Bulletin of High Institute of Public Health
Vol. 37 No. 4 [2007]

Pesticides in Shallow Groundwater: Exposure Estimates and Prediction of Cancer risk

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ABSTRACT: A Monitoring system of shallow groundwater samples gathered from 7 villages in Etay El-Baroud rural area aiming at detecting the extent of water contamination via pesticide residues and the potential health risks imposed on community residents consuming such water, were the main targets of the current study. Chronic daily intake (CDI) of the detected pesticides was estimated for different exposure pathways and different age categories at both 50^{th} and 90^{th} percentiles of probability. Data disclosed that organochlorine pesticides were prevalent and ΣDDT, heptachlor and endrin represent the most critical contaminants. ΣCDI values of ingestion pathway were higher than those resulting from dermal pathway in an age-dependent manner particularly among children at 90^{th} percentile. Estimated cancer risk and non-cancer risk values resulting from oral exposure were higher than dermal exposure. Children cancer risk was age-dependent and the total risk due to exposure ranged from $1.02x10^{-4}$ to $3.01x10^{-4}$ and $5.76x10^{-4}$ to $2.09x10^{-3}$ at 50^{th} and 90^{th} percentiles, respectively. Adults are expected to be exposed to higher burden of risk than children through the both tested pathways where, risk values recorded $7.68x10^{-4}$ and $3.07x10^{-3}$ at 50^{th} and 90^{th} percentiles, respectively. Residents (either children or adults) may be at risk since under the current exposure estimations since the predicted risk values exceeded the EPA threshold value ($1x10^{-4}$ -$1x10^{-6}$) particularly at 90^{th} percentile. Furthermore, hazard index values showed a higher trend than unity (2.19-6.48) at 90^{th} percentile in case of children while the value increased in case of adults (9.37). Risk prevention could be reached by minimizing the use of pesticides, raising farmer awareness with particular emphasis on using low-leaching-potential pesticides over high risk areas.

INTRODUCTION

The widespread use of synthetic organic pesticides over the past several decades has led to their frequent detection in groundwater,[1] surface water,[2] aquatic biota and, sediment. [3] According to FAO reports at 1995,[4] the quantities of pesticides active ingredient consumed in Egypt were 5760 MT; of which 63% insecticides and Egypt was one of the most pesticide consumers among 17 countries in the Near East region. Although the use of organochlorine pesticides had been

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curtailed since the early 1980s, their residues still find their way to our water and foodstuffs.[5-7] Surveys carried out in El-Behira Governorate; our study area; showed a widespread contamination of tap and subsurface water samples with residues of several organochlorine pesticides. [8]

Groundwater may represent the primary source of water in many rural areas in Egypt for human consumption, irrigation, and animal watering. Therefore, the occurrence of agricultural pesticides in groundwater could represent a threat to public health and the environment. Shallow, permeable water table aquifers are the most susceptible to contamination via agricultural pesticides, but susceptibility of all aquifers to contamination is determined largely by site-specific characteristics.[9] Water and pesticides are released to the transmission zone via preferential and matrix flows.[10] Perhaps rapid nonuniform transport of solutes via these flow paths can result in contaminants reaching the ground water before they degrade or can be adsorbed by the soil.[11,12]

The interplay between hydrogeologic setting, groundwater recharge, soil conditions, pesticide use, and pesticide behavior in the vadose zone determines whether groundwater in a particular area is likely to become contaminated with pesticides. Groundwater sensitivity to pesticides, presence of applied water (irrigation), and crop type are the three factors generally determining groundwater vulnerability to pesticides. Areas of high vulnerability are primarily located where irrigation occurs and groundwater sensitivity to pesticides is high. Of particular concern are areas where ground water is shallow.[11]

The cost of continuous widespread national monitoring and sampling of groundwater bodies is often prohibitive, but a number of different parametric and

mathematical models have been incorporated into groundwater vulnerability systems with the aim of assessing risk at the regional scale.[13,14] Exposure to contaminants in shallow groundwater may occur through drinking the water when using shallow groundwater as a drinking water source, through inhalation of volatile contaminants when using shower, and through dermal contact when using to bathe.[9]

Therefore, the goal of this study was to evaluate community exposure to pesticides in domestic water originates from shallow groundwater, and to evaluate the relative significance of exposure pathways (i.e., ingestion, dermal contact) among them.

MATERIAL AND METHODS

Study area

Etay El-Broud district in El-Behira Governorate with an area of 306 km^2, a total population of 369.984, and agricultural activities occupying 270.48 km^2, is characterized by presence of hand-pumps as major source of drinking and domestic purposes. The pumps are installed at average of 18-24 m depth. Source of water is shallow groundwater which is potentially contaminated by agricultural drainage and sewage effluents. Seven villages were covered during our survey as illustrated in Figure 1. During the survey, a questionnaire regarding the lifespan, depth of hand pumps, in addition to water quality produced and its relation with the profound health problems was tested in 35 households randomly selected.

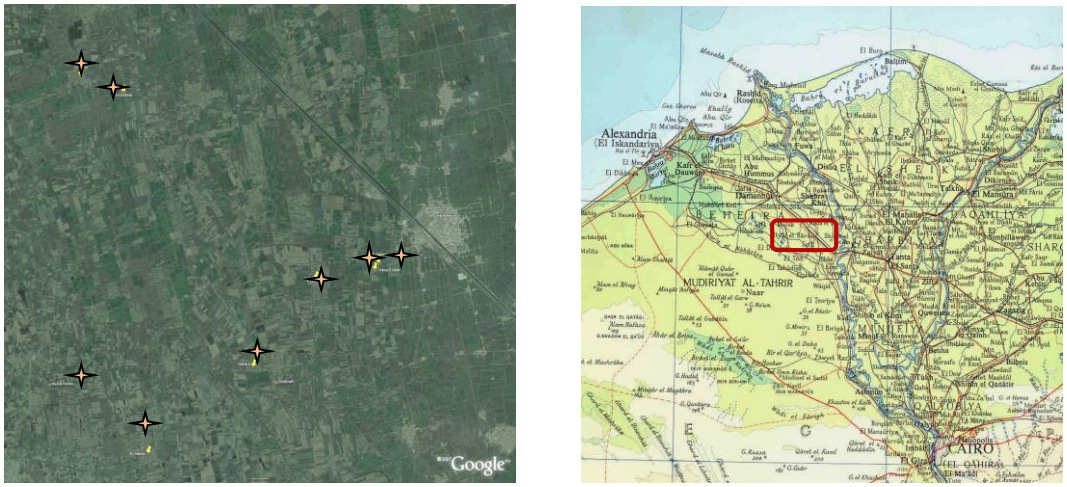

Fig (1): Illustrating map showing the sampling sites of shallow groundwater in Etay El-Baroud district, Behira Governorate.

Sampling

Water samples were collected on spatio-temporal basis during 2002 according to standard methods.[15] Sampling covered approximately 35 locations of hand pumps dogged at different depths with different years of usage. Sites were selected in part based on elevated risk of pesticide contamination due to factors such as proximity to pesticide application, presence of a high water table, permeable soils that allow leaching. Composite samples from deeper depths were gathered so it was preferable to take the sample when the stream flow remains quite steady and water was allowed to run for at least 15 min. Two liters of water were collected, kept in deep freeze until lab analysis.

Pesticide residues

Water samples were extracted, cleaned up and fractionated at the Central lab of Pesticides, ARC according to USEPA official methods. [16] Multi-residues were identified via GC-chromatography

(HP 6890 Series) equipped with EC and FP detectors using temperature program. Confirmation was made using another column (CP-Cill3-CCB). Recovery percentage range was 67-104% for organochlorine and organophosporus compounds.

Exposure assessment

Calculation of contaminant concentrations in exposure pathways; ingestion and dermal based on USEPA guidelines[17-20] was performed. Chronic daily intake (CDI) through ingestion pathway was estimated according to the following equation:

$$CDI_{ing} = \frac{Cw.Ir.Ef.Ed}{Bw.At}$$

Where; Cw is pesticide concentration in water expressed as mg. L^{-1}; Ir is ingestion rate (age- specific values;[21] Ef is exposure duration (365 days.$year^{-1}$); Ed is exposure duration expressed as year; Bw is average body weight (age-specific value),[21] and At is average time (365 day.$Year^{-1}$). In case of dermal absorption pathway, CDI was determined as follows:

$$CDI_{dermal} = \frac{Cw.Sa.Et.Ef.Ed.Cf}{Bw.At}$$

Where; Cw is pesticide concentration in water expressed as mg. L^{-1}; Sa is skin surface available for contact expressed as m^2; Et is exposure time (2.6 hr. day^{-1}), [21-23] and Cf is volumetric conversion factor for water (1 L=1000 cm^2).

Cancer Risk estimation

Estimation of cancer risks through ingestion and dermal routes of exposure depends on the availability of cancer slope factors (S.F.) which are provided in the integrated risk information system**.** [20] In brief, cancer risk was estimated as follows:

$$Cancer-risk = CDI \times S.F.$$

Where; S.F. is slope factor of a specific substance. Total exposure cancer risk was assumed to be the collective risk of exposure pathways.

Non-cancer risk estimation

Such risk was evaluated based on the reference doses (RfDs) of contaminants. Thus the hazard quotient (HQ) of pesticides in each exposure pathway was calculated as follows:

$$HQ_{oral} = \frac{CDI_{oral}}{RfD}$$

Where; RfD is reference dose for specified substance, which is listed on USEPA Website.[19,20] Hazard Index (HI) is the sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways.

Data analysis

Residue data were expressed as range and mean values. Exposure estimation data were tabulated according to difference in age from 0-18 for children and 18-70 for adults, and analyzed using ANOVA[24] to determine difference between groups and statistical significance was assigned when $p<0.05$. All exposure estimations, risk, and hazard estimate calculations were performed according to the 50th and 90th percentiles of probability.

RESULTS AND DISUSSION

Through a screening questionnaire conducted in the studied villages, it was found that over 70% of residents depend mainly on shallow groundwater for drinking and domestic purposes. The life-span of hand pumps ranged from 5-10 year as 30% of surveyed residents said, others (40%) used hand pumps for 10-20 year and 30% use it for longer periods (>20 year). 55% of the hand pumps were digged at 10-20 meter depth underground, while 30% were digged at >20 meter and 15% at less than 10 meters. In most cases, the distance that separates the hand pumps and agricultural drains recorded less than 5 meters which reflects lack of community awareness. Most of the respondents (75%) were convinced that the hand pumped drinking water in their village is contaminated and this perception

originates from the opinion of 60% of them about the causal linkage between the poor quality of water and the health status of the people drinking such water; others see that turbidity and unusual taste causing them getting infected with water-related diseases.

Groundwater vulnerability

The study area was anticipated to have a considerable risk of pesticide contamination in shallow groundwater, based on abundance of agricultural lands, variation in cropping pattern allover the year, frequent land irrigation, detectable pesticide residues, shallow depth of water table, in addition to high permeability of the aquifers, make them vulnerable to contamination. For risk assessment purposes, all agricultural lands were assumed to be in use and that these fields receive the pesticide for which risk predictions are to be determined.

Mean levels of pesticide residues in collected shallow ground water samples are exhibited in Table 1. Organochlorine pesticides were the most detected in most of the samples while organophosphorus compounds were presented only by malathion in 5 villages. Residues of ΣDDT, heptachlor, and endrin were the most critical contaminants in shallow groundwater samples collected from 7 villages in Etay El-Baroud rural area. Mean concentration of pesticide residues varied from below detection limits-BDLs (2-6 ng) to 0.09 ppb for lindane, 0.20 ppb for Σ drins, 0.185 ppb for heptachlor, 0.06 ppb for heptachlor epoxide, 0.2 ppb for ΣDDT and 0.09 ppb for malathion. The order of decreasing concentration was; ΣDDT> heptachlor > endrin > lindane > malathion > heptachlor epoxide > dieldrin > aldrin.

Comparatively, the EU Drinking Water Directive would suggest that pesticides can be expected to be detected in shallow groundwater at low concentrations (below the maximum EU drinking water standard of 0.1 ppb).[25] Whereas, the permissible

limits of organochlorines in drinking water stated by WHO[26] were, DDT (2 ppb) aldrin/dieldrin (0.03 ppb), heptachlor and heptachlor epoxide (0.03 ppb), lindane (2 ppb). Thus according to EU standard, total drins, heptachlor, total DDT are exceeding the limit while lindane and malathion are on the borders. But according to WHO standards, total drins, heptachlor and heptachlor-epoxide are exceeding the limit while total DDT and lindane residues are within the range. Following EPA drinking water standards and health advisories,[27] most of the detected residues are below the MCL values of EPA but their health advisories and cancer risk posed on people over long-term exposure is existing as indicated in Table 2.

Concentrations above these ranges are likely to indicate point source pollution rather than normal agricultural use. Common activities producing such pollution may include; non-agricultural, amenity use of general weed killers, poor practice in pesticide storage or disposal of pesticide spray tank washings, sheep dip and other livestock chemicals into the subsurface, landfill disposal of pesticide processing wastes.[25]

Worldwide, several pesticide residues have been detected in the groundwater, like atrazine, in groundwater of several states of Canada,[28] atrazine/nitrates/2,4-D in Cortland County, New York,[29] chlorpyrifos, dieldren, DDT, and 2,4-D in Minnesota.[30] On the other hand, our results match with previous survey held in the same governorate where subsurface water samples were found to be contaminated with residues of heptachlor, dieldrin, DDT and its metabolites, total HCH isomers and aldrin with high levels[31] and support the findings of previous investigation reporting pesticide residues in surface and ground water during chemical control of cotton pest in Egypt.[32] It was suggested that the detectable amounts of organochlorine pesticides in water may be

due to continuous degradation of DDT and HCH to their metabolites and isomers[33] and such amounts found their way to the subsurface water through penetration of the soil.[31] Soil samples collected from three governorates in Egypt were previously proved to contain residues of lindane, chlordane and DDT metabolites.[34]

Leaching of agricultural pesticide to shallow groundwater in highly vulnerable aquifers can be a hazard, and the potential persistence of toxic compounds in these systems is a risk.[35] As illustrated in Tables (3a&b), chronic daily intake (CDI) of the detected pesticides was estimated through different pathways of exposure and different age categories of all residents at both 50th and 90th percentiles of probability. Such data disclosed that ΣCDI values of ingestion pathway were higher than those resulting from dermal one. CDI values at 90th percentile were logically higher than the 50th percentile. For general instance, rate of consumption of adults is higher than that for children at both probabilities. In case of children; the most vulnerable group of the community, it can be noticed that CDI values for children were age-dependent where ages 6-18y recorded higher values than at 0-6y. Significant difference was observed among different age groups particularly at 90th percentile of probability. A marked decrease in CDI value was observed at children age category (9-12y) through ingestion pathway compared with the other age categories (6-9, 12-18y), whereas, higher values were recorded in case of dermal exposure pathway compared with the other age categories at both tested percentiles. Such finding reflects their habits and behavior related to water contact either for drinking or other domestic purposes. For adults, CDI values were similar at all tested age categories (18-70).

It is worthy to mention that malnutrition was obviously common among residents of

the studied villages and such finding could therefore bring about an increased susceptibility to pesticide intoxication, especially in women and children.[36] Malnourishment, and toxic chemicals interact with each other and with the immune system.[37] Consequently, pesticides immunosuppressive effects could have more pronounced health consequences in developing countries than elsewhere, and pesticides could significantly affect immune responses at very low doses.[38]

Cancer risk

Estimated cancer risk value resulting from oral exposure was higher than dermal exposure due to elevation in CDI values in case of ingestion pathway as indicated above. As shown in Table (4), risk values were age-dependent in both exposure pathways at different probabilities particularly in case of children. Adults are exposed to higher risk burden than children through both tested pathways. Sum of total cancer risks from both exposure pathways, in case of children, was also found to be age-dependent. For children at age category of 9-12y, they were found to be exposed to slightly higher risk than those at 12-18y exposed dermally to the detected pesticides at 50^{th} percentile. Risk imposed on children 12-18y due to dermal exposure was very close to the value calculated for adults. Children total cancer risks from all exposures to carcinogens ranged from $1.02x10^{-4}$ to $3.01x10^{-4}$ and $5.76x10^{-4}$ to $2.09x10^{-3}$ at 50^{th} and 90^{th} percentiles, respectively. In case of adults, the values were similar for the two age groups ($7.68x10^{-4}$ and $3.07x10^{-3}$) at 50^{th} and 90^{th} percentiles, respectively. Thus all residents (either children or adults) are suggested to be at risk since the calculated risk values exceeded the EPA acceptable range for excess risk of cancer of $1x\ 10^{-4}$ to $1x\ 10^{-6}$. DDT, heptachlor, and endrin were suggested to be the large contributors to the overall risk.

There has been an increase in public concern that chronic low exposure to pesticide residues in food and water might pose a serious cancer risk to the general population.[39] While epidemiological studies have often implicated pesticides as causative agents in human cancer,[40,41] it has usually been at a marginal level of significance. It was suspected that DDT and its breakdown product DDE, still persisted in the environment long after being banned, may be involved in the causation of breast cancer as a result of estrogenic activity**.** [42] DDT is classified by EPA as a B2 carcinogen, based on the induction of malignant liver tumors in several strains of mice. DDT also has toxic effects on the gastrointestinal tract, heart, immune system, and nervous system**.**[43] Also aldrin, which was detected in many samples, is readily converted to dieldrin in the environment and EPA classified both aldrin and dieldrin as B2 carcinogens. Additionally, endrin was also classified as carcinogen, rapidly adsorbed through the skin, and poisons the central nervous system and liver. Endrin is also reported to produce malformations when given to mammals during pregnancy, and to have immunotoxic effects**.**[44]

Health hazards (HQ)

Value of HQ was found to be age-dependent in both kinds of exposure as illustrated in Table (5). Health hazards due to oral exposure were higher than that due to the dermal one. Oral ingestion exhibited no expected hazards for children at 50th percentile while a relatively higher systemic toxicity was expected for all age groups at 90th percentile. Dermal exposure caused potential systemic toxicity only at 90th percentile at relatively older ages (12-70y). Hazard Index (HI) values resulting from sum of both pathways of exposure exceeding the level of concern or threshold value (HI=1) indicating alarming sign of systemic toxicity for age categories from 12 to 70y, at 50 percentile. Whereas, HI

values at 90th percentile were critically high enough to strengthen the potential systemic toxic effect on different organs particularly for older ages (Hi=9.37). Doses below the threshold are taken into the body, metabolized, and passed out of the body without harm.

Exposures to different contaminants with the same mechanism of toxicity may be additive however, the net effect may be synergistic or antagonistic. Synergistic effects, which, though not directly affecting the same organ system, may increase the risk from one contaminant based on the presence or effect of some other contaminants. Also, burdening one detoxification system may impair the functioning of another detoxification system. Infants, young children, and individuals with compromised immune systems and undeveloped organs may be more susceptible to illnesses from contaminated shallow groundwater.(38)

Uncertainty

Samples were collected from known and suspected areas of contamination "biased sampling" to delineate the nature and extent of contamination. The data exhibited wide ranges of values and variability for certain residues and such variability may be the result of combining samples collected from known areas of contamination (biased samples) and samples collected randomly. Combining samples provides a more accurate representation of the site-wide contamination than either sampling scheme by itself. A significant source of uncertainty is the consumption rates in the study area due to the conditions of low water depth, frequent periods when water is unavailable, low water flow, inaccessibility of some areas, may both limit the accessibility of the shallow groundwater.

Furthermore, full determination and toxicity values are not available for all compounds. Therefore, health

risks/hazards cannot be quantitatively assessed for all contaminants and the total risk/hazard for the site may be underestimated in such circumstances. Summation of carcinogenic risks from individual contaminants may also lead to some uncertainty. Antagonistic or synergistic effects are not accounted for in this characterization, resulting in potential over- or under-estimations of carcinogenic risk. Another limitation with the hazard index approach is the assumption that dose additivity is applied to all compounds for all exposure media and pathways. This assumption implies that all compounds induce the same effect by the same mechanism of action. Consequently, the application of the HI equation to a number of compounds that are not expected to induce the same type of effects and do not act by the same mechanism will overestimate the potential for adverse effects.

CONCLUSION

According to the obtained data, estimated cancer risk and non-cancer risk values resulting from oral exposure were higher than that of dermal exposure and adults are expected to be exposed to higher risk burden than children through both tested pathways. Thus for the maximally exposed individual, people who meet the assumptions made in this assessment with the established uncertainties, there is a potential for human health risk that exceeds the criteria established by the EPA.

RECOMMENDATIONS

Minimizing the use of pesticides will obviously reduce the risks of water contamination. Pest control should be achieved by integrated pest management with minimal use of pesticides. Education of pesticide users on the proper handling and application methods is important in minimizing environmental impacts with particular emphasis on using low-leaching-potential pesticides over "high risk" areas

and leaving an unsprayed buffer strip when applying near surface water or wetlands. A significant additional element of protection for drinking water-supplies can be provided if their intake is at significant depth below the water-table.

Finally, given the wide range of pesticide compounds in use in agriculture, and their many toxic metabolites, an approach to groundwater pollution risk assessment based on the key properties of the pesticide compounds (mobility, solubility) and of the geological media (propensity to preferential flow in vadose zone) is needed for target monitoring and resource protection.

Table (1): Mean concentration of pesticide residues in shallow groundwater obtained by hand-pumps in Etay El-Baroud district during 2002.

Village	Pesticide (ug.L^{-1})							
	Lindane	*Aldrin*	*Heptachlor*	*Hept-epoxide*	*Dieldrin*	*Endrin*	*ΣDDT*	*Malathion*
El-salam	(1.0×10^{-2}-3.0×10^{-2}) **2.0×10^{-2}**	(1.8×10^{-2}-3.8×10^{-2}) **2.8×10^{-2}**	(0.6×10^{-1}-1.8×10^{-1}) **1.2×10^{-1}**	(1.6×10^{-2}-2.5×10^{-2}) **2.1×10^{-2}**	(4.0×10^{-3}-1.0×10^{-2}) **8.0×10^{-3}**	(4.0×10^{-2}-8.7×10^{-1}) **4.5×10^{-1}**	(1.0×10^{-2}-1.4×10^{-1}) **5.8×10^{-2}**	**ND**
Abou El-Fadl	(1.0×10^{-2}-3.2×10^{-2}) **2.1×10^{-2}**	**ND**	**ND**	(1.0×10^{-2}-2.4×10^{-2}) **1.5×10^{-2}**	(1.2×10^{-2}-4.5×10^{-2}) **2.9×10^{-2}**	(1.0×10^{-2}-1.5×10^{-1}) **7.8×10^{-2}**	(2.0×10^{-2}-1.2) **2.6×10^{-1}**	(0.0-2.8×10^{-1}) **1.4×10^{-1}**
El-Nokrash	(2.0×10^{-2}-6.0×10^{-2}) **3.8×10^{-2}**	(0.0-4.0×10^{-2}) **2.0×10^{-2}**	**ND**	(0.0-1.0×10^{-2}) **6.0×10^{-3}**	(0.0-1.2×10^{-2}) **6.0×10^{-3}**	(1.0×10^{-2}-4.1×10^{-1}) **1.2×10^{-1}**	(1.0×10^{-2}-3.6×10^{-1}) **1.2×10^{-1}**	(2.1×10^{-2} - 4.4×10^{-2}) **2.0×10^{-1}**
El-Behy	(2.0×10^{-2}-1.1×10^{-1}) **5.9×10^{-2}**	(2.4×10^{-2}-1.2×10^{-1}) **8.3×10^{-2}**	(1.2×10^{-2}-1.1) **3.3×10^{-1}**	(1.0×10^{-2}-1.6×10^{-2}) **1.3×10^{-2}**	(0.0-1.5×10^{-1}) **7.5×10^{-2}**	(0.0-2.6×10^{-1}) **1.3×10^{-1}**	(1.0×10^{-2}-6.0×10^{-1}) **5.0×10^{-1}**	(0.0-3.3×10^{-2}) **1.7×10^{-2}**
El-Salmia	(1.0×10^{-2}-4.0×10^{-2}) **2.5×10^{-2}**	(2.0×10^{-3}-3.3×10^{-2}) **1.2×10^{-2}**	(1.0×10^{-2}-5.8×10^{-2}) **3.4×10^{-2}**	(0.0-4.9×10^{-1}) **2.5×10^{-1}**	(0.0-1.0×10^{-1}) **5.2×10^{-2}**	(2.0×10^{-3}-1.6×10^{-2}) **6.0×10^{-3}**	(1.4×10^{-2}-3.0×10^{-1}) **1.0×10^{-1}**	**ND**
El-Nebira	(2.0×10^{-3}-1.7×10^{-1}) **6.1×10^{-2}**	(1.0×10^{-2}-2.8×10^{-2}) **1.4×10^{-2}**	(6.3×10^{-2}-2.0×10^{-1}) **1.6×10^{-1}**	**ND**	**ND**	(0.0-1.1×10^{-1}) **5.0×10^{-2}**	(1.8×10^{-2}-2.0×10^{-1}) **1.0×10^{-1}**	(5.9×10^{-2}-7.1×10^{-2}) **6.5×10^{-2}**
Gabares	(1.0×10^{-2}-1.1) **3.9×10^{-1}**	(0.0-3.0×10^{-3}) **1.5×10^{-3}**	(6.8×10^{-2}-4.1×10^{-1}) **2.4×10^{-1}**	**ND**	(0.0-3.0×10^{-3}) **1.5×10^{-3}**	**ND**	(3.2×10^{-2}-8.1×10^{-1}) **1.5×10^{-1}**	(0.0-2.8×10^{-2}) **1.4×10^{-2}**
Mean	**8.8×10^{-2}**	**2.6×10^{-2}**	**1.77×10^{-1}**	**6.1×10^{-2}**	**2.9×10^{-2}**	**1.4×10^{-1}**	**2.0×10^{-1}**	**8.7×10^{-2}**

ND: Not Detected

Table (2): EPA drinking water standards and health advisories (2006).

Pesticide Residue	Std MCL (mg/L)	Health advisories		mg/L at 10^{-4} cancer risk	Cancer description
		10 Kg-child			
		One-day (mg/L)	Ten-day (mg/L)		
Aldrin	--	0.0003	0.0003	0.0002	B2
Dieldrin	--	0.0005	0.0005	0.0002	B2
Endrin	0.002	0.02	0.005	--	D
Heptachlor	0.0004	0.01	0.01	0.0008	B2
Hept-epoxide	0.0002	0.01	--	0.0004	B2
Lindane	0.0002	1	1	--	S
Malathion	--	0.2	0.2	--	D

Not : B2 *indicates sufficient evidence in animals of probable carcinogenicity and inadequate or no evidence in humans*

D *Not classifiable as to human carcinogenicity* ***S****: Suggestive evidence of carcinogenic potential*

10^{-4} Cancer Risk: *The concentration of a chemical in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in 10,000.*

Drinking Water Advisory: *A nonregulatory concentration of a contaminant in water that is likely to be without adverse effects on health.*

One-Day HA: *The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for up to one day of exposure.*

Ten-Day HA: *The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for up to ten days of exposure.*

Table (3a): Chronic daily intake of pesticides in hand-pumped drinking water through ingestion pathway.

Pesticide	**CDI** (mg. Kg^{-1}. day^{-1})											
	Children age (year)								**Adult age** (year)			
	0-6		**6-9**		**9-12**		**12-18**		**18-55**		**70**	
	50^{th}	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**
Lindane	$3.0x10^{-6}$	$2.0x10^{-5}$	$5.1x10^{-6}$	$3.1x10^{-5}$	$5.5x10^{-6}$	$3.2x10^{-5}$	$9.0x10^{-6}$	$5.4x10^{-5}$	$1.6x10^{-5}$	$7.5x10^{-5}$	$1.6x10^{-5}$	$7.5x10^{-5}$
Aldrin	$8.8x10^{-7}$	$5.9x10^{-6}$	$1.5x10^{-6}$	$9.3x10^{-6}$	$1.6x10^{-6}$	$9.6x10^{-6}$	$2.7x10^{-6}$	$1.6x10^{-5}$	$4.7x10^{-6}$	$2.2x10^{-5}$	$4.7x10^{-6}$	$2.2x10^{-5}$
Heptachlor	$5.9x10^{-6}$	$4.0x10^{-5}$	$1.0x10^{-5}$	$6.3x10^{-5}$	$1.1x10^{-5}$	$6.5x10^{-5}$	$1.8x10^{-5}$	$1.1x10^{-4}$	$3.2x10^{-5}$	$1.5x10^{-4}$	$3.2x10^{-5}$	$1.5x10^{-4}$
Hept. epoxide	$2.0x10^{-6}$	$1.5x10^{-5}$	$3.5x10^{-6}$	$2.1x10^{-5}$	$3.8x10^{-6}$	$2.2x10^{-5}$	$6.2x10^{-6}$	$3.7x10^{-5}$	$1.1x10^{-5}$	$5.1x10^{-5}$	$1.1x10^{-5}$	$5.1x10^{-5}$
Dieldrin	$9.8x10^{-7}$	$6.6x10^{-6}$	$1.7x10^{-6}$	$1.0x10^{-5}$	$1.8x10^{-6}$	$1.1x10^{-5}$	$2.9x10^{-6}$	$1.8x10^{-5}$	$5.3x10^{-6}$	$2.5x10^{-5}$	$5.3x10^{-6}$	$2.5x10^{-5}$
Endrin	$4.7x10^{-6}$	$3.2x10^{-5}$	$8.1x10^{-6}$	$4.9x10^{-5}$	$8.8x10^{-6}$	$5.2x10^{-5}$	$1.4x10^{-5}$	$8.5x10^{-5}$	$2.5x10^{-5}$	$1.2x10^{-4}$	$2.5x10^{-5}$	$1.2x10^{-4}$
ΣDDT	$6.8x10^{-6}$	$4.6x10^{-5}$	$1.2x10^{-5}$	$7.1x10^{-5}$	$1.3x10^{-5}$	$7.4x10^{-5}$	$2.1x10^{5}$	$1.2x10^{-4}$	$3.6x10^{-5}$	$1.7x10^{-4}$	$3.6x10^{-5}$	$1.7x10^{-4}$
Malathion	$2.9x10^{-6}$	$1.9x10^{-5}$	$6.9x10^{-6}$	$3.1x10^{-5}$	$5.5x10^{-6}$	$3.2x10^{-5}$	$8.9x10^{-6}$	$5.3x10^{-5}$	$1.6x10^{-5}$	$7.5x10^{-5}$	$1.6x10^{-5}$	$7.5x10^{-5}$
ΣCDI	$2.72x10^{-5}$	$1.85x10^{-4}$	$4.88x10^{-5*}$	$2.85x10^{-4*}$	$5.10x10^{-5}$	$2.98x10^{4}$	$8.27x10^{5*}$	$4.93x10^{4*}$	$1.46x10^{4}$	$6.88x10^{4}$	$1.46x10^{4}$	$6.88x10^{4}$

Table (3b): Chronic daily intakes of pesticides in hand-pumped drinking water through dermal absorption pathway

Pesticide	**CDI** (mg. Kg^{-1}. day^{-1})											
	Children age (year)								**Adult age** (year)			
	0-6		**6-9**		**9-12**		**12-18**		**18-55**		**70**	
	50^{th}	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**	**50^{th}**	**90^{th}**
Lindane	$1.2x10^{-5}$	$3.7x10^{-5}$	$3.0x10^{-5}$	$1.0x10^{-4}$	$4.3x10^{-5}$	$1.4x10^{-4}$	$3.5x10^{-5}$	$1.2x10^{-4}$	$5.6x10^{-5}$	$1.9x10^{-4}$	$5.6x10^{-5}$	$1.9x10^{-4}$
Aldrin	$1.5x10^{-7}$	$5.0x10^{-7}$	$4.0x10^{-7}$	$1.3x10^{-6}$	$5.1x10^{-7}$	$1.7x10^{-6}$	$4.1x10^{-7}$	$3.3x10^{-5}$	$1.6x10^{-5}$	$5.3x10^{-5}$	$1.6x10^{-5}$	$5.3x10^{-5}$
Heptachlor	$1.0x10^{-6}$	$3.4x10^{-6}$	$2.5x10^{-6}$	$8.2x10^{-6}$	$3.5x10^{-6}$	$1.2x10^{-5}$	$2.8x10^{-6}$	$9.3x10^{-6}$	$4.5x10^{-6}$	$1.5x10^{-5}$	$4.5x10^{-6}$	$1.5x10^{-5}$
Hept. epoxide	$3.5x10^{-7}$	$1.2x10^{-6}$	$9.1x10^{-7}$	$3.0x10^{-6}$	$1.2x10^{-6}$	$3.9x10^{-6}$	$9.4x10^{-7}$	$3.1x10^{-6}$	$1.5x10^{-6}$	$5.1x10^{-6}$	$1.5x10^{-6}$	$5.1x10^{-6}$
Dieldrin	$1.7x10^{-7}$	$5.6x10^{-7}$	$4.4x10^{-7}$	$1.4x10^{-6}$	$5.7x10^{-7}$	$1.9x10^{-6}$	$4.6x10^{-7}$	$1.5x10^{-6}$	$7.3x10^{-7}$	$2.4x10^{-6}$	$7.3x10^{-7}$	$2.4x10^{-6}$
Endrin	$8.1x10^{-7}$	$2.7x10^{-6}$	$2.1x10^{-6}$	$7.0x10^{-6}$	$2.8x10^{-6}$	$9.2x10^{-6}$	$2.2x10^{-6}$	$7.3x10^{-6}$	$3.5x10^{-6}$	$1.3x10^{-5}$	$3.5x10^{-6}$	$1.3x10^{-5}$
ΣDDT	$1.2x10^{-6}$	$3.8x10^{-6}$	$3.0x10^{-6}$	$1.0x10^{-5}$	$3.9x10^{-6}$	$1.3x10^{-5}$	$3.1x10^{-6}$	$1.1x10^{-5}$	$5.1x10^{-6}$	$1.7x10^{-5}$	$5.1x10^{-6}$	$1.7x10^{-5}$
Malathion	$5.0x10^{-7}$	$1.7x10^{-6}$	$1.3x10^{-6}$	$4.3x10^{-6}$	$1.7x10^{-6}$	$5.7x10^{-6}$	$1.4x10^{-6}$	$4.6x10^{-6}$	$2.2x10^{-6}$	$7.3x10^{-6}$	$2.2x10^{-6}$	$7.3x10^{-6}$
ΣCDI	**$1.62x10^{-5}$**	**$5.09x10^{-5}$**	**$4.06x10^{-5*}$**	**$1.35x10^{-4*}$**	**$8.87x10^{-5*}$**	**$1.87x10^{-4}$**	**$4.63x10^{-5*}$**	**$1.90x10^{-4*}$**	**$8.95x10^{-5}$**	**$3.03x10^{-4}$**	**$8.95x10^{-5}$**	**$3.03x10^{-4}$**

*Significant difference between groups at $p<0.05$.

Table (4): Cancer risk estimates for pesticides in hand-pumped drinking water through different exposure pathways.

Pesticide	Children age (year)								Adult age (year)			
	0-6		6-9		9-12		12-18		18-55		70	
	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}
	Oral exposure											
Lindane	$5.4x10^{-6}$	$3.6x10^{-5}$	$9.2x10^{-6}$	$5.6x10^{-5}$	$1.0x10^{-5}$	$5.8x10^{-5}$	$1.6x10^{-5}$	$9.7x10^{-5}$	$2.9x10^{-5}$	$1.4x10^{-4}$	$2.9x10^{-5}$	$1.4x10^{-4}$
Aldrin	$1.6x10^{-5}$	$1.0x10^{-4}$	$2.6x10^{-5}$	$1.6x10^{-4}$	$2.7x10^{-5}$	$1.6x10^{-4}$	$4.6x10^{-5}$	$2.7x10^{-4}$	$8.0x10^{-5}$	$3.7x10^{-4}$	$8.0x10^{-5}$	$3.7x10^{-4}$
Heptachlor	$2.7x10^{-5}$	$1.8x10^{-4}$	$4.6x10^{-5}$	$2.8x10^{-4}$	$5.0x10^{-5}$	$2.9x10^{-4}$	$8.2x10^{-5}$	$4.9x10^{-4}$	$1.4x10^{-4}$	$6.8x10^{-4}$	$1.4x10^{-4}$	$6.8x10^{-4}$
Hept. epoxide	$1.8x10^{-5}$	$1.4x10^{-4}$	$3.2x10^{-5}$	$1.9x10^{-4}$	$3.5x10^{-5}$	$2.0x10^{-4}$	$5.6x10^{-5}$	$3.4x10^{-4}$	$1.0x10^{-4}$	$4.6x10^{-4}$	$1.0x10^{-4}$	$4.6x10^{-4}$
Dieldrin	$1.6x10^{-7}$	$1.1x10^{-6}$	$2.7x10^{-7}$	$1.7x10^{-6}$	$2.9x10^{-7}$	$1.7x10^{-6}$	$4.8x10^{-7}$	$2.8x10^{-6}$	$8.4x10^{-7}$	$3.9x10^{-6}$	$8.4x10^{-7}$	$3.9x10^{-6}$
ΣDDT	$2.3x10^{-6}$	$1.6x10^{-5}$	$4.1x10^{-6}$	$2.4x10^{-5}$	$4.4x10^{-6}$	$2.5x10^{-5}$	$7.1x10^{-6}$	$4.1x10^{-5}$	$1.2x10^{-5}$	$5.8x10^{-5}$	$1.2x10^{-5}$	$5.8x10^{-5}$
Total risk	**$6.89x10^{-5}$**	**$4.73x10^{-4}$**	**$1.18x10^{-4}$**	**$7.12x10^{-4}$**	**$1.27x10^{-4}$**	**$7.35x10^{-4}$**	**$2.08x10^{-4}$**	**$1.24x10^{-3}$**	**$3.62x10^{-4}$**	**$1.71x10^{-3}$**	**$3.62x10^{-4}$**	**$1.71x10^{-3}$**
	Dermal exposure											
Lindane	$2.2x10^{-5}$	$6.7x10^{-5}$	$5.4x10^{-5}$	$1.8x10^{-4}$	$7.7x10^{-5}$	$2.5x10^{-4}$	$6.3x10^{-5}$	$2.2x10^{-4}$	$1.0x10^{-4}$	$3.4x10^{-4}$	$1.0x10^{-4}$	$3.4x10^{-4}$
Aldrin	$2.6x10^{-6}$	$8.5x10^{-6}$	$6.8x10^{-6}$	$2.2x10^{-5}$	$8.7x10^{-6}$	$2.9x10^{-5}$	$7.0x10^{-6}$	$5.6x10^{-4}$	$2.7x10^{-4}$	$9.0x10^{-4}$	$2.7x10^{-4}$	$9.0x10^{-4}$
Heptachlor	$4.6x10^{-6}$	$1.5x10^{-5}$	$1.1x10^{-5}$	$3.7x10^{-5}$	$1.6x10^{-5}$	$5.2x10^{-5}$	$1.3x10^{-5}$	$4.2x10^{-5}$	$2.0x10^{-5}$	$6.7x10^{-5}$	$2.0x10^{-5}$	$6.7x10^{-5}$
Hept. epoxide	$3.2x10^{-6}$	$1.1x10^{-5}$	$8.3x10^{-6}$	$2.7x10^{-5}$	$1.1x10^{-5}$	$3.6x10^{-5}$	$8.6x10^{-6}$	$2.8x10^{-5}$	$1.4x10^{-5}$	$4.6x10^{-5}$	$1.4x10^{-5}$	$4.6x10^{-5}$
Dieldrin	$2.7x10^{-8}$	$8.9x10^{-8}$	$7.1x10^{-8}$	$2.3x10^{-7}$	$9.2x10^{-8}$	$3.1x10^{-7}$	$7.3x10^{-8}$	$2.4x10^{-7}$	$1.2x10^{-7}$	$3.9x10^{-7}$	$1.2x10^{-7}$	$3.9x10^{-7}$
ΣDDT	$4.1x10^{-7}$	$1.3x10^{-6}$	$1.0x10^{-6}$	$3.4x10^{-6}$	$1.3x10^{-6}$	$4.4x10^{-6}$	$1.1x10^{-6}$	$3.7x10^{-6}$	$1.7x10^{-6}$	$5.8x10^{-6}$	$1.7x10^{-6}$	$5.8x10^{-6}$
Total risk	**$3.28x10^{-5}$**	**$1.03x10^{-4}$**	**$8.12x10^{-5}$**	**$2.69x10^{-4}$**	**$1.14x10^{-4}$**	**$3.72x10^{-4}$**	**$9.28x10^{-5}$**	**$8.54x10^{-4}$**	**$4.06x10^{-4}$**	**$1.36x10^{-3}$**	**$4.06x10^{-4}$**	**$1.36x10^{-3}$**
Σrisk	**$1.02x10^{-4}$**	**$5.76x10^{-4}$**	**$1.99x10^{-4}$**	**$9.81x10^{-4}$**	**$2.41x10^{-4}$**	**$1.11x10^{-3}$**	**$3.01x10^{-4}$**	**$2.09x10^{-3}$**	**$7.68x10^{-4}$**	**$3.07x10^{-3}$**	**$7.68x10^{-4}$**	**$3.07x10^{-3}$**

Table (5): Non- Cancer risk estimates for pesticides in hand-pumped drinking water through different exposure pathways.

Pesticide	Children age (year)								Adult age (year)			
	0-6		6-9		9-12		12-18		18-55		70	
	50th	90th	50th	90th	50th	90th	50th	90th	50th	90th	50th	90th
	Oral exposure											
Lindane	0.01	0.07	0.02	0.10	0.02	0.11	0.03	0.18	0.05	0.25	0.05	0.25
Aldrin	0.03	0.30	0.05	0.31	0.05	0.32	0.09	0.53	0.16	0.73	0.16	0.73
Heptachlor	0.01	0.08	0.02	0.13	0.02	0.13	0.04	0.22	0.06	0.30	0.06	0.30
Hept. Epoxide	0.15	1.15	0.27	1.62	0.29	1.69	0.48	2.85	0.85	3.92	0.85	3.92
Dieldrin	0.02	0.13	0.03	0.21	0.04	0.21	0.06	0.35	0.11	0.49	0.11	0.49
Endrin	0.02	0.11	0.03	0.16	0.03	0.17	0.05	0.28	0.08	0.40	0.08	0.40
ΣDDT	0.01	0.09	0.02	0.14	0.03	0.15	0.04	0.24	0.07	0.34	0.07	0.34
Malathion	$1.5x10^{-4}$	$9.9x10^{-4}$	$3.5x10^{-4}$	$1.6x10^{-3}$	$2.7x10^{-4}$	$1.6x10^{-3}$	$4.5x10^{-4}$	$2.7x10^{-3}$	$7.9x10^{-4}$	$3.7x10^{-3}$	$7.9x10^{-4}$	$3.7x10^{-3}$
THQ	**0.250**	**1.931**	**0.440**	**2.672**	**0.480**	**2.782**	**0.790**	**4.653**	**1.381**	**6.434**	**1.381**	**6.434**
	Dermal exposure											
Lindane	0.04	0.12	0.10	0.33	0.14	0.47	0.12	0.40	0.19	0.63	0.19	0.63
Aldrin	$5.0x10^{-3}$	0.02	0.01	0.04	0.02	0.06	0.01	1.10	0.53	1.77	0.53	1.77
Heptachlor	$2.0x10^{-3}$	$6.8x10^{-3}$	$5.1x10^{-3}$	0.016	$6.9x10^{-3}$	0.023	$5.6x10^{-3}$	0.02	$8.9x10^{-3}$	0.029	$8.9x10^{-3}$	0.029
Hept. Epoxide	0.03	0.09	0.07	0.23	0.09	0.30	0.07	0.24	0.16	0.39	0.16	0.39
Dieldrin	$3.3x10^{-3}$	0.01	$8.8x10^{-3}$	0.03	0.01	0.04	$9.1x10^{-3}$	0.03	0.02	0.05	0.02	0.05
Endrin	$2.7x10^{-3}$	$9.0x10^{-3}$	$7.0x10^{-3}$	0.02	$9.3x10^{-3}$	0.03	$7.3x10^{-3}$	0.02	0.01	0.04	0.01	0.04
ΣDDT	$2.4x10^{-3}$	$7.6x10^{-3}$	$6.0x10^{-3}$	0.02	$7.8x10^{-3}$	0.03	$6.2x10^{-3}$	0.02	0.01	0.03	0.01	0.03
Malathion	$2.5x10^{-5}$	$8.4x10^{-5}$	$6.7x10^{-5}$	$2.2x10^{-4}$	$8.6x10^{-5}$	$2.9x10^{-4}$	$6.9x10^{-5}$	$2.3x10^{-4}$	$1.1x10^{-4}$	$3.7x10^{-4}$	$1.1x10^{-4}$	$3.7x10^{-4}$
THQ	**0.085**	**0.263**	**0.207**	**0.686**	**0.284**	**0.953**	**0.228**	**1.830**	**0.929**	**2.939**	**0.929**	**2.939**
HI	**0.335**	**2.194**	**0.647**	**3.358**	**0.764**	**3.735**	**1.018**	**6.483**	**2.310**	**9.373**	**2.310**	**9.373**

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