	150	75	11,3	5	8	40
Maneb	150	80	12,0	5	8	40

The findings related to relative risk levels indicate orders of magnitude difference among pesticides used against the same pest or weed. Relative risk levels increase with increasing amount of overall THP value. There is also another direct correlation between risk levels and the active ingredients. This result is expected because the major part of a pesticide corresponds to the highest amount of pesticide released to the environment indicating highest environmental risk.

Table 7. Relative risk levels of pesticides used for white fly in vegetables

	(A)	(B)	(C)	(D)	(E)	(F)
Pesticides	Recommended application dose, (ml/da)	Active ingredient, mg/l	Consumed dose, mg/da ((A×B)/1000)	Consumption factor	Overall THP value (T+H+P)	Relative risk level (D×E)
Formathion	150	36	5,4	1	5	5
Permethrin	50	250	12,5	1	8	8
Deltamethrin	100	25	2,5	1	9	9
Cypermethrin	40	200	8,0	1	9	9
Bifenthrin	70	100	7,0	1	10	10
Pirimiphos methyl	200	500	100,0	5	3	15
Amitraz	300	200	60,0	4	4	16
Endosulfan	150	360	54,0	3	11	33
Chlorpyrifos ethyl	200	480	96,0	5	9	45

Care must be taken during the evaluation of relative risks. For example, a pesticide with a relative risk level of 45 must not be considered as 9 times more risky than a pesticide with a risk value of 5. However, it must be assessed that a pesticide with a value of 45 is more risky than a pesticide with a value of 5.

In the Buyukcekmece watershed, it is observed that the pesticides with higher risk level are in use and are favoured by the farmers. Mancozeb and maneb used against stinking smut of wheat (Table 6), endosulfan and chlorpyrifos ethyl used against white fly in vegetables (Table 7) are those that are preferred in the area. It is well known that the local farmers always prefer to buy and use the least expensive pesticides available in the region. Therefore, it can clearly be seen from this field survey and from the estimated relative risk levels that those pesticides that bear lower prices are the ones with comparatively higher overall risk levels. The results were further submitted to the local authorities and farmers. The interests of the farmers were unexpectedly more appealing than of the authorities. More importantly, they asked to continue this model by adding a cost - risk comparison.

CONCLUSIONS

There exist various methods to indicate the distribution and concentration of pesticides among environmental components. In this study, THP method which is further developed by adding a consumption factor to reach to overall environmental risk levels, is used to compare the environmental impacts of certain pesticides among themselves through ranking from 'best' to 'worst' in a specific agricultural area within the boundaries of a watershed. This method may be used just to make a rough comparison rather than a detailed investigation covering almost every environmental aspect that affects the efficiency of pesticides. It may be regarded as a preliminary study that puts forth rather significant findings. It may give rise to a more detailed and complicated application of other available methods. Even by the application of this method, pesticides of similar effect on pests that are ranked according to their overall environmental impact indicated the huge difference of relative risk levels.

Such an attemp t of applying the THP method to find out the relative risk levels of pesticides to be used against the same pests forms an example for cross compliance that would lead to planning agricultural pollution abatement strategies especially in developing countries. The farmers may easily be convinced to use the most environmentally friendly pesticide if a simple explanation of the THP method is done together with an updated cost-risk analysis to reach to a technically and economically optimised selection.

REFERENCES

Tomlin, C.D.S. (1998). *The Electronic Pesticide Manual*, 12th edn, Version 1.0. British Crop Protection Council, London.

Extoxnet (2003). (Extension Toxicology Network) Pesticide Information Profiles (PIP’s), (http://ace.orst.edu/info/extoxnet/ pip/ghindex.html).

Kates, R.W. (1981). *Risk Assessment of Environmental Hazard*, The Gresham Press, Great Britain.

Kolluru, R.V. (1996). *Risk Assessment for Environmental Professionals*, McGraw Hill Inc., NewYork.

Development of an Hazard Rating for Specific Water Pollutants (1982). Organisation for Economic Co-operation and Development Publications, Paris.

Richardson, M. (1988). *Risk Assessment of Chemicals in the Environment*, The Royal Society of Chemistry, London.

Tanik, A., Beler Baykal, B. and Gonenc, I.E. (1999). The impact of agricultural pollutants in six drinking water reservoirs, *Water Science and Technology*, 40(2), 11-17.

Tanik, A., Yazgan, M.S., Gonenc, I.E. and Ucarli, I. (2001) Trends in pesticide use in a world metropolis, Istanbul. In: *6th International HCH and Pesticides Forum Book*, J.Vijgen, S.Pruszynski, S.Stobiecki, W.Siliwinski (edn.), PPI, Poland, pp.457-464.

Yazgan, M.S. (2002) Pesticide Contamination in Terkos Drinking Water Reservoir of Istanbul. *Proceedings of 6th International Conference on Diffuse Pollution*, Sep 30 – Oct 4, 2002; Amsterdam, pp. 608-613.

Yazgan, M.S., Tanik, A. (2002). Transportation Pathways of Pesticides in two Major Watersheds of Istanbul. *Proceedings of the 6th International Conference on Diffuse Pollution*, Sep 30 – Oct 4, 2002, Amsterdam, pp. 51-58.