

## Research Article

### Risk Assessment of Polycyclic Aromatic Hydrocarbons concentration in Cold Smoked Mullet Fish (*Mugil Cephalus*)

Hafez NE<sup>1</sup>, Awad AM<sup>1</sup>, Ibrahim SM<sup>2</sup>, Mohamed HR<sup>2\*</sup> and El-Lahamy AA<sup>2</sup>

<sup>1</sup>Department of Food Science and Technology, Faculty of Agriculture, Fayoum University, Egypt

<sup>2</sup>Fish Processing and Technology Laboratory, Fisheries Division, National Institute of Oceanography and Fisheries, Egypt

#### Abstract

The purpose of this work was to determine the concentration and risk assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in cold-smoked mullet fish samples which were pre-frozen at -18°C for 6 months. Fish samples were obtained from two fish farms; A (Al-Batts drain) and B (El-Wadi drain), El-Fayoum governorate, Egypt. 16 components of PAHs concentration were determined by GC-MS. Results showed that the total concentration of PAHs recorded 16.2 and 7.4ppb sample of A and B-smoked mullet fish products, respectively. Also, levels of Benzo [a] Pyrene (B {a} P) equivalent were 0.0378 and 0.029ppb in A and B-products, respectively. Besides, content of Low Molecular Weight (LMW) components was higher in A-smoked mullet product than medium MW and vice versa in case B-smoked product however, high MW was not detected in products. In conclusion, PAHs concentration in smoked products processed from pre-frozen mullet samples for 6 months at -18°C are considered a minimally contaminated (16.2ppb) for A-smoked product and not contaminated (7.4ppb) for B-smoked product compared with recommended levels. In addition to the component of Benzo [a] Pyrene (B {a} P) was not detectable in all smoked fish products.

**Keywords:** Frozen mullet fish; GC-MS; PAHs; Smoking

\*Corresponding author: Mohamed HR, Fish Processing and Technology Laboratory, Fisheries Division, National Institute of Oceanography and Fisheries, Egypt, Tel: +20 33929900; E-mail: hassanaboali66@yahoo.com

**Citation:** Hafez NE, Awad AM, Ibrahim SM, Mohamed HR, El-Lahamy AA (2019) Risk Assessment of Polycyclic Aromatic Hydrocarbons concentration in Cold Smoked Mullet Fish (*Mugil Cephalus*). J Toxicol Cur Res 3: 008.

**Received:** March 21, 2019; **Accepted:** April 21, 2019; **Published:** April 30, 2019

**Copyright:** © 2019 Hafez NE, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

#### Introduction

Smoking is one of the oldest methods used to process and preserve fish. It is a process of treating fish by exposing it to smoke from smoldering wood or plant materials. This process is usually characterized by an integrated combination of salting, drying, heating and smoking operations in a smoking chamber. The preservation properties of smoking treatment are mainly due to the partial drying and the precipitation of aliphatic and aromatic vapors on fish surface [1-6]. Food cooking and processing methods at high temperatures such as smoking, drying, roasting, baking or frying are recognized as a major source of food contamination by PAHs [7-9].

PAHs compounds are containing 2 or more fused aromatic rings. Polycyclic aromatic hydrocarbons containing 4 rings such as chrysene and benzo [a] anthracene consider weakly carcinogenic compounds, while PAHs which have 5 or more rings are a potentially carcinogenic and mutagenic for human such as Benzo [a] Pyrene (BaP), benzo [g,h,i] perylene, benzo [b] fluoranthene, indeno [1,2,3-c,d] pyrene and benzo [k] fluoranthene [10-12].

Wood smoke contains a hundreds (at least 100) of PAHs and their derivatives which have carcinogenic compounds such as Benzo [a] Pyrene (BaP). BaP consider a marker for carcinogenic PAHs in smoked fish and the maximum level is 2µg/kg. After metabolic activation in mammalian cells to diol-epoxides, PAHs bind covalently to cellular macromolecules, including DNA, thereby causing errors in DNA replication and mutations that initiate the carcinogenic process. This mechanism of activation, with some modifications, occurs with all carcinogenic PAHs [13]. The classification of the International Agency of Research on Cancer for Benzo [a] Pyrene (BaP) was changed from group 2A (probably carcinogenic to humans) to group 1 (carcinogenic to humans), chrysene was changed from group 3 (not classifiable for humans) to group 2B (possibly carcinogenic to humans), and benzo [a] anthracene was re-grouped from 2A to 2B [14,15].

Therefore, the main purpose of this work was to determine the concentration and risk assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in cold-smoked mullet fish samples which were obtained from two fish farms, El-Fayoum governorate, Egypt and frozen storage at -18°C for 6 months.

#### Materials and Methods

##### Fish samples

Mullet fish (*Mugil cephalus*) samples were obtained after directly catch from two fish farms (A and B). The main resources of irrigation water were agricultural discharge for A (Al-Batts drain) and B (El Wadi drain) during August, 2015 at El-Fayoum governorate, Egypt. They were transported immediately to Fish Processing and Technology Lab, Shakshouk Station for Water Resource, National Institute of Oceanography and Fisheries (NIOF), Egypt. Average of weight 525±25gm and length 36±1cm for raw samples from Farm A (Al-Batts drain) while, the average weight of raw mullet samples

from Farm B (Agricultural discharge) was 545±5gm and length was 37.75±0.25cm, respectively. After that, fish samples were carefully washed with tap water, glazed, packed in polyethylene bags and stored at -18°C for 6 months.

### Smoking process

After 6 months of raw mullet fish frozen storage, Fish samples (from A and B farm) were thawed at 4°C then soaked in 10% brined solution (Sodium chloride) for two hrs., rinsed with tap water for 1 min and semi-dried at 25°C for two hrs. The smokehouse had inside dimensions of 1.20×1.0×3.5m with pours-metal plates localized above the smoke source by 75cm. the Semi-dried fish samples were hooked at distance about 250cm in smoking house. Traditional cold smoking was carried out at 28-32°C for 8-10hrs. Using sawdust as smoke source. After smoking the fish samples were cooled under ambient temperature.

### Analytical methods

The edible of smoked mullet fish products was manually separated, homogenized, packed in polyethylene bags and then stored in a freezer at -20°C till analysis. PAHs were determined at Central Laboratory of Residue Analysis of Pesticides and Heavy Metals in Food (QCAP), Agricultural Research Centre. Cairo, Egypt as described by [16]. Chemicals and Reagents; acetone (Riedel-de Häen, purity 99.8%), acetonitrile (Sigma-Aldrich, purity>99.9%), toluene (Merck), dichlorom-ethane chromatography grade, and n-hexane (purity>99.0%) were used.

### B {a} P equivalent

The  $BaP_{eqi}$  was calculated as the sum of  $BaP_{eqi}$  value for individual PAHs. The  $BaP_{eqi}$  value was calculated for each PAH from its concentration in the sample ( $C_{PAHi}$ ) multiplied by its toxic equivalency factor ( $TEF_{PAHi}$ ) [17].

$$BaP_{eqi} = \sum (BaP_{eqi}) = \sum (C_{PAHi} \times TEF_{PAHi})$$

$C_{PAHi}$ : Concentration of each PAH in the sample;  $TEF_{PAHi}$ : Toxic equivalency factor for each individual PAH.

### Statistical analysis

The results obtained were analyzed statistically using the Least Significant Difference test (LSD) at ( $P \leq 0.05$ ) and were expressed as Mean±SD using SPSS 16 for windows

## Results and Discussion

### Polycyclic Aromatic Hydrocarbons (PAHs)

Table 1 shows the PAHs concentration of cold smoked mullet fish flesh. 16 components of PAHs were detected in edible part of investigated smoked products including; Naphthalene (NA), Acenaphthylene (ACL), Acenaphthene (ACE), Fluorine (FLU), Phenanthrene (PHE), Anthracene (ANT), Fluoranthene (FLA), Pyrene (PYR), Benzo [a] Anthracene (BaA), Chrysene (CHR), Benzo [b] Fluoranthene (BbF), Bonzo [k] Fluoranthene(BkF), Benzo [a] Pyrene (BaP), Dibenzo [a,h] Anthracene (DahA), Benzo [g,h,i] Pyrene (BghiP) and Indeno [1,2,3-cd] Pyrene (IcdP). The results showed that A-smoked samples contained 5 compounds; Phenanthrene (4.9ppb), Fluorene (3.8µg/kg), Fluoranthene (2.6ppb), Pyrene (2.5ppb) and Anthracene (2.5ppb).  $\Sigma 16PAHs$  was 16.2ppb. While B-smoked samples contained

5 compounds; Fluoranthene (2.6ppb), Pyrene, Anthracene (2.4ppb), Fluorene and Phenanthrene (<LOQ) and they were lower than the limit of quantification of PAHs (<LOQ) (< 2ppb) and  $\Sigma 16PAHs$  were 7.4ppb.

Compound	Abbrev.	Mw	Rings	Concentration ( ppb )	
				Farm (A)	Farm (B)
Chrysene	CHR	228	4	ND	ND
Anthracene	ANT	178	3	2.4	2.4
Acenaphthene	ACE	153	3	ND	ND
Benzo(b)Fluoranthene	BbF	252	5	ND	ND
Benzo(k)fluoranthene	BkF	252	5	ND	ND
Dibenzo(a,h)Anthracene	DahA	278	5	ND	ND
Fluorene	FLU	166	3	3.8	<LOQ
Naphthalene	NA	128	2	ND	ND
Benzo(a)pyrene	BaP	252	5	ND	ND
Benzo(g,h,i)perylene	BghiP	276	6	ND	ND
Indeno(1,2,3-c,d)pyrene	IcdP	276	6	ND	ND
Acenaphthylene	ACY	152	3	ND	ND
Fluoranthene	FLA	202	4	2.6	2.6
Pyrene	PYR	202	4	2.5	2.4
Benzo(a)anthracene	BaA	228	4	ND	ND
Phenanthrene	PHE	178	3	4.9	<LOQ
$\Sigma 16PAHs$				16.2	7.4

**Table 1:** Concentration of Polycyclic Aromatic Hydrocarbons (PAHs) in cold-smoked mullet fish samples pre-frozen for 6 months at -18°C.

**Note:** Farm (A): Al-Batts Drain. Farm (B): El-Wadi Drain. Mw: Molecular weight. LOQ: <2µg/kg. ND: not detected.

### Toxic Equivalent Factors (TEFs) and B {a} P equivalent of PAHs found in smoked mullet fish samples

Toxic Equivalency Factor (TEF) is an estimate of the relative toxicity of individual PAH fraction compared to benzo (a) pyrene. TEFs have been applied as a useful tool for the regulation of compounds with a common mechanism of actions (e.g. PAHs) [18]. Even if this presentation of PAH content is empirical because the effects of PAHs in a mixture are insufficiently understood, with this approach it is possible to express PAH contamination of food by a single value as reported by [19,20]. Benzo [a] Pyrene (BaP) has been well characterized as the most potent carcinogenic PAH after dibenz [a,h] anthracene. Therefore, the total PAH concentration is expressed as Benzo[a] Pyrene Equivalents ( $BaP_{eqi}$ ) to illustrate the toxic potency [21].

The Toxic Equivalent Factors (TEFs) and B [a] P Equivalent of PAHs in smoked mullet fish are presented in table 2. The B [a] P Equivalent of Fluorene; Phenanthrene; Anthracene; Fluoranthene and Pyrene were 0.0038; 0.0049; 0.024; 0.0026 and 0.0025 respectively and the  $\sum(BaP_{eqi})$  was 0.0378 for farm A smoked samples (Figure 1). In the other farm samples (B) the B [a] P Equivalent of Anthracene; Fluoranthene and Pyrene were 0.024; 0.0026 and 0.0024 respectively and the sum of B [a] P Equivalent  $\sum(BaP_{eqi})$  were 0.029 (Figure 2).

### Molecular weight of PAHs in smoked fish

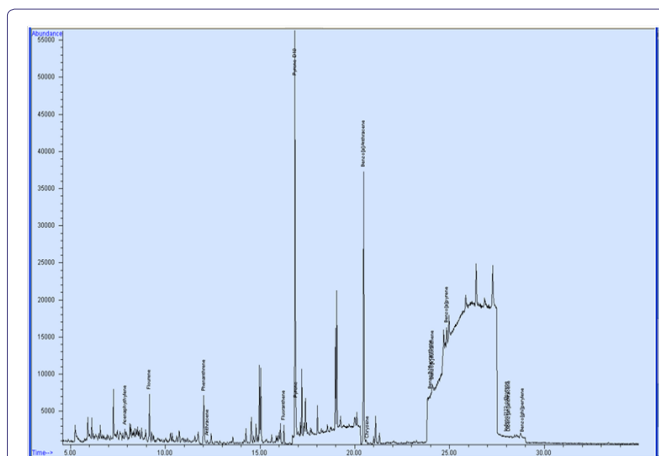
Table 3 illustrates the Molecular Weights (MW) of PAHs in smoked mullet fish. The total concentration of the Low Molecular Weights (LWM) of PAHs was higher than the Medium Molecular

Weights (MMW) in smoked fish farm (A). The concentration of LWM in smoked fish farm (A) was 11.1ppb while MMW was 5.1ppb. On the other side, for samples from B farm the total concentration of medium molecular weights of PAHs 5µg/kg, and LMW was 2.4µg/kg. The high molecular weight compounds not detected in samples from both farms A and B, Most of the carcinogenic PAHs fall within the group of the HMW [22]. This can be suggested to have been influenced by low fat and pyrolysis resulted from melted dropping onto the heat source. This is due to the average temperature of the smoking processes does not favor the production of HMW PAHs. The temperature range of 500-900°C is known to favor the production of HMW PAHs from thermal breakdown of lignin in lignocelluloses during wood combustion and also from pyrolysis of fats in fish [23-27].

Compound	TEF	Farm (A)		Farm (B)	
		Conc.(ppb)	BaP <sub>eqi</sub>	Conc. (ppb)	BaP <sub>eqi</sub>
Naphthalene	0.001	ND	-	ND	-
Acenaphthylene	0.001	ND	-	ND	-
Acenaphthene	0.001	ND	-	ND	-
Fluorene	0.001	3.8	0.0038	<LOQ	-
Phenanthrene	0.001	4.9	0.0049	<LOQ	-
Anthracene	0.01	2.4	0.024	2.4	0.024
Fluoranthene	0.001	2.6	0.0026	2.6	0.0026
Pyrene	0.001	2.5	0.0025	2.4	0.0024
Benzo(a)anthracene	0.1	ND	-	ND	-
Chrysene	0.01	ND	-	ND	-
Benzo(b)fluoranthene	0.1	ND	-	ND	-
Benzo(k)fluoranthene	0.1	ND	-	ND	-
Benzo(a)pyrene	1.0	ND	-	ND	-
Indeno(1,2,3,c)pyrene	0.1	ND	-	ND	-
Dibenzo(a,h)anthracene	1.0	ND	-	ND	-
Benzo(g,h,i)perylene	0.01	ND	-	ND	-
$\Sigma(\text{BaP}_{\text{eqi}})$			0.0378		0.029

**Table 4:** Toxic Equivalent Factors (TEFs) and B [a] P Equivalent of PAHs found in pre-frozen cold smoked mullet fish for 6 months at -18°C.

**Note:** TEF: Toxic Equivalent Factor; BaP<sub>eqi</sub>[a]: P equivalent. Farm (A): Al-Batts Drain; Farm (B): El-Wadi Drain.



**Figure 2:** GC-MS chromatogram of smoked mullet fish (farm B).

Concentrations (ppb) of the PAHs for Farm A Samples			Concentrations (ppb) of the PAHs for Farm B Samples		
HMW	MMW	LMW	HMW	MMW	LMW
-	5.1	11.1	-	5	2.4

**Table 3:** Total mean concentration (ppb) of PAHs in cold smoked fish, according to their molecular weights.

**Note:** HMW: High Molecular Weight; MMW: Medium Molecular Weight; LMW: Low Molecular Weight.

Farm (A): Al-Batts Drain; Farm (B): El-Wadi Drain; was not detectable.

### Category of PAH concentration

The categories of PAHs concentration as not contaminated (<10ppb); minimally contaminated (10-99ppb); moderately contaminated (100-1000 ppb) and highly contaminated(>1000ppb) [29].

Category of PAH concentration (ppb) in the studied smoked samples is shown in table 4. Concentrations of PAHs were 16.2 and 7.4ppb in smoked fish from farms (A) and (B), respectively. Based on these results, categories of concentration of PAH are considered a minimally contaminated (10-99ppb) for A-smoked product, may be due to pollutants presented in Al-Battsdrain and not contaminated (<10ppb) for B-smoked product compared with recommended levels as set by [28].

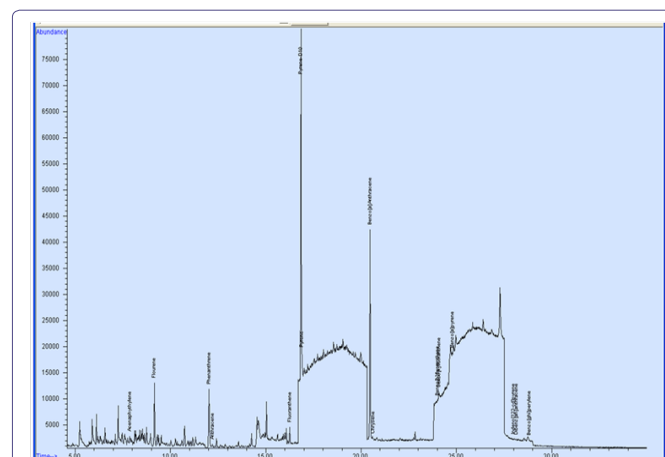
A-Smoked Mullet Product		B-Smoked Mullet Product	
Category	ΣPAHs (ppb)	Category	ΣPAHs (ppb)
Minimally contaminated	16.2	Not contaminated	7.4

**Table 3:** Category of PAH concentration (ppb) in the studied cold smoked mullet samples.

**Note:** Farm (A): Al-Batts Drain. Farm (B): El-Wadi Drain.

### Conclusion

It could be concluded PAHs concentration in smoked mullet products processed from pre-frozen mullet samples for 6 months at -18°C are considered a minimally contaminated (16.2ppb) for A-smoked mullet product and not contaminated (7.4ppb) for B-smoked product compared with recommended levels. In addition to the component



**Figure 1:** GC-MS chromatogram of smoked mullet fish (farm A).

of Benzo [a] Pyrene (B [a] P) was not detectable in all smoked fish products.

## References

- Swastawati F, Suzuki T, Dewi EN (2000) The effect of liquid smoke on the quality and omega-3 fatty acids content of tuna fish (*Euthynnus affinis*). *Journal of Coastal Development* 3: 573-579.
- Simko P (2002) Determination of polycyclic aromatic hydrocarbons in smoked meat products and smoke flavouring food additives. *J Chromatogr B Analyt Technol Biomed Life Sci* 770: 3-18.
- Hultmann L, Bencze Rora<sup>®</sup> AM, Steinsland I, Rustad T, Ska<sup>®</sup>ra T (2004) Proteolytic activity and properties of proteins in smoked salmon. *Food Chemistry* 85: 377-378.
- Stołyhwo A, Sikorski ZE (2005) Polycyclic aromatic hydrocarbons in smoked fish-A critical review. *Food Chemistry* 91: 303-311.
- Bilgin, Ş, Ünlüsayın M, İzci L, Günlü A (2008) The determination of the shelf life and some nutritional components of gilthead seabream (*Sparus aurata* L., 1758) after cold and hot smoking. *Turkish Journal of Veterinary and Animal Sciences (Turkey)* 32: 49-56.
- Shalaby AR (2000) Relation between mackerel fish smoking and its chemical changes with emphasis on biogenic amines. *J Agric Sci Mansoura Univ* 25: 353-365.
- CCFAC (2005) Codex Committee on Food Additives and Contaminants. Discussion paper on polycyclic aromatic hydrocarbons contamination. 37th Session, The Hague, The Netherlands.
- Yurchenko S, Mölder U (2005) The determination of polycyclic aromatic hydrocarbons in smoked fish by gas chromatography mass spectrometry with positive-ion chemical ionization. *J Food Comp Anal* 18: 857-869.
- Scientific Committee on Foods of EC, SCF (2002) Opinion of the Scientific Committee on Food on the risks to human health of Polycyclic Aromatic Hydrocarbons in food. Scientific Committee on Foods of EC, SCF, Brussels.
- Martorell I, Perelló G, Martí-Cid R, Castell V, Llobet JM, et al. (2010) Polycyclic Aromatic Hydrocarbons (PAH) in foods and estimated PAH intake by the population of Catalonia, Spain: Temporal Trend. *Environ Int* 36: 424-432.
- Zhang H, Xue M, Dai Z (2010) Determination of polycyclic aromatic hydrocarbons in aquatic products by HPLC-fluorescence. *J Food Compos Anal* 23: 469-474.
- Alomirah H, Al-Zenki S, Al-Hooti S, Zaghoul S, Sawaya W, et al. (2011) Concentrations and dietary exposure to Polycyclic Aromatic Hydrocarbons (PAHs) from grilled and smoked foods. *Food Control* 22: 2028-2035.
- Falcó G, Domingo JL, Llobet JM, Teixidó A, Casas C, et al. (2003) Polycyclic aromatic hydrocarbons in foods: Human exposure through the diet in Catalonia, Spain. *J Food Protect* 66: 2325-2331.
- IARC (1987) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Overall Evaluations of Carcinogenicity. IARC Monographs. International Agency for Research on Cancer, Lyon, France.
- IARC (2010) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Some Non-heterocyclic Polycyclic Aromatic Hydrocarbons and Some Related Exposures. International Agency for Research on Cancer, Lyon, France.
- Khorshid M, Souaya ER, Hamzawy AH, Mohammed MN (2015) QuEChERS Method followed by solid phase extraction method for gas chromatographic mass spectrometric determination of polycyclic aromatic hydrocarbons in fish. *Int J Anal Chem*.
- Nisbet IC, LaGoy PK (1992) Toxic Equivalency Factors (TEFs) for Polycyclic Aromatic Hydrocarbons (PAHs). *Regul Toxicol Pharmacol* 16: 290-300.
- Isioma T, Ozekeke O, Lawrence E (2017) Human health risk assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in smoked fish species from markets in Southern Nigeria. *Toxicol Rep* 4: 55-61.
- AFSSA (2003) AFSSA opinion on a request for an opinion on the risk assessment of benzo [a] pyrene B [a] P and other polycyclic aromatic hydrocarbons (PAHs), present in various commodities or in certain vegetable oils, as well as PAH concentration levels in commodities beyond which health problems may arise. French Food Safety Agency.
- Varlet V, Serot T, Monteau F, Le Bizet B, Prost C (2007) Determination of PAH profiles by GC-MS/MS in salmon processed by four cold-smoking techniques. *Food Addit Contam* 24: 744-757.
- Perugini M, Visciano P, Giammarino A, Manera M, Di Nardo W, et al. (2007) Polycyclic aromatic hydrocarbons in marine organisms from the Adriatic Sea, Italy. *Chemosphere* 66: 1904-1910.
- EFSA (2002) European Food Safety Authority. Scientific Committee on Food. Opinion on the risks to human health of polycyclic aromatic hydrocarbons in food, Italy.
- Maga JA (1988) *Smoke in Food Processing*. CRC Press, Florida, USA.
- Bartle KD (1991) Analysis and occurrence of PAHs in food. In: Creaser CS, Purchase R (eds.). *Food Contaminants: Sources and Surveillance*. Royal Society of Chemistry, London, UK. Pg no: 41-60.
- Nakamura T, Kawamoto H, Saka S (2008) Pyrolysis behavior of Japanese cedar wood lignin studied with various model dimers. *Journal of Analytical and Applied Pyrolysis* 81: 173-182.
- Essumang DK, Dodoo DK, Adjei JK (2013) Effect of smoke generation sources and smoke curing duration on the levels of Polycyclic Aromatic Hydrocarbon (PAH) in different suites of fish. *Food Chem Toxicol* 58: 86-94.
- Chukwujindu MA, Francisca IB, Iwekumo A, Eferhire A, Grace OBI (2016) Concentrations and risks of polycyclic aromatic hydrocarbons in smoke-cured fish products in Nigeria. *International Journal of Environmental Studies* 73: 827-843.
- Seyedeh LMN, Wan RI, Mohamad PZ (2013) Residual concentration of PAHs in seafood from hormozgan province, Iran: Human health risk assessment for Urban population. *International Journal of Environmental Science and Development* 4: 393-397.



- Journal of Anesthesia & Clinical Care  
Journal of Addiction & Addictive Disorders  
Advances in Microbiology Research  
Advances in Industrial Biotechnology  
Journal of Agronomy & Agricultural Science  
Journal of AIDS Clinical Research & STDs  
Journal of Alcoholism, Drug Abuse & Substance Dependence  
Journal of Allergy Disorders & Therapy  
Journal of Alternative, Complementary & Integrative Medicine  
Journal of Alzheimer's & Neurodegenerative Diseases  
Journal of Angiology & Vascular Surgery  
Journal of Animal Research & Veterinary Science  
Archives of Zoological Studies  
Archives of Urology  
Journal of Atmospheric & Earth-Sciences  
Journal of Aquaculture & Fisheries  
Journal of Biotech Research & Biochemistry  
Journal of Brain & Neuroscience Research  
Journal of Cancer Biology & Treatment  
Journal of Cardiology: Study & Research  
Journal of Cell Biology & Cell Metabolism  
Journal of Clinical Dermatology & Therapy  
Journal of Clinical Immunology & Immunotherapy  
Journal of Clinical Studies & Medical Case Reports  
Journal of Community Medicine & Public Health Care  
Current Trends: Medical & Biological Engineering  
Journal of Cytology & Tissue Biology  
Journal of Dentistry: Oral Health & Cosmesis  
Journal of Diabetes & Metabolic Disorders  
Journal of Dairy Research & Technology  
Journal of Emergency Medicine Trauma & Surgical Care  
Journal of Environmental Science: Current Research  
Journal of Food Science & Nutrition  
Journal of Forensic, Legal & Investigative Sciences  
Journal of Gastroenterology & Hepatology Research  
Journal of Gerontology & Geriatric Medicine  
Journal of Genetics & Genomic Sciences  
Journal of Hematology, Blood Transfusion & Disorders  
Journal of Human Endocrinology  
Journal of Hospice & Palliative Medical Care  
Journal of Internal Medicine & Primary Healthcare  
Journal of Infectious & Non Infectious Diseases  
Journal of Light & Laser: Current Trends  
Journal of Modern Chemical Sciences  
Journal of Medicine: Study & Research  
Journal of Nanotechnology: Nanomedicine & Nanobiotechnology  
Journal of Neonatology & Clinical Pediatrics  
Journal of Nephrology & Renal Therapy  
Journal of Non Invasive Vascular Investigation  
Journal of Nuclear Medicine, Radiology & Radiation Therapy  
Journal of Obesity & Weight Loss  
Journal of Orthopedic Research & Physiotherapy  
Journal of Otolaryngology, Head & Neck Surgery  
Journal of Protein Research & Bioinformatics  
Journal of Pathology Clinical & Medical Research  
Journal of Pharmacology, Pharmaceutics & Pharmacovigilance  
Journal of Physical Medicine, Rehabilitation & Disabilities  
Journal of Plant Science: Current Research  
Journal of Psychiatry, Depression & Anxiety  
Journal of Pulmonary Medicine & Respiratory Research  
Journal of Practical & Professional Nursing  
Journal of Reproductive Medicine, Gynaecology & Obstetrics  
Journal of Stem Cells Research, Development & Therapy  
Journal of Surgery: Current Trends & Innovations  
Journal of Toxicology: Current Research  
Journal of Translational Science and Research  
Trends in Anatomy & Physiology  
Journal of Vaccines Research & Vaccination  
Journal of Virology & Antivirals  
Archives of Surgery and Surgical Education  
Sports Medicine and Injury Care Journal  
International Journal of Case Reports and Therapeutic Studies

Submit Your Manuscript: <http://www.heraldopenaccess.us/Online-Submission.php>