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TOXIC EFFECT OF FORMALDEHYDE: A SYSTEMATIC REVIEW

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ABSTRACT

Formaldehyde is one of the potent toxic industrial chemicals that are very commonly used in various industries, labs, and biological museums, etc. The toxicity of formaldehyde is well-known. It causes respiratory distress if inhaled in higher concentration thus, causing lung damage. It is also found to be mutagenic due to its rapid reactivity being a small molecule having electrophilic carbon. The current review focuses on the characteristic properties of formaldehyde, Sources, and uses of formaldehyde. This review further brings about the toxicity of formaldehyde on different organs and organ systems of the body. Its genotoxicity and carcinogenicity are described. And later the various ways of decontaminating the formaldehyde are discussed to neutralize its harmful impacts. From this review, we have concluded that formaldehyde is a highly toxic chemical that needs proper protective measures while handling and should not be directly exposed. There should be proper decontaminating agents for emergencies, where there is the mass production of formaldehyde.

Keywords: Formaldehyde, Toxicity, Organs, Genotoxicity, Carcinogenicity.

I. INTRODUCTION

Formaldehyde, the simplest naturally occurring aldehyde, is generally represented as HCHO. HCHO has been identified as a potent cancer-causing and mutagenic chemical, however the degree of the cancer threat due to the presence of formaldehyde in people is yet to be defined [1]. Usually formaldehyde exposures happen by inhalation or by absorption through skin or eye. It easily enters the lungs, gastrointestinal tract, and to lesser degree through skin. Formaldehyde (HCHO) is a highly reactive, lethal, and mutagenic carbonyl group containing molecule that all living beings produce in minor quantities under normal digestive conditions.

(It is additionally a significant and compulsory moderate in common and designed ('manufactured') methylotrophic and format trophic pathways and in engineered pathways to which methanol supplies diminishing force however not carbon[2][3]. Formaldehyde, widely used for fixing various tissues, is basically used for study of various DNA-protein interactions. Due to the electrophilic carbon, which may fastly attack electron-rich thiol as well as amino groups forming covalent bond. Hence, the molecule has high reactive nature[4][5]. Rapid reactivity of formalin to amino and thiol moieties attributes to the mutagenic activity. With amines, for example, the 6-amino moiety of peptidyl lysine, HCHO yields a carbinolamine that can either be oxidized to a N-formyl subsidiary or undergo dehydration, yielding a labile Schiff base that can form cross-joins (methylene spans) with different amino acids and nucleobases[2]. Formaldehyde is one of the significant products of the chemical industry, positioning 23rd in production volume ($6.73*10^9$lb/yr; $3.05*10^6$mt/yr)[1] among synthetic concoctions prepared in the U.S [6].It is discharged by inadequate burning of wood, flammable gas, and cigarette smoking[7].It is utilized in the assembling of pitches, molecule board and pressed wood, materials, cowhide merchandise, paper, and pharmaceuticals. Formaldehyde is likewise a basic molecule in cell digestion that is required for the biosynthesis of purines, thymidine, and certain amino acids[6].Formaldehyde is a natural poison that has been delegated as a known cancer-causing agent (bunch 1) to human and creatures by the Global Organization for Exploration on Malignant growth (IARC). It also causes an intense respiratory tract aggravation and initiates squamous cell carcinomas in the nasal depression region and lung in humans and rodents[7]. This in order with the perception that formaldehyde inhalation can cause nasopharyngeal malignancy in people and may form cancer causing cell in the nasal entries of rodents[4]. The intense unfavorable impacts of formaldehyde, including tangible aggravation and sharpening, have been audited by the National Institute of Sciences[1]. Presentation of trial creatures to formaldehyde brings about its quick metabolic consolidation into DNA, RNA, and proteins, illustrating that exogenous formaldehyde blends promptly with the endogenous pool and in the covalent official of formaldehyde to these macromolecules. The covalent responses of formaldehyde with macromolecules are commonly acknowledged as the key reasons for its poisonous impacts[6].

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II. CHARACTERISTIC PROPERTIES

2.1 Physical Properties:

Formaldehyde is a combustible, dismal gas at room temperature and has a sharp, choking out smell. On condensation, formaldehyde turns into watery form that bubbles at 19°C while it get freeze at -15°C[1]. Since it polymerizes promptly, it is sold and moved distinctly in arrangement or in the polymerized state. Formaldehyde as a hydrophilic compound requires stabilizers such as methanol or methyl/ethyl cellulose[1]. Boiling point of HCHO is (760) mm hg: -6°F (-21°C) & with molecular weight 30.0 Dalton. Formaldehyde reacts with solid oxidizers, alkalis, acids, phenols and urea. The most common form of commercialized formaldehyde, known as formalin, consist of 37% by weight formaldehyde while consist of 6 to 15% methanol. Different wellsprings of formalin incorporate blends of lower or higher sub-atomic weight polyoxymethylene glycols H(CH20) nOH, referred to separately as para-formaldehyde, or polyoxymethylene and the c trimer trioxane which is cyclic. These polymeric structures are hard in nature[1]. It can be present in all three solid, aqueous as well as gaseous phase. Commercial formaldehyde formulations are clear and remains stable over 16-21°C. They are promptly obtained by dissolving exceptionally packed formaldehyde in desired alcohol. Add more reference and validate these facts from multiple reference

2.2 Chemical properties:

Formalin, an extensively reacting molecule with a single carbonyl side associated with two hydrogen molecules, H2C = 0 (F16). HCHO (CAS No. 50-00-00) and the simplest aldehyde, with HCHO as molecular formulae, and 30.3as a molecular weight. It's dry gas with a sharp odor at standard temperatures. Liquid formal aldehyde, called Formalin, is an answer of 37% (by weight) formaldehyde gas in water, normally with lo-15% methanol added to forestall polymerization. Formaldehyde is forms several economical polymers, for example, the strong PA formaldehyde (HCHO) and the stable cyclic polymer trioxane or trioxymethylene $(HCHO)_3$ [8].

III. SOURCE AND USE

Formaldehyde, a widely used compound is present almost everywhere across the globe. It has specific purpose in tissue safeguarding, cowhide tanning, treating, the assembling of materials" and furthermore as a biocide." It has been distinguished in the blood of typical human subjects, and is shaped and debased by metabolic procedures in most different species."[9]. The formaldehyde sources can be broadly categorized as Exogenous and Endogenous sources. Environment and Human Diet contribute a major share under exogenous sources of formaldehyde exposure while endogenous sources include. Folate-derivatives breakdown and next categorized Protein and nucleic acid demethylations and various other metabolic sources. Table 1 presents the scope of formaldehyde fixation to which laborers are usually exposed under different conditions.

3.1 Toxicity:

In insignificant fixation, formaldehyde is non-toxic to people, however exposure to higher concentration may bring about extreme and harmful impacts [18].Formaldehyde can enter the body through inhalation, ingestion or dermal retention[8]. Following fundamental assimilation, formaldehyde undergoes oxidation to formic corrosive by catalyst. Formaldehyde in the liver and in erythrocytes [18]. Various reports have recorded the lethal impacts of formaldehyde exposure through several experimental studies since it is retained by all surfaces of the body. When excessive formaldehyde enters the circulatory system, formaldehyde yields formic corrosive which can quickly necrose cells in the liver, kidneys, heart, and cerebrum. Formic corrosive can be eliminated through the kidney as sodium salt or further oxidized to carbon dioxide and water. The half-life existence period of formic corrosive has been documented to be 90 min [18]. A case study was carried out at Department of Anatomy at South Valley University, Egypt. The study was carried among 167 students who were exposed to formalin routinely. Approximately 79.6% of the students suffered from unpleasant smell. The study explains effect on various body parts due to exposure of formaldehyde depicted in Fig. 1[19]. The toxicity of formaldehyde in various organs is illustrated Fig.1 A, B.

3.2 Effect on eyes and skin:

Extended exposure to low concentrations of the fume can bring about mild to severe eye irritation[9]. Intense bodily fluid layer aggravation is the most widely recognized antagonistic impact of formaldehyde exposure, frequently prompting dry skin, dermatitis, tearing eyes, wheezing, and hacking [20]. At levels of 25-50 ppm, tissue harm might happen, at the same time, on expulsion from introduction, recuperation will in general be quick

and complete. Aqueous solutions of formaldehyde are emphatically bothering to the eye and may cause serious eye consumes[9]. In an investigation directed in China, volunteers presented to formaldehyde in the scope of 0.25 to 3.0 ppm experienced eye, nose, and throat bothering. Kulle detailed that eye disturbance was the prevailing side effect with a straight pattern at a portion scope of 0.5–3 ppm. Although no impact was seen underneath 0.5 ppm, 21% experienced mellow eye aggravation at 1 ppm. A Finish study announced that formaldehyde can cause tangible bothering more successfully than the blend of normal unstable natural mixes (VOCs) [20]. Fluid arrangements of formaldehyde are firmly bothering to the eye and may cause extreme eye consumes. However, the degree of harm relies upon the convergence of the arrangement[9].

Skin refinement following dermal exposure to formaldehyde has been very much archived. Human skin affectability factor by formaldehyde has been related with numerous circumstances of dermal exposure, contact with formalin, formaldehyde-containing pitches, formaldehyde-treated textures, formaldehyde containing family items, facial tissues, and so forth [20]. Progressively serious introduction brings about solidifying and tanning of the skin because of protein coagulation. Most instances of dermatitis are brought about by contact with formalin however, occurrences have been accounted for from inhalation of formaldehyde fume[9].Accepting that all breathed in formaldehyde is stored in the nasal depression, one can gauge the pace of affidavit onto the mucosal surface by partitioning the measure of formaldehyde breathed in per unit time by the mucosal surface territory[1].Formaldehyde has been generally identified to affect dermal unfavourably in occupationally vulnerable medical attendants, specialists, and dental specialists, just as restorative laborers, material specialists, and development laborers [20].

3.3 Effect on Respiratory system:

The basic impacts of formaldehyde introduction are different side effects brought about by disturbance of the mucosa in the eyes and upper respiratory tract. In an examination directed in China, 66 laborers in the synthetic business presented occupationally to formaldehyde were accounted for to experience the ill effects of blockage in the cornea, nasal layer, and pharynx[20]. A great many people can identify formaldehyde, by smell, at levels in the demeanour of 1 ppm or less. Levels of 2-3 ppm for the most part cause gentle bothering of the eyes, nose and throat, and few individuals can work easily under these conditions for a whole 8 h shift[9]. Asthma initiated by the inhalation of formaldehyde might be named an aggravation actuated asthma, as short exposures to significant level formaldehyde are recognized to cause an unexpected beginning of asthmatic manifestations called "Responsive aviation routes brokenness disorder" (RADS). Due to its aviation route bothering properties, it might likewise irritate prior asthma [20].Due to contrasts in aviation route life systems and wind current among rodents and people (e.g., rodents are commit nose breathers), tissue harm in people requires formaldehyde air fixations much higher than those related with tissue harm in rodents (Kimbell et al., 2001; Conolly et al., 2004)[21].Respiratory framework harmfulness of formaldehyde happens even in low focuses (0.5 ppm). It causes clinical side effects, for example, consuming sensation in the nose and throat, trouble of breathing, hacking, and wheezing in intense impacts. At higher fixations, aspiratory edema, aggravation, and pneumonia are creating. It is expressed that among laborers presented to formaldehyde, the death pace of lung malignancy is 30% higher. It was accounted for that the probability for the advancement of unfavourably susceptible asthma increments proportionately with level of indoor formaldehyde focus, particularly when levels surpass 0.08 ppm[20]. The response of formaldehyde with little particles, for example, amino acids and nucleotides produces labile conjugates. These may convey formaldehyde to tissues that are remote from the respiratory tract [18]. Levels in the area of 10 ppm cause articulated lachrymation and can be endured for just a couple of moments, while breathing troubles and hacking happen at levels of 10-20ppm. Instances of aspiratory edema, pneumonitis and passing have been accounted for following human inward breath of elevated levels of formaldehyde[18]. In that capacity, formaldehyde-initiated asthma should be the aftereffect of a hypersensitive reaction. Albeit a few examinations researched immunoglobulin G (IgG) as well as immunoglobulin E (IgE) antibodies to formaldehyde/human serum egg white conjugates, the outcomes were not predictable [20]. In Ahvaz, Iran a study was carried out in an education hospital. There, 30 participants were exposed to formaldehyde while 30 were kept as a control. The main aim of study was to analyse the respiratory symptoms which were influenza, cold and asthma. The result obtained from this survey is illustrated in Fig. 2 A-D respectively where(F28). HerePFT refers to Pulmonary function test while SD refers to Standard deviation, FVC here is Forced vital capacity while the FEV1 is Forced expiratory volume in the first second, PEF refers to Peak expiratory flow[22].

3.4 Effect on gastrointestinal tract:

Intense ingestion of formaldehyde will prompt (1) bothering and consumes of the mouth and throat, (2) consumes and ulceration of the gastrointestinal tract, (3) chest or stomach torment, (4) queasiness, (5) retching, (6) the runs, and (7) gastrointestinal discharge[20]. Ingestion of formalin causes prompt irritation of the linings of the mouth, throat and gastrointestinal tract[9]. Formaldehyde ingestion may likewise bring about metabolic acidosis, tachypnoea, jaundice, proteinuria, haematuria, and intense renal disappointment[20]. On ingestion into the circulatory system, formaldehyde is used to formic corrosive, which is then eliminated via urinary system as the sodium salt or oxidized further to carbon dioxide and water. This detoxification procedure can manage low centralizations of formaldehyde, however high fixations offer ascent to acidosis and tissue harm [9]. Inward breath presentation to formaldehyde causes various cell impacts contingent upon its fixation and introduction span. In momentary examinations, it was discovered that formaldehyde caused cell multiplication in the nasal epithelium at dosages of 2 ppm or more[20]. The formalin-instigated destructive harm of gastrointestinal tract relies on the span of contact among formalin and the gastrointestinal tract. Esophageal ignites with formalin is uncommon on account of the quick section through throat. In the event that present, it might be likely because of ingestion of high focuses and huge sums and industrious regurgitating, which opens the throat to formalin over and over [18].

3.5 Effects on reproductive organs:

Formaldehyde has been tried for teratogenicity in a few creature animal groups by an assortment of courses, yet was most certainly not seen as teratogenic in any of the investigations. At the point when pregnant rodents were presented ceaselessly to formaldehyde fume at a degree of 1 mg m^{-3}, no promptly recognizable anomalies were found in the undeveloped organisms, albeit some biochemical changes were identified[9]. A couple of studies discovered menstrual issue and dysmenorrhea in ladies who were occupationally presented to formaldehyde. Long haul formaldehyde presentation at a portion of 2.46 mg m^{-3}should harmfully affect the regenerative capacity of male rodents with a development of oxidative pressure[20]. Examined the miscarriage rate in 86 pregnancies of 77 ladies who were presented to formaldehyde in the home. The degrees of introduction were not announced, however were adequate to have caused eye, nose, and throat disturbance among the subjects. Right now, unsuccessful labour rate (1 1.6%) was seen as no higher than that announced in past investigations of unexposed populace[9].The impact of formaldehyde on the male conceptive framework has been concentrated. They sun covered rodents persistently to levels of 0.5 mg m-3 for a half year and noticed a 20% abatement in the weight coefficients of the testicles. These discoveries propose an unfriendly impact on the male conceptive framework in the rodent. In any case, without histological information, their actual neurotic criticalness can't be evaluated [9].

3.6 Genotoxicity:

It has been observed that formaldehyde exposure can actuate DNA and chromosomal harm in human fringe platelets. A line of proof showed that formaldehyde itself (not a metabolite) is able to do straightforwardly react with DNA and creates genotoxic impacts on gateway of-passage tissues, particularly subsequent to surpassing biotransformation limits[23]. In a Portuguese case-control study, sister-chromatid trade and MN frequencies in fringe lymphocytes were essentially higher in uncovered subjects (mean formaldehyde level of 0.5 ppm) than the control group [20].

3.7 Carcinogenicity:

Diseases of the nasal entries are amazingly uncommon, while malignant growths of the lungs and skin are widespread. Diverse epidemiologic systems are required to explore uncommon and common tumours[1]. Formaldehyde has been found to cause neoplasms in rats, when given by subcutaneous injections and more recently has been shown to cause nasal cancer in rats and mice exposed to the vapor [9].Formaldehyde exposure can initiate the DNA-harm reaction kinase ATM also, the tumor silencer P53 in human cells. Notwithstanding immediate DNA harm, it has as of late been accounted for that formaldehyde advances BRCA2 debasement. BRCA2 (a.k.a FANCD1) is a tumour silencer engaged with DNA fix by mistake free homologous recombination. The decrease in BRCA2 levels is especially compromising for people conveying heterozygous BRCA2 changes and may prompt carcinogenesis [4].It was found that formaldehyde exposure can initiate DNA and chromosomal harm in human fringe platelets. A line of proof demonstrated that formaldehyde itself (not a metabolite) is able to do straightforwardly responding with DNA and creating genotoxic consequences for entryway of-section

issues, particularly in the wake of surpassing biotransformation limits[20]. Used in the nasal mucosa, formaldehyde reacts covalently with DNA, RNA, and proteins. The covalent reactions of formaldehyde with macromolecules are regularly recognized as the essential purposes behind its hurtful effects[6].Considering the exhaustive inquiries about and enormous scope human examinations directed universally, the Worldwide Office for Exploration on Malignant growth (IARC) classified formaldehyde as a human cancer-causing agent (carcinogen) that can cause nasopharyngeal disease [24][20].The finding that formaldehyde is cancer-causing in rodents has normally caused worry that it may likewise be cancer-causing in people. In any case, notwithstanding the broad mechanical utilization of the compound, no obvious epidemiological proof that formaldehyde is a human cancer-causing agent yet [9].A study was carried out in Bauru, Brazil where 23 beauty salons were tested for formaldehyde toxicity. The hairdressers were of 23 salons were tested for the formaldehyde exposure while straightening hair (Fig.2)[25].

IV. DISCUSSION

Formaldehyde is widely used throughout the world. The occupational exposure without protective measures is severely injurious. The accidental exposure lead to high concentration released into the environment that could even be lethal. It was found from various studies that concentrartion of .25 and 3.0 ppm causes irritation in eyes, nose and throat. Formaldehyde, one of the top 20 high volume production industrial chemicals, used in a wide spectrum of applications. The exposure limits have been described in the review in different scenarios. It was estimated that more than 2 million workers and professionals in the United States are exposed to formaldehyde. Formaldehyde is proven as a human and animal carcinogen and is categorised as class 1 carcinogen by WHO, International agency for research on cancer. In addition, epidemiological studies provided limited evidence for the induction of leukaemia in humans, but the results are inconsistent across different studies, and no mechanisms for the induction of leukaemia have been established. Formaldehyde's well-known toxicity and carcinogenicity, coupled with widespread human exposure, has raised long-standing public concerns over its safety. However the degree of the cancer threat due to the presence of formaldehyde in people is yet to be defined [1]. Formaldehyde is also commonly used as fixative for slide preparations and specimens storage. Due to the electrophilic carbon, which may fastly attack electron-rich thiol as well as amino groups forming covalent bond with DNA and proteins. The spectroscopic analysis of interaction of formaldehyde with BSA shows that Formaldehyde decreases the amount of α-helix and promotes the unfolding of protein leading to loosening of its skeleton [33].Various studies have also show that formaldehyde causes DNA-Protein cross linking. It also

Hence, the molecule has high reactive nature[4]. In insignificant fixation, formaldehyde is non-toxic to people, however exposure to higher concentration may bring about extreme and harmful impacts [18].Formaldehyde can enter the body through inhalation, ingestion, or dermal retention [8].). The toxicity of formaldehyde in various organs is illustrated. Extended exposure to low concentrations of the fume can bring about mild to severe eye irritation[9]. Intense bodily fluid layer aggravation is the most widely recognized antagonistic impact of formaldehyde exposure, frequently prompting dry skin, dermatitis, tearing eyes, wheezing, and hacking [20]. Skin refinement following dermal exposure to formaldehyde has been very much archived. Human skin affectability factor by formaldehyde has been related with numerous circumstances of dermal exposure, contact with formalin, formaldehyde-containing pitches, formaldehyde-treated textures, formaldehyde containing family items, facial tissues, and so forth[20]. Intense ingestion of formaldehyde will prompt (1) bothering and consumes of the mouth and throat, (2) consumes and ulceration of the gastrointestinal tract, (3) chest or stomach torment, (4) queasiness, (5) retching, (6) the runs, and (7) gastrointestinal discharge [20]. Ingestion of formalin causes prompt irritation of the linings of the mouth, throat and gastrointestinal tract[9]. It has been observed that formaldehyde exposure can actuate DNA and chromosomal harm in human fringe platelets. Diseases of the nasal entries are amazingly uncommon, while malignant growths of the lungs and skin are widespread. Diverse epidemiologic systems are required to explore uncommon and common tumours[1].

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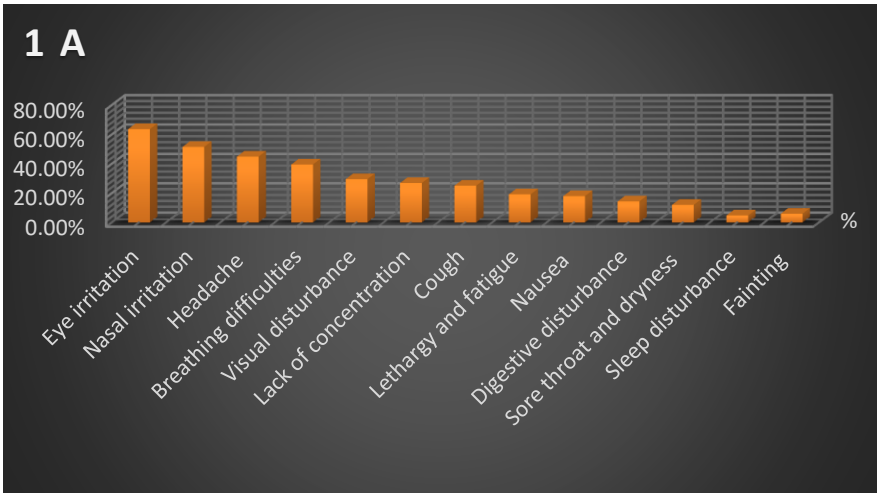
V. HELPFUL HINTS

Figures and Tables



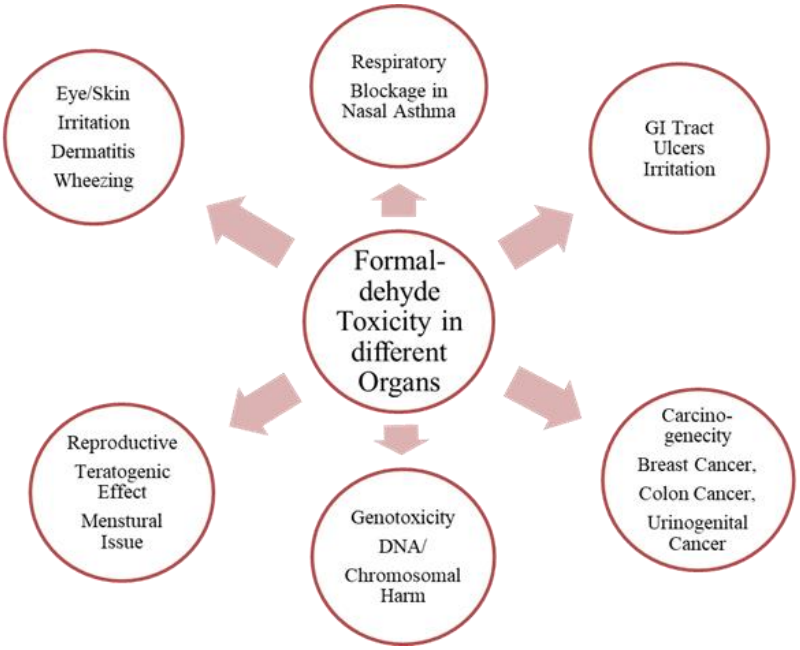
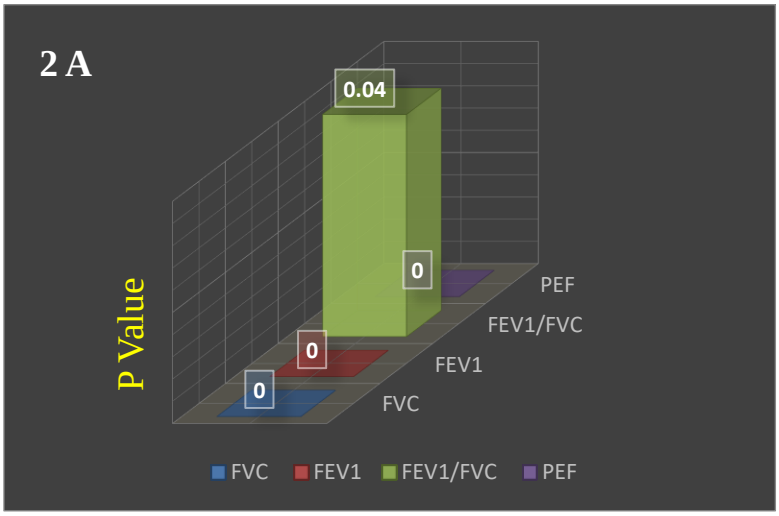


Fig.1. (A) Graph Between problem with %. **(B)**Toxic effect of formaldehyde in different body organs.



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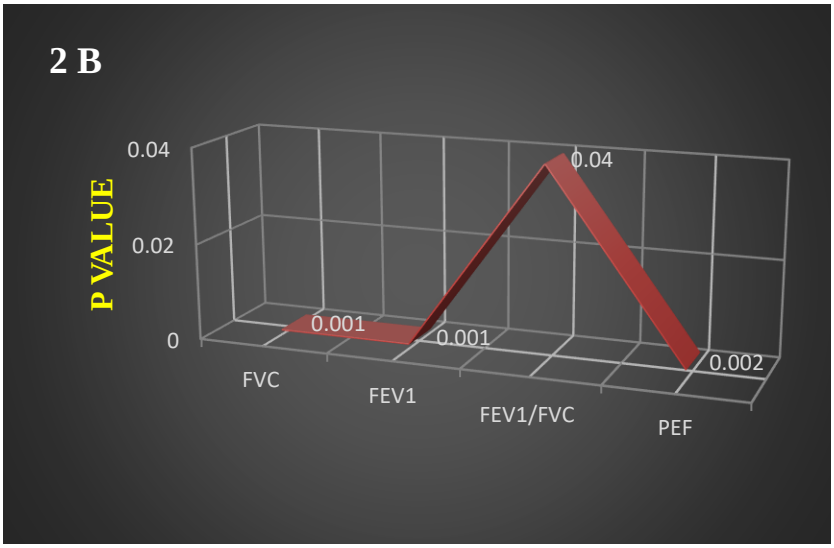

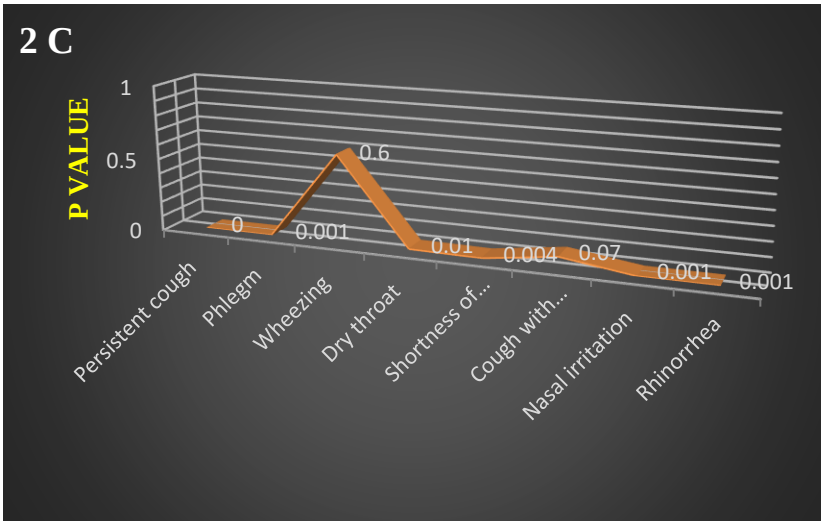

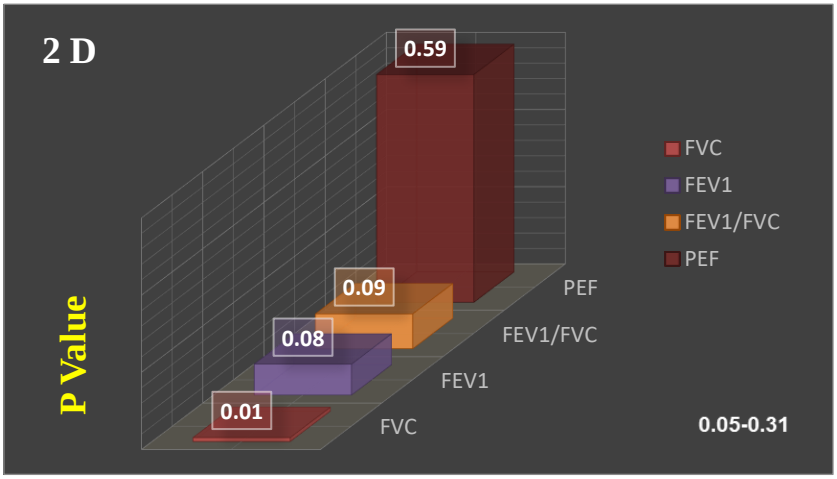

Fig. 2. The result obtained from this survey is illustrated. **(A)** Comparative PFT between two groups. **(B)** PFT before and after exposure to formalin in exposed group. **(C)** Respiratory symptoms in two groups. **(D)** Relationship between occupational exposure to formalin and respiratory function in exposed group[22].

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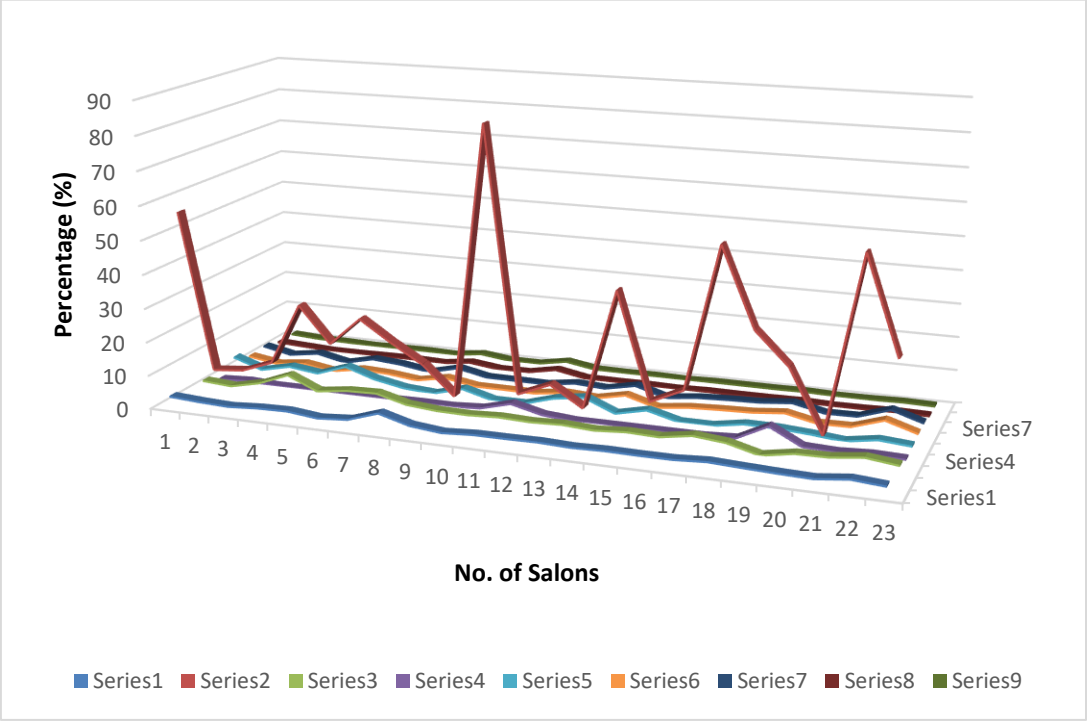

Fig. 3. Comparison between the physical characteristics of the beauty salons and the formaldehyde concentrations obtained in samples(Series 1 is Ceiling height (m) , Series 2 is Size of workspace (m2), Series 3 is Doorway openings (m2), Series 4 is Window openings (m2), Series 5 is Airflow Velocity (m/s), Series 6 is Active Sampling in NIOSH Method (ppm), Series 7 is Active Sampling in IPT Method (ppm), Series 8 is Passive Sampling in UMEX Method (ppm) and Series 8 is Passive Sampling in IPT Method (ppm))[25].

Table 1: Some Case Studies of Formaldehyde Exposure Levels for the Workers of Various location.

Worker Types	Location of Study	Range of Exposure (ppm)	Reference
Chemicals Workers	Turin, Italy	0.04 to 0.4	[10]
Cleaner	Denver, USA	0.15 to 0.21	[11]
Electrician/Mechanic	Massachusetts, USA	0.06 to 0.18	[12]
Firefighter	Arizona, USA	0.10 to 2.20	[13]
Furniture workers	Copenhagen, Denmark	0.16 to 0.4	[14]
Mortuary employees	Utah, USA	0.5 to 1.5	[15]
Office Workers	Tainan, Taiwan	0.07 to 0.13	[16]
Plywood, Particle Board Production Workers	Hawaii, USA	0.28 to 3.48	[17]

Table 2: Table representing various mechanism for removal of formaldehyde[26].

Method	Techniques	Example	References
Physiochemical Method	Oxidation Catalysis	Metal Catalyst	[27]
	Photocatalytic oxidation	Tio_2 Catalyst	[28]
	Physical adsorption	Activated Carbon	[29]
Biological Method	Phyto-remidiation	*Chlorophytumcomosum* *Fatsia japonica*	[30][31]

		Ficusbenjamina	
	Microbial removal	*Methylobacterium sp.* *Debaryomycesvanriji* *Aspergillus nomius*	[32]

Data obtained in this study indicate that genotoxic risk due to FA occupational exposure cannot be excluded. In the current FA level of exposure measured in pathologic anatomy laboratories, the DNA and chromosomal damage observed in peripheral blood lymphocytes of exposed workers might be induced by FA exposure, and be increased with the levels of exposure (positive correlation between FA exposure levels and MN frequency and TL). Although in this study the presence of centromeric signals in the MN was not assessed, the significant increase in DNA damage obtained in the comet assay (a clastogenicity assay) suggests a clastogenic mode of action of FA as the primary cause of the observed damage. Nevertheless, these results must be cautiously interpreted, owing to the relatively low number of exposed and control individuals included in this study.

VI. CONCLUSION

A lot of data obtained in this study reveal that genotoxic peril due to FA occupational exposure which cannot be neglected as its a danger at focuses underneath those at which disease enlistment can be shown in a constant bioassay. In the current mechanistic investigations in this survey give a much more complete image of the aetiology of formaldehyde assessed in pathologic life frameworks labs, the DNA and chromosomal damage found in periphery blood lymphocytes of revealed experts might be affected by Formaldehyde introduction, and be extended with the degrees of introduction (positive association between F formaldehyde presentation levels and MN repeat and TL) and also initiated in nasal malignancy , the responses of formaldehyde with biological macromolecules, the mutagenic impacts of formaldehyde, and the dosages conveyed to respiratory tract tissues. Despite the way that in this examination the proximity of centromeric signs in the MN was not reviewed. The extended exposure of FA low concentrations of the fume can bring about mild to severe eye irritation. We presume that human conceptive and formative poison levels coming about because of formaldehyde. presentation might be a danger to human wellbeing, especially given its far reaching introduction in everyone including its most susceptible members, women of child-bearing age and young children. There are various Physiochemical and Biological mechanism for evacuation of formaldehyde. Irrespective, these results must be carefully interpreted, inferable from the modestly low number of revealed and control individuals associated with this examination. This formaldehyde is among exceptionally poisonous synthetic chemicals, so more examination ought to be done to forestall its poisonousness by setting up a decontaminating agent which should mask its impact and should itself be non-hazardous. Administrative organizations in numerous nations have set up rule esteems for convergences of formaldehyde in indoor air. IARC has ordered formaldehyde as a human cancer-causing agent (Group 1) in view of adequate epidemiological proof of nasopharyngeal malignancy, and an ongoing IARC working gathering additionally discovered adequate proof for myeloid leukaemia.

CONFLICT OF INTEREST

The authors report no conflict of interest.

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VII. REFERENCE

[1] Norton Nelson, Richard J. Levine, Roy E. Albert, Aaron E. Blair, Richard A. Griesemer, Phillip Jo Landrigan, Leslie T. Stayner, James A. Swenbergt, "Contribution of Formaldehyde to Respiratory Cancer," *Environmental Health Perspectives*, vol.**70**, pp. **23–35**, **1986**.

[2] Jenelle A. Patterson, Hai He, Jacob S. Folz, Qiang Li, Mark A. Wilson, Oliver Fiehn, Steven D. Bruner, Arren Bar-Even, Andrew D. Hanson, "Thioproline formation as a driver of formaldehyde toxicity in Escherichia coli,", *The Biochemical journal,* vol.**477**, Issue.**9**, pp.**1745–1757**, **2020**. doi: 10.1042/BCJ20200198

[3] A. Bar-Even, E. Noor, A. Flamholz, and R. Milo, "Design and analysis of metabolic pathways supporting formatotrophic growth for electricity-dependent cultivation of microbes," *Biochim. Biophys. Acta - Bioenerg.*, vol. **1827**, Issue.**8–9**, pp.**1039-1047**, **2013**.

[4] Hernán Reingruber, Lucas Blas Pontel, "Formaldehyde metabolism and its impact on human health," *Current Opinion in Toxicology*, Vol.**9**, pp.**28-34**, **2018**. doi: 10.1016/j.cotox.2018.07.001

[5] E. A. Hoffman, B. L. Frey, L. M. Smith, and D. T. Auble, "Formaldehyde crosslinking: A tool for the study of chromatin complexes," *J. Biol. Chem.*, vol. **290**, Issue.**44**, pp. **26404–26411**, **2015**.

[6] d'Henry A. Heck, Mercedes Casanova, Thomas B. Starr, "Formaldehyde Toxicity - New Understanding," *Critical Reviews in Toxicology*, Vol.**20**, Issue.**6**, pp.**397-426**, **1990.** doi: 10.3109/10408449009029329.

[7] K. Seyrek, H. Aksit, and H. Kose, "Inhalation of formaldehyde and xylene induces apoptotic cell death in the lung tissue," *Toxicology and Industrial Health,* Vol.**25**, Issue.**7**, pp.**455-461**, **2009**. doi: 10.1177/0748233709106824

[8] Robert A. Squire, Lorraine L. Cameron, "An Analysis of Potential Carcinogenic Risk from Formaldehyde," *Regulatory Toxicology and Pharmacology*, vol. **4**, Issue.**2**, pp.**107-129**, **1984**. doi: 10.1016/0273-2300(84)90034-5

[9] G. A. Wartew, "The Health Hazards of Formaldehyde," *Journal of Applied Toxicology*, vol. **3**, Issue.**3**, pp. **121–126**, **1983**. doi: 10.1002/jat.2550030303

[10] E. Carraro, S. Gasparini, and G. Gilli, "Identification of a Chemical Marker of Environmental Exposure to Formaldehyde," *Environmental Research*, vol. **80**, Issue.**2**, pp. **132–137**, **1999**. doi: 10.1006/enrs.1998.3875

[11] Larry G. Anderson, John A. Lanning, Regina Barrell, Joyce Miyagishima, Richard H. Jones, Pamela Wolfe, "Sources and sinks of formaldehyde and acetaldehyde: An analysis of Denver's ambient concentration data," *Atmospheric Environment*, vol. **30**, Issue.**12**, pp. **2113–2123**, **1996**. doi: 10.1016/1352-2310(95)00175-1

[12] D K Milton, M D Walters, K Hammond, J S Evans, "Worker exposure to endotoxin, phenolic compounds, and formaldehyde in a fiberglass insulation manufacturing plant," *Am Ind Hyg Assoc J.*, vol. **57,** Issue.**10,** pp.**889-896**, **2010**. doi: 10.1080/15428119691014396

[13] D. M. Bolstad-Johnson, J. L. Burgess, C. D. Crutchfield, S. Storment, R. Gerkin, J. R. Wilson, "Characterization of Firefighter," *American Industrial Hygiene Association Journal*, vol. **61**, Issue.**5**, pp. **636–641**, **2000**.

[14] Vinzents P, Laursen B, "A national cross-sectional study of the working environment in the Danish wood and furniture industry--air pollution and noise," *Ann Occup Hyg,* vol. **37**, Issue.**1**, pp. **25–34**, **1993**. doi: 10.1093/annhyg/37.1.25

[15] Anthony Suruda, Paul Schulte, Mark Boeniger, Richard B. Hayes, Gordon K. Livingston, Kyle Steenland, Patricia Stewart, Robert Herrick, Donald Douthit, Marilyn A. Fingerhut, "Cytogenetic Effects of Formaldehyde Exposure in Students of Mortuary Science," *Cancer Epidemiology, Biomarkers & Prevention*, vol.**2**, pp.**453–460**, **1993**.

[16] P.-C. Wu Y.-Y. Li C.-C. Lee C.-M. Chiang H.-J. J. Su, "Risk assessment of formaldehyde in typical office buildings in Taiwan," *Indoor Air*, Vol.**13**, Issue.**4**, pp. **359–363**, **2003**. doi: 10.1111/j.1600-0668.2003.00205.x

[17] Tan Malaka M.D., Dr. P.H. & Arthur M. Kodama Ph.D., "Respiratory Health of Plywood Workers Occupationally Exposed to Formaldehyde," *Archives of Environmental Health: An International Journal*, Vol.**45**, Issue.**5**, pp. **288-294**, **1990**. doi: 10.1080/00039896.1990.10118748

[18] C. K. Pandey, A. Agarwal, A. Baronia, and N. Singh, "Toxicity of ingested formalin and its management," *Human & Experimental Toxicology*, Vol.**19**, Issue.**6**, pp. **360–366**, **2000**. doi: 10.1191/096032700678815954

[19] Yasser A Ahmed, Mohammed Abdelsabour-Khalaf, Eman Abdelrahim, Ahmed Ghallab, "Toxic effects of formalin on the medical students of South Valley University following repeated exposure at the anatomy laboratories," *SVU-International Journal of Veterinary Sciences*, Vol. **3**, Issue.**1**, pp. **80–86**, **2020**.

[20] Ki Hyun Kim, Shamin Ara Jahan, Jong Tae Lee, "Exposure to formaldehyde and its potential human health

Hazards," *Journal of Environmental Science and Health - Part C Environmental Carcinogenesis and Ecotoxicology Reviews,* Vol.**29**, Issue.**4,** pp.**277-299**, **2011**.

[21] R. Golden, "Identifying an indoor air exposure limit for formaldehyde considering both irritation and cancer hazards," *Crit Rev Toxicol.*, vol. **41**, Issue.**8**, pp.**672–721**, **2011**. doi: 10.3109/10408444.2011.573467

[22] H. A. Rangkooy, L. Marghzari, B. F. Dehaghi, K. A. Angali, "Survey effect of exposure to formaldehyde on pulmonary function test in hospital staffs," *Asian Journal of Pharmaceutics*, Vol.**12**, Issue.**2**, pp. **580–584**, **2018**.

[23] Kim YH, Jo MS, Kim JK, Shin JH, Baek JE, Park HS, An HJ, Lee JS, Kim BW, KH Kim, *et al.*, "Short-term inhalation study of graphene oxide nanoplates," *Nanotoxicology*, Vol.**12**, Issue.**3**, pp.**224–238**, **2018**.

[24] Zhang L, Freeman LE, Nakamura J, Hecht SS, Vandenberg JJ, Smith MT, Sonawane BR,"Formaldehyde and leukemia: Epidemiology, potential mechanisms, and implications for risk assessment," *Environmental and Molecular Mutagenesis*, vol. **51**, Issue.**3**, pp.**181–191**, **2010**.

[25] Marcelo Eduardo Pexe, Amanda Marcante, Maciel Santos Luz, Pedro Henrique Manzani Fernandes, Francisco Chiaravalloti Neto, Ana Paula Sayuri Sato, Kelly Polido Kaneshiro Olympio, "Hairdressers are exposed to high concentrations of formaldehyde during the hair straightening procedure," *Environ Sci Pollut Res,* Vol.**26**, pp.**27319–27329**, **2019**. doi: 10.1007/s11356-019-05402-9

[26] Yunhai Shao, Yanxin Wang, Rui Zhao, Weihong Zhong, *et al.*, "Biotechnology progress for removal of indoor gaseous formaldehyde," *Applied Microbiology and Biotechnology*, Vol.**104**, Issue.**2**, **2020**. doi: 10.1007/s00253-020-10514-1

[27] S. Rong, P. Zhang, F. Liu, and Y. Yang, "Engineering Crystal Facet of α-MnO2 Nanowire for Highly Efficient Catalytic Oxidation of Carcinogenic Airborne Formaldehyde," *ACS Catal.*, Vol. **8**, Issue.**4**, pp. **3435–3446**, **2018**. doi: 10.1021/acscatal.8b00456

[28] Y. Liao, C. Xie, Y. Liu, H. Chen, H. Li, and J. Wu, "Comparison on photocatalytic degradation of gaseous formaldehyde by TiO 2, ZnO and their composite," *Ceramics International*, Vol.**38**, Issue.**6**, pp.**4437–4444**, **2012**.

[29] J. P. Bellat *et al.*, "Capture of formaldehyde by adsorption on nanoporous materials," *J. Hazard. Mater.*, Vol. **300**, pp.**711–717**, **2015**. doi: 10.1016/j.jhazmat.2015.07.078

[30] G. Khaksar, C. Treesubsuntorn, and P. Thiravetyan, "Effect of endophytic Bacillus cereus ERBP inoculation into non-native host: Potentials and challenges for airborne formaldehyde removal," *Plant Physiol. Biochem.*, Vol. **107**, pp.**326–336**, **2016**.

[31] R. A. Wood, M. D. Burchett, R. Alquezar, R. L. Orwell, J. Tarran, and F. Torpy, "The potted-plant microcosm substantially reduces indoor air VOC pollution: I. Office field-study," *Water. Air. Soil Pollut.*, vol. **175**, Issue.**1–4**, pp.**163–180**, **2006**.

[32] A. B. Darlington, J. F. Dat, and M. A. Dixon, "The biofiltration of indoor air: Air flux and temperature influences the removal of toluene, ethylbenzene, and xylene," *Environ. Sci. Technol.*, vol. **35**, Issue.**1**, pp. **240–246**, **2001**.

[33] Yihong Liu, Rutao Liu, Yue Mou, Guangjun Zhou, "Spectroscopic Identification of Interactions of Formaldehyde with Bovine Serum Albumin," *J Biochem Mol Toxico.,* Vol.**25**, Issue.**2**, pp.**95-100**, **2011**. doi: 10.1002/jbt.20364