Risk of Chromosomal Aberrations associated with Residential Proximity to an Industrial Area

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ABSTRACT *A study onthe cytogenetic damagein residents living in and around the Patancheru and Bollarum Industrial area, Hyderabad, Telangana state was carried out using chromosomal aberrations as parameter. For comparison, people who were living in the non-industrial area wereincluded (control group).The subjects were clinically examined and information on demographic characteristics such as age, BMI, habits andduration of staywas collected.Blood samples from the residents of industrial area and non-industrial area were collected and analysed for chromosomal aberrations. The results showed a high frequency of chromosomal aberrations in the peripheral lymphocytes of the residentsof industrial area (8.07%) and compared to the frequency of the chromosomal aberrations observed in the residents of the non-industrial area(2.61%).The results further showed a gradual increase with duration of stay in the residents of the industrial area. The statistical analysis of the resultsshowed that the increase in the frequency of chromosomal aberrations in residents of the industrial area was significant (P value< 0.01 &< 0.05) compared to the control subjects.The cytogenetic effectsin the residents might be due to exposure to the industrial pollutants in this area. The present study suggest that chromosomal aberrationanalysis may be considered as suitable biomarkerto predict the cancer risk in the populations exposed to industrial pollution .*

Keywords: *Industrial Pollution, Chromosomal aberrations,lymphocytes, blood*

1. INTRODUCTION

Population monitoring for health effects of environmental pollution is a critical problem especially in the case of mixed, low level chemical exposures. Studies have also reported chromosomal abnormalities in offspring associated with a maternal residence near waste sites (Brender et al., 2008), very few studies have examined the health effects in people living near industrial facilities(Hans Orru et al.,2018,AdilAlwahaibi and Ariana Zeka.,2016,Prashanth et al.,2017). Since it is not possible to control the background exposure conditions, it is difficult to identify the pollutants responsible for the observed effects in residents.

There have also been limited studies of the mutagenic effects on non-occupational exposure to individual chemicals (Infante.,1976). Mixed exposure studies have been conducted mainly in populations residing in the vicinity of old chemical dumps (Vrijheid.,2000,Heath., 1982). Many of the animal model(Iji and Adeogun.,2014) and human population studies (Leelavathi and Mathivanan., 2015) showed relationship between exposure to industrial pollution and chromosomal aberrations. The epidemiologic studies showed increased risks of chromosomal aberrationsin children of women lived near hazardous waste sites (Dolk et al.,1998;Sandra et al.,1992; Lisa A et al.,1997).

In several animal models including wild rats (Eckl and Riegler., 1997,ChibuisiAlimba et al.,2009) and mice (Yahya et al.,2017) pollutants at hazardous waste sites and in solid waste leachates are known to induce chromosomal aberrations and DNA damage.

Epidemiological studies were carried out all over the world established ill health effects (Subodh Kumar Rastogi et al., 2008) and cytogenetic damage (AnushaPawar et al.,2016,SrinivasChinde et al.,2014,Solange Costa et al., 2015) in the industrial workers . Thus it is highly pertinent to understand the health problems and cytogenetic effects in people living in and nearby industrial areas.

Chemical exposure to both women and men may cause chromosomal abnormalities or gene mutations in the offspring and also disturb the development of the fetus through heritable changes (epigenetic mechanisms) in egg or semen cells (Marja-LiisaLindbohm and MarkkuSallmén, 2017).

2. NEED FOR THE STUDY ON PEOPLE OF PATANCHERU AND BOLLARUM INDUSTRIAL AREAS

The present study was conducted in the residents of Patancheru-Bollarum industrial area to evaluate the risk of cytogenetic damage.

The Patancheru-Bollarum industrial Estate was established in the year 1975 in Medak district of Telangana state and is about 30 kms from Hyderabad.It is one of the most industrially polluted areas. Patancheru-Bollarum cluster is one of most important industrial areas having an enormous number of industries manufacturing pharmaceutical drugs, paints, pesticides, steel, plastics, textiles, leather, rubber, bulk drug manufacturing units, etc., earning the State the nickname 'bulk drug capital' of the country. These industries release lot of effluents, which are toxic and contaminate the air, soil and water. The impact is such that a pungent and acrid odouris released in this area.This region has traditionally relied on ground water for sustenance and is supported by seasonal streams like the NakkaVagu and IskaVagu. Recent reports suggest that both groundwater of the region and the surface water in NakkaVagu are heavily polluted due to domestic sewage, industrial effluents and also due to partially treated effluents from the common effluent treatment plant (CETP) of this region. As per the study of CPCB, the Patancheru –Bollaramindustrial area was considered as critically polluted area(ACTION PLAN-PTN-BLM.,2010).Very few studies were carried out on the health hazards in people living in this industrial area. Thus in the present study an attempt is made to understand the cytogenetic damage in the residents of this area.

3. METHODOLOGY

Study population

195 peopleliving in and around Patancheru–Bollarum industrial areas were enrolled for the study (exposed group). For comparison199 people belonging to the same age group and socioeconomic status and who were not occupationally exposed to chemical compounds and living away from the industrial area were selected (control group).This study was approved by the institutional ethics committee.

All participants were informed about the objectives of the investigation and written consent was obtained from each person. Personal information on the age, weight, height, duration of stay, habits (smoking & nonsmoking) were collected from the subjects from both the groups and entered in a questionnaire specially proposed for this purpose.

The following inclusion and exclusion criteria was followed for the selection of subjects .

Inclusion: 1. Residents with a minimum stay of 1 year
2. Residents not occupationally exposed to physical or biological agents

Exclusion: 1.Residents with less than one year stay
2. Industrial workers
3. Couples moved to the industrial area after conceiving elsewhere.

Analysis of chromosomal aberrations in peripheral blood of the industrial residents

Cytogenetic damage was assessed by analysing the chromosomal aberrations in the residents of both industrial area and nonindustrial areas.

3 ml blood sample was drawn from each subject from the residents of both theindustrial and non-industrial areas and cultures were setup following the method of Moorhead et al., (1960).0.5 ml blood from each individual was added to 5ml medium and each sample was maintained in duplicate. A control batch of cultures was always set up simultaneously for each batch of the study group and all the cultures were incubated at 37^0C for 72 hours. 2 hours prior to the termination at the 70th hour colchicine (0.3 ul/ml) was added to all the cultures to inhibit the spindle formation. At the end of 72 hours each culture was decanted into 15 ml centrifuge tube and centrifuged at 1000 rpm for 10 minutes. The supernatant was discarded. 5ml of pre-warmed hypotonic solution (0.75 M KCI) was added to the pellet and the cells were incubated at 37^0 C for 20 minutes. After the hypotonic treatment, the cell suspension was centrifuged at 1000 rpm for 10 minutes. The supernatant was removed and to the pellet the pre-chilled fixative (3:1 methanol and acetic acid) was added carefully along the walls, to avoid clumping of the cells. The cells were allowed to stand for 10 min. After 10 minutes the cell suspension was centrifuged at 1000 rpm for 10 min. The supernatant was removed and fresh fixative was added to the pellet. This process was repeated for 3 to 4 times and the final cell suspension was made in 1ml of fresh fixative.

Preparation of the slides.

The micro slides were cleaned and kept in chilled distilled water before use. Two or three drops of cell suspension were dropped on each micro slide using a Pasteur pipette. The slides were air dried. All the slides were coded and stained in 2% Giemsa (2 ml of Giemsa, 2ml of Sorenson's buffer and 46 ml of distilled water) for 5 minutes. After staining, the slides were rinsed in distilled water and dried. The slides were then observed under the microscope.

Scoring of chromosomal aberrations

For each individual 100 well spread metaphases were screened and scored for structural (gaps, breaks, dicentrics) and numerical aberrations (polyploids). However, gaps and polyploids were not included in the total number of aberrations. Well spread metaphases were micro photographed.

Statistical analysis

The differences in the frequencies of chromosomal aberrations and the demographic data between the residents of the industrial area andnon-industrialarea wereanalysedfor significance using chi-squarep value and t-test.

4. RESULTS

The present study was conducted to evaluate cytogenetic effects in 195 subjects from the Patancheru and bollarum industrial area and 199 subjects from non-industrial area (control group) and the results are as follows.

The demographic characteristics of the study population are represented in **Table 1**.

The mean ageof the residents of the industrial area was33.18 yrs. as against 36 yrs. of the residents of the non-industrialarea. Nearly 51% of the residents of the industrial area were obese having BMI ≥25 Kg/m2 while only 43.21 % were obese in control group.The results also showa higher prevalence of underweights (4.61%) in industrial residents than in people who were living in nonindustrial area (3.01%).The Mean weight of industrial residents was 65 kg and that of control subjects was 63 kg.43.58% of industrial residents had a normal weight and53.26% of control subjects have normal weights.94.87 % were non-vegetariansamong study subjects as against 85.42% in controls.69.23% literates and 23.07% smokers were observed among the study subjects and 83.92% literates, and 7% smokerswere observed among the control group.

Table – 1.Demographic data of the Residents of industrial andnon-industrial areas

S.No.	Parameter	Industrial residents	Non industrial residents	P-Value
1	Age (Years)			
	Mean ± SD	33.18±10.59	36.0±13.29	0.020*
2	Height (cm)			
	Mean ± SD	158.29±8.00	160.09±7.00	0.017*
3	Weight (Kg)			
	Mean ± SD	65.0±12.00	63+10.39	0.008**
4	BMI (Kg/m2)			
	Under weight (<18.5)	9 (4.61%)	6(3.01)	0.14
	Normal (18.5-24.9)	85 (43.58%)	106(53.26)	
	Obese (>25)	100 (51.28%)	86(43.21)	
5	Veg	13 (6.66 %)	29(14.57)	0.009**
	Non-Veg	185(94.87%)	170(85.42)	
6	Literates	135 (69.23%)	167(83.92)	0.000**
	Illiterates	60(30.76%)	32(16.08)	
7	Duration of Exposure (Years)			
	Range	0.9 -30 years		
8	Smokers	45(23.07)	14(7)	0.000**
	Non-smokers	150(76.92)	185(93)	

*p<0.05 Significant **p<0.01 highly significant

The results on the incidence of chromosomal aberrations in the residents living in the industrial area are presented in Tables 2. An increased incidence in the frequency of chromosomal aberration was observed in the industrial residents when compared to the control group. While the frequency of aberrations

was 2.61% in the residents of non-industrial area it has increased to 8.07% in the residents of the industrial area.The results in both the groups were categorized as smokers and nonsmokers .The frequency of chromosomal aberrations was assessed to understand the influence of smoking. The results showed an increased percentage of chromosomal aberrations (8.85) among the smokers of industrial residents as against the frequency (3.83) observed among the smokers from non-industrial area (Table-2).

Table-2 Frequency of Chromosomal aberrations in the residents of the Patancheru- Bollarum Industrial area

Group	No. of Samples	No.of Metaphases screened	Chromosomal aberrations				Total no. of Aberrations
			Gaps	Breaks	Dicentrics	Polyploids	
1. Residents of non- industrial area (Controls group)	199	19900	182(0.91)	339(1.70)	182(0.91)	122(0.61)	521(2.61)
Smokers	12	1200	17(1.41)	25(2.08)	21(1.75)	16(1.33)	46(3.83)
Non Smokers	187	18700	154(0.82)	277(1.48)	144(0.77)	101(0.54)	421(2.251)
2. Residents of industrial area (Exposed group)	195	19500	524(2.68)	987(5.06)	587(3.01)	384(1.97)	1574(8.07)
Smokers	33	3300	100(3.03)	148(5.48)	91(3.37)	64(2.37)	239(8.85)
Non-Smokers	168	16800	430(2.55)	849(5.05)	505(3.00)	335(1.99)	1354(8.05)
3.**P-value**			0.006*	0.003 *	0.414	0.534	0.004 *

*p<0.05 Significant **p<0.01 highly significant

Values in the parenthesis are percentages.

Table 3.Frequency of chromosomal aberrations in the duration of residence in the Patancheru - Bollarum Industrial area.

Group		No. of Samples	No.of Metaphases	Chromosomal aberrations				Total no. of Aberrations
				Gaps	Breaks	Dicentrics	Polyploids	
1. Residents of the non-industrial area(controls)		199	19900	182 (0.91)	339(1.70)	182 (0.91)	122 (0.61)	521(2.61)
2. Residents of Industrial Area (by duration of residence)	1-5 yrs.	92	9200	137 (1.48)	259 (2.87)	168 (1.82)	128 (1.39)	427 (4.65)
	6-10 yrs.	54	5400	162* (3.00)	323** (5.98)	181** (3.35)	114* (2.10)	504** (9.33)
	11-15 yrs.	21	2100	78** (3.71)	158** (7.52)	85 (4.04)	52** (2.48)	243** (11.57)
	>15 yrs.	28	2800	141** (5.03)	247** (8.82)	153 (5.46)	90** (3.20)	400** (14.28)

*p<0.05 Significant **p<0.01 highly significant

Values in the parenthesis are percentages.

The effect of duration of residence (stay) on the chromosomal aberrations in the residents of the Patancheru- Bollarum industrial area was studied and the results are presented in Table 3.

The frequency of chromosomal aberrations showed a gradual increase in the residents of the industrial area with the increase in the duration of residence. While the frequency of chromosomal aberrations was 4.65 % in the residents with 1- 5 years of stay, it has increased to 9.33% in the residents with 6-10 years. Further increase in the incidence of chromosomal aberrations was seen in the residents with 11-15 years residence (11.57%) and more than 15 years (14.28%) of residence.

The statistical analysis of the results using chi squareshowed that the increase in the chromosomal aberrations in the residents with increased years of their stay was significant. Suggesting dosage effect.

4. DISCUSSION

Acquisition of scientific knowledge and technologies, their application in industrialization, rapid urbanization and increasing needs of man has resulted in pollution of the environment and affected all parts of the biosphere making survival of living organismsprecarious. Industrial pollution has become more significant and a global reality. Hence there is a high risk in the population living in villages nearby industrial areas for adverse health effects due to contamination of air, water and soil with industrial pollutantsand nearby villages are contaminated with high levels of heavy metals.Extensive studies have clearly showed the health problems (Heron and Pickering.,2003) in workers of pharmaceutical industry, cytogenetic effectsin cement (Divvyapriya and suja.,2012, Calistus Jude.,2002) and leather (Subodh Kumar Rastogi et al.,2008:AnushaPawar et al.,2016), agricultural (Fatihtaspinar and Ismail toroz .,2017) industries.However Studies on the adverse effects in people living in and around industrial areas are very scanty. Studies carried out on people living near to industrial dumps and in children playing close to industrial waste indicated certain health problems(Ihedioha et al.,2017).

In this context a study was taken up to know the possible detrimental effects in the residents of Patancheru and Bollarum area where many industries are located.The present study carried out in the residents of the Patancheru and Bollarum industrial area showed a significant increase in the chromosomal aberrations, thus suggesting cytogenetic damage compared to the controls.

In our study we observed significant increase of chromosomal aberrations in the residents of this area thus induced effects have an attributions. Smoking also considered as an important factor in cytogenetic studies on occupational and industrial exposures, a significant increase in chromosomal aberrations were observed in smokers when compared to non-smokers. Our results confirm previous reports (Vladimir et al., 2015, Anusha C Pawar et al.,2016).Thus data generated clearly provided evidence for the cytogenetic damage in the residents of the industrial area due to undue exposure to industrial pollution at Patancheru and Bollarum industrial area where a number of pharmaceutical, rubber, iron, bulk drug, steel, leather, cement and paint industries are located.The effects might be attributed to the indirect effect of exposure to pollutants liberated from the industries.

Chromosomal aberrations have been reported in human populationgroups with occupational exposure to specific chemicals, such as Lead (Urmisha Das and Madhusnata De.,2013**)**),vinylchloride (Ducatman et al., 1975, Czeizel et al., 1977) benzene (Watanabe et al.,1980)pesticides (Brian et al (2009), nickel(MahaFahmy et al.,2014,Waksvik et al .,1982) and styrene (Watanabe et al., 1983).

The industrial management has to take proper measures to control the release of industrial gases and wastes in to the environment. The results of the above study showed adverse effect on chromosomes. Further studies are needed to understand the consequences of exposure of childrenliving in this area.

5. CONCLUSION

The results clearly showedinduced chromosomal aberrationsin the residents of the industrial area compared to matched controls and the same can be attributed to environmental pollution with industrial pollutants. The study also demonstrates that factors such as cigarette smoking and duration of residence are associated with the increased frequencies of chromosomal aberrations in the industrial residents. Thus the study suggested that long term exposure to the industrial pollution and stay in the industrial area might cause adverse genetic consequences in the population resulting the health of future generation.

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7. REFERENCES

1. Adil Al-Wahaibi and ArianaZeka , Health impacts from living near a major industrial park in Oman Al-Wahaibi and Zeka BMC Public Health (2015) 15:524.
2. Anusha C Pawar, Jithender Kumar Naik S, RaghavendernRao M.V, SireeshaBala. A, Krishna Sowmya.J,Sireesha K, Mangesh V and AnithaKumari,Analysis of Chromosomal Aberrations in PBL of Chrome Tanning Industrial Workers,Adv Biotech & Micro 1(1): AIBM.MS.ID.555552 (2016).
3. Brender JD, Zhan FB, LangloisPH,Suarez L, Scheuerle A. Residential proximity to waste sites and industrial facilities and chromosomal anomalies in offspring.
4. Brian C.-H. Chiu, PhD, 2009, Pesticides, Chromosomal Aberrations, and Non-Hodgkin's Lymphoma, J Agromedicine. 14(2): 250–255.
5. Calistus Jude, L, K. Sasikala, R. Ashok Kumar, S. Sudha and J. Raichel, Haematological and Cytogenetic Studies in Workers Occupationally Exposed to Cement Dust,Int J Hum Genet, 2 (2): 95-99 (2002
6. ChibuisiAlimba, G., A. AdekunleBakare and G. OlatubosunArinola, Effects of Municipal Solid Waste Leachate on Leucocyte and Differential Counts in Rat, Global Journal of Environmental Research 3 (3): 205-210, 2009
7. Cordier, S., 'Evidence for a role of paternal exposures in developmental toxicity', Basic &Clinical Pharmacology & Toxicology, Vol. 102, 2008, pp. 176-181. Available at: [1]
8. Czeizel A. Genetic study on polyvinyl chloride workers.Mutat Res 1977;46:215-6.
9. DivyaPriya S, Suja S, The Effect of Cement Dust Exposure on Hematological and Cytogenetic Studies of Cement Workers, January – March 2012 RJPBCS Volume 3 Issue 1 Page No. 615
10. Ducatman A, Hirschhorn K, Selikoff IJ. Vinyl chlorideexposure and human chromosome aberrations.Mutat Res1975;31:163-8.
11. Eckl, P.M, Riegler. D, Levels of chromosomal damage in hepatocytes of wild rats living within the area of a waste disposal plant ,The Science of the Total Environment 196 (1997) 141-149
12. Ekong EB, Jaar BG, Weaver VM.2006.Lead-related nephrotoxicity: a review of the epidemiologic evidence.Kidney Int. 70(12):2074-84.

13. Fatihtaspinar and Ismail toroz .2017.Analysis of fluoride pollution from fertilizer industry and phosphogypsum piles in agricultural area gulerdartan. Jr. of Industrial Pollution Control 33(1)(2017) pp 662-669.
14. Final action plan for improvement of environmental parameters in critically polluted areas of "patancheru-bollaram cluster" andhrapradesh, a.p. Pollution control board,2010.
15. Hans Orru, Jane Idavain, Mihkel Pindus, Kati Orru, KaisaKesanurm, Aavo Lang and JelenaTomasova, Residents' Self-Reported Health Effects and Annoyance in Relation to Air Pollution Exposure in an Industrial Area in Eastern-Estonia, Int. J. Environ. Res. Public Health 2018, 15, 252; doi:10.3390/ijerph15020252
16. Heath CW. Epidemiology of dump exposures. In: Chemical and radiation hazards to children. Columbus, Ohio: Ross Laboratories, 1982:10-7.
17. Heron RJ, Pickering FC.Health effects of exposure to active pharmaceutical ingredients (APIs), Occup Med (Lond).2003 Sep;53(6):357-62.
18. Hugo M. de Oliveira, Gracilene P. Dagostim, Arielle Mota da Silva, Priscila Tavares, Luiz A. Z. C. da Rosa, and Vanessa M. de Andrade, Occupational risk assessment of paint industry workers Indian J Occup Environ Medv.15(2); May-Aug 2011
19. Ihedioha, J.N.P., O. Ukoha,N. R. Ekere.2017. Ecological and human health risk assessment of heavy metal contamination in soil of a municipal solid waste dump in Uyo, Nigeria.Environmental Geochemistry and Health , Volume 39, Issue 3, pp 497–515.
20. Iji. O.T, and A.O. Adeogun, Industrial Effluent Induced Chromosomal Aberration in Catfish from Ogun River, Lagos, Nigeria, Pakistan Journal of Biological Sciences, Volume 17 (5): 675-681, 2014
21. Infante PF. Oncogenic and mutagenic risks in communities with polyvinyl chloride production facilities. Ann NY Acad Sci1976;271:49-57.
22. Jean D. Brender, RN, PhD, Juliana A. Maantay, PhD, MUP, and JayajitChakraborty, PhD, MS, Residential Proximity to Environmental Hazards and Adverse Health Outcomes, Am J Public Health. 2011 December; 101(Suppl 1): S37–S52.
23. KyriakiRemoundou and Phoebe Koundouri .2009. Review Environmental Effects on Public Health: An Economic Perspective. Int. J. Environ. Res. Public Health 6, 2160-2178.
24. Leelavathi.D, and Mathivanan.V. Scoring of chromosomal aberration among a human population in the suburbans of Chennai exposed to environmental pollutants, International journal of novel trends in pharmaceutical sciences, volume 5, number ,feb - 2015
25. Maheshwari R. , Gupta S. , Das K., Impact of Landfill Waste on Health: An Overview IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT), Volume. 1 Issue. 4, 2015, PP 17-23
26. Marja-LiisaLindbohm and MarkkuSallmén, Reproductive effects caused by chemical and biological agents, Finnish Institute of Occupational Health, 2017.
27. PrashanthChiliveri, VanithaBaluka, Kirmani N, Sreedevi. T and, PP Reddy, Assessment of health problems and reproductive outcome in residents of uppal industrial area in Telangana State, Volume 4; Issue 5; May 2017; Page No. 219-222.
28. PrincyAgarwal, AnjuGoyal, RajatVaishnav, Chemical hazards in pharmaceutical industry: an overview , Asian J Pharm Clin Res, Vol 11, Issue 2, 2018, 27-35
29. Solange Costa1, Sandra Carvalho1, Carla Costa1, Patrícia Coelho, Susana Silva, Luís S. Santos, Jorge F. Gaspar, Beatriz Porto, Blanca Laffon and João P, Increased levels of chromosomal aberrations and DNA damage in a group of workers exposed to formaldehyde , Mutagenesis, 2015, 30, 463–473
30. SrinivasChinde& Monika Kumari&KanapuramRudrama Devi &UpadhyayulaSuryanarayanaMurty& Mohammed FazlurRahman&SrinivasInduKumari& Mohammed Mahboob&Paramjit Grover, Assessment of genotoxic effects of lead in occupationally
31. Subodh Kumar Rastogi, AmitPandey, and SachinTripathi, Occupational health risks among the workers employed in leather tanneries at Kanpur, Indian J Occup Environ Med. 2008 Dec; 12(3): 132–135.
32. Talkhan OF, AbdElwahab SA, Shalapy EM. 2016. Biochemical studies on the effect of different water resources in Hail region on liver and kidney functions of rats. Environ Monit Assess.;188(8):484.
33. TordKjellstrom, Sharon Friel, Jane Dixon, Carlos Corvalan, Eva Rehfuess, Diarmid Campbell-Lendrum,Fiona Gore, and Jamie Bartram.2007. Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 84, No. 1 doi:10.1007/s11524-007-9171-9.
34. Urmisha Das and Madhusnata De, Chromosomal Study on Lead Exposed Population,Int J Hum Genet, 13(1): 53-58 (2013)
35. Vladimir G. Druzhinin, Maxim Yu. Sinitsky, Aleksey. V. Larionov,Valentin P. Volobaev, Varvara, Minina and Tatiana A. Golovina1, Assessing the level of chromosome aberrations in peripheral blood lymphocytes in long-term resident children under conditions of high exposure to radon and its decay products,Mutagenesis, 2015, 30, 677–683
36. Vrijheid,M. Health Effects of Residence near Hazardous Waste Landfill Sites: A Review of Epidemiologic Literature, Environmental Health Perspectives, Vol. 108, 2000, pp. 101-112
37. Yahya A. Shekha, Mustafa S. Al-Attar1 Mohammed A. Saleem, Janan J. Toma1 Siraj M. Abdulla, Effect of landfill leachates extract of Erbil city on abnormal sperm morphology and chromosomal aberrations in male albino mice ,ZANCO Journal of Pure and Applied Sciences ZJPAS (2017), 29 (6); 18-27