HOW TO BIOMONITOR EXPOSURE TO NANOPARTICLES IN WORKERS: A REVIEW

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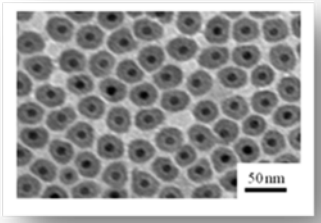
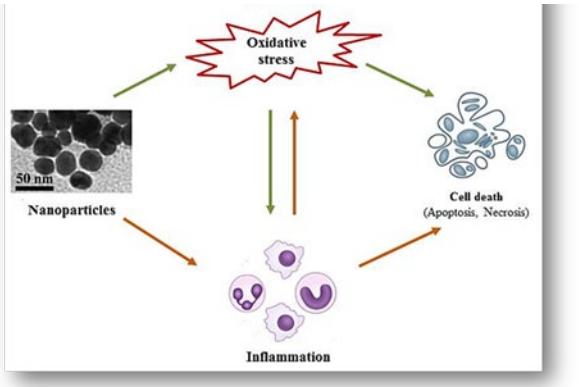


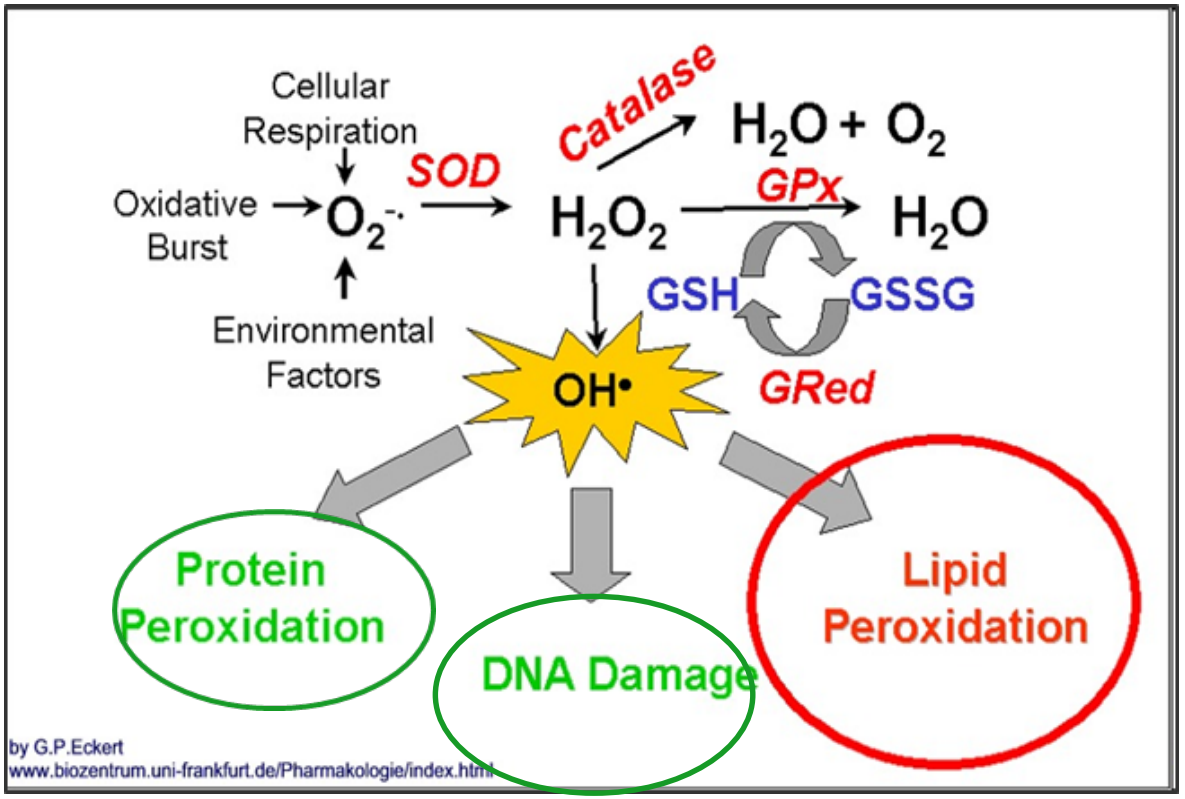
Nanoparticles

- The number of applications of nanomaterials increases enormously
- **Workers and researchers** are engaged in the development, and production of nano-enabled composites
- **Limited data** available on exposures and health effects
- **Experimental studies** – oxidative stress, inflammation, lung fibrosis, cardiovascular disorders, cancer *(Huang 2017, Runa 2017)*
- Unique physical and chemical properties
- Higher reactivity and cytotoxicity
- What markers could be used in workers?



NANOPARTICLES

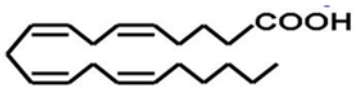
- **Cause oxidative stress, inflammation and cell death**
- **Proteins, nucleic acids and lipids damage**



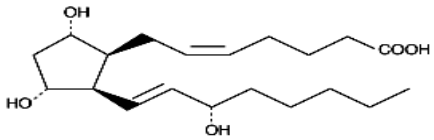
Lipid peroxidation – direct (by ROS)

polyunsaturated acids of the cellular membranes

Arachidonic acid



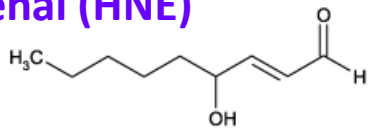
isoprostanes (8-isoprostane)



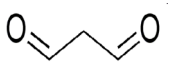
n-hexanal (C_6), n-heptanal (C_7), C_8,..- C_{12}

hydroxy-*trans*-2-hexenal (HHE)

hydroxy-*trans*-2-nonenal (HNE)



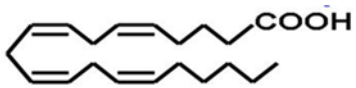
malondialdehyde (MDA)



biologically active aldehydes (C_6-C_{12}…, HHE, HNE, MDA)

Lipid peroxidation – enzymatic

lipids of the membranes



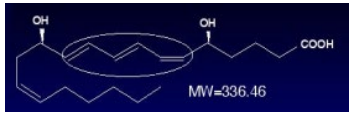
Arachidonic acid

5-lipoxygenase ***ALOX5 AP (FLAP) mediator***

leukotrienes formed in leukocytes - MARKERS OF INFLAMMATION

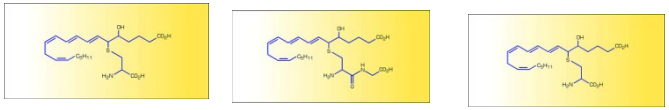
LTA_4

LTB_4



LTB_4 – target: neutrophils are activated and attracted into the lungs; COPD

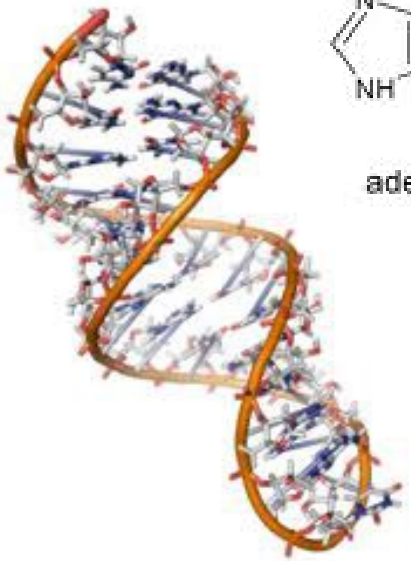
cysteinyl - LTC_4, LTD_4, LTE_4

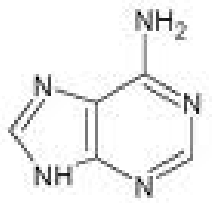


cys LT - targets:
- **bronchial muscles,**
- **vessels** – increase of permeability,
- **acute and chronic inflammation,**

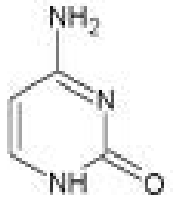
bronchial asthma, experimental lung fibrosis

Markers of oxidation of NUCLEIC ACIDS

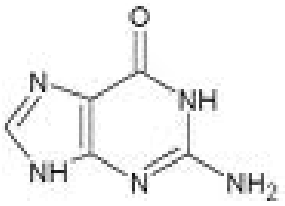




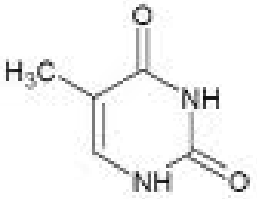
adenin - A



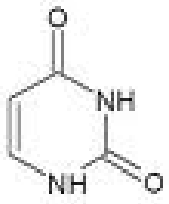
cytosin - C



guanin- G

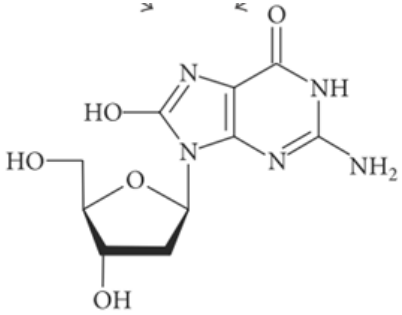


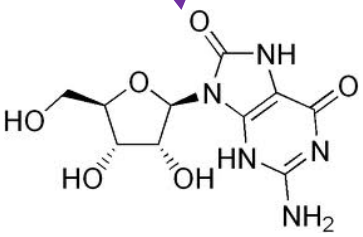
thymin - T

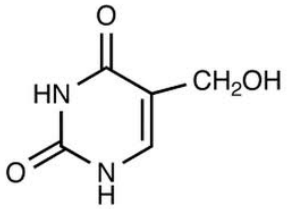


uracil - U

Oxidation products





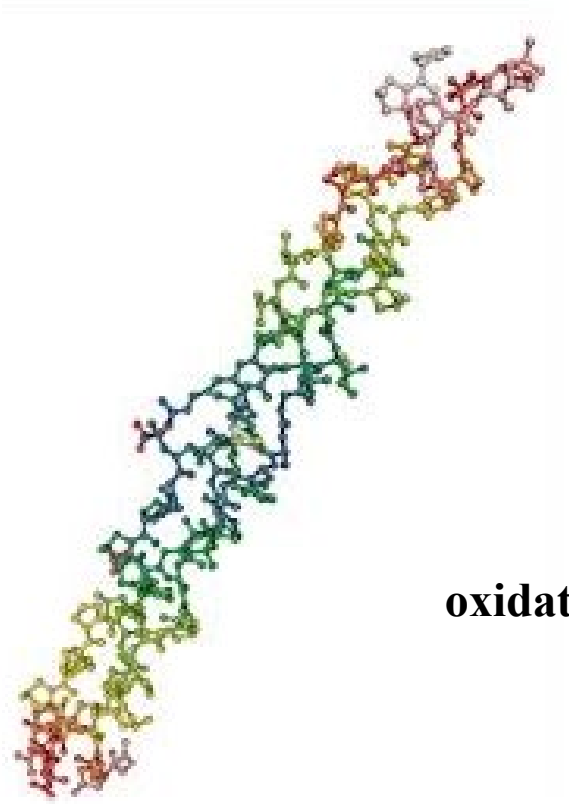


8-hydroxy-2'-deoxyguanosine
8-OHdG (DNA)

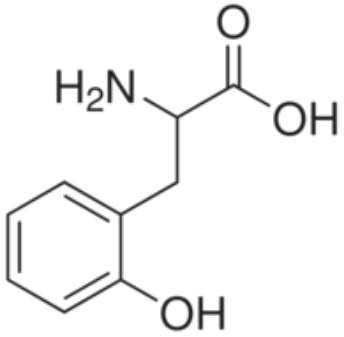
8-hydroxyguanosine
8-OHG (DNA)

5-hydroxymethyluracile
5-OHMeU (RNA)

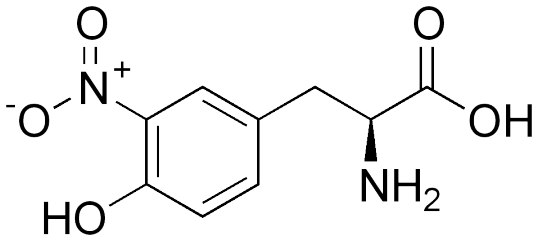
Oxidation of PROTEINS



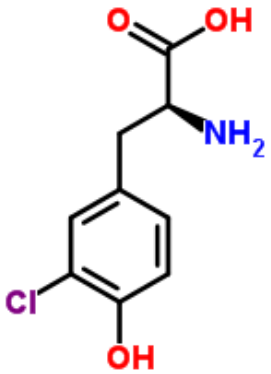
Biotransformation products



***o*-Tyrosine –**
oxidation of phenylalanine



3-Nitrotyrosine –nitration of tyrosine



3-Chlorotyrosine –oxidized by HOCl formed by myeloperoxidase from leukocytes

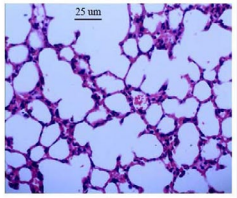
Molecular Mechanisms of Nanosized Titanium Dioxide-Induced Pulmonary Injury in Mice

Bing Li[1☯], Yuguan Ze[1☯], Qingqing Sun[1☯], Ting Zhang[2,3☯], Xuezi Sang[1], Yaling Cui[1], Xiaochun Wang[1], Suxin Gui[1], Danlin Tan[1], Min Zhu[1], Xiaoyang Zhao[1], Lei Sheng[1], Ling Wang[1], Fashui Hong[1*], Meng Tang[2,3*]

Li 2013

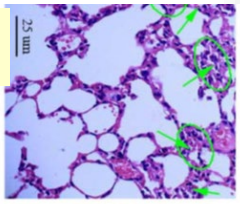
Nasal application of nano-TiO_2 suspension (6 nm) daily for 90 days

2.5-10 mg/kg b.w.



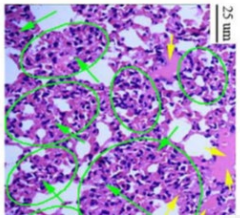
controls

2.5 mg/kg



- *interstitium thickening*
- *inflammatory infiltration*
- *apoptosis*
- *oedema*
- *deposits of agglomerated TiO2*

5 mg/kg



10 mg/kg

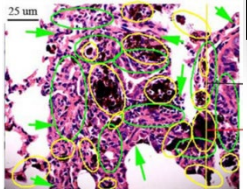
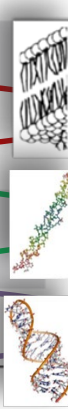


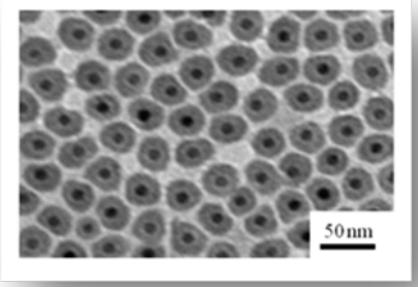
Table 3. Oxidative stress in the mouse lung after nasal administration with nano-TiO_2 for 90 consecutive days.

Oxidative stress	TiO_2 NPs (mg/kg BW)			
	0	2.5	5	10
$O_2^{\cdot-}$ (nmol/mg prot. min)	23±1.15a	30.27±1.51b	39.18±1.96c	50±2.50d
H_2O_2 (nmol/mg prot. min)	43±2.15a	61.22±3.06b	78.96±3.95c	110±5.50d
MDA (μmol/mg prot)	1.08±0.05a	1.59±0.08b	2.89±0.15c	5.15±0.26d
Carbonyl (μmol/mg prot)	0.54±0.03a	0.98±0.05b	1.85±0.09c	3.04±0.15d
8-OhdG (mg/g tissue)	0.42±0.02a	2.26±0.11b	4.25±0.21c	7.12±0.36d

Letters indicate significant differences between groups ($p<0.05$). Values represent means ± SE (N = 5).



MDA -malondialdehyde, **PC-** protein carbonyl, **8-OHdG** 8-hydroxy-2-deoxyguanosine



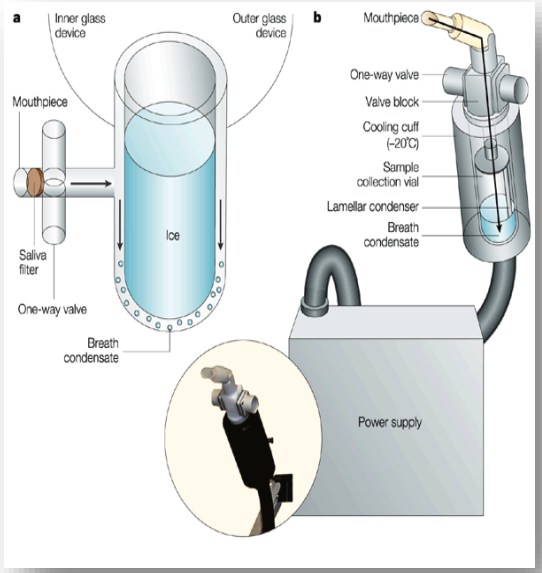
NANOPARTICLES

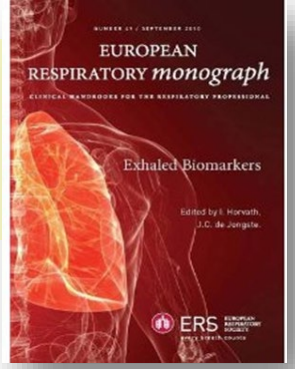
- 1 - Workers exposed to nanoTiO_2 - 2012, 2013
- 2 - Office employees from nanoTiO_2 plant - 2013
- 3 - Workers exposed to nano Fe-oxides - 2013
- 4 – Researchers handling nanocomposites - 2016-2020

Exhaled breath condensate (EBC) collection *Horváth et al. 2017*

EBC

EcoScreen (Jaeger)





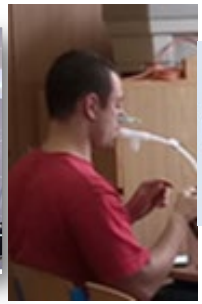
Research method – 90ies of the 20th century - non-invasive collection (15 min) of substances from the respiratory system (120 L air) after cooling to -10° C.

EBC liquid contains:

1) **condensed H_2O - 99%**
2) **water soluble particles**
3) **non-soluble particles from the droplets released from the bronchoalveolar lining fluid during expiration and contraction of respiratory bronchioles**

Pelclová D et al. 8-isoprostane and leukotrienes in EBC in Czech subjects with silicosis. Ind Health. 2007
Pelclová D et al. Increased 8-isoprostane, marker of oxidative stress in EBC in asbestos exposure. Ind Health. 2008

ANALYSIS OF THE SAMPLES
liquid chromatography- electrospray ionization - tandem mass spectrometry (LC/ESI/MS-MS)



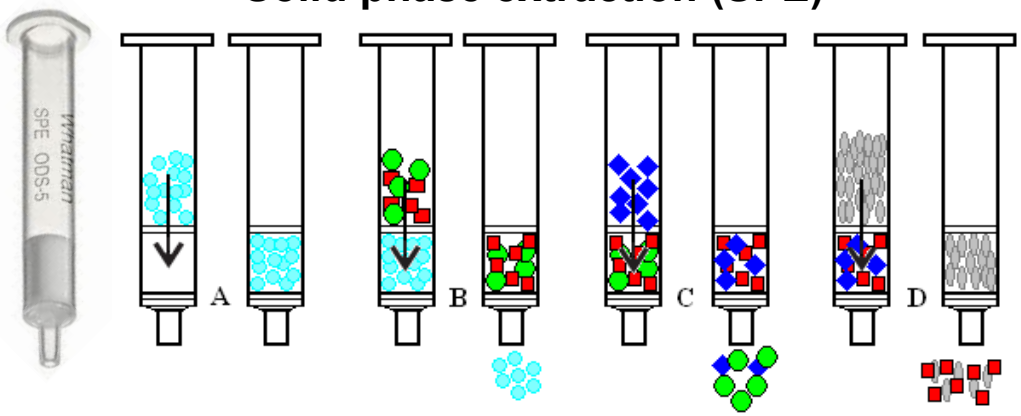
EBC

Samples - SPE

LC/ESI/MS-MS ANALYSIS

QUANTITATIVE AND QUALITATIVE DATA EVALUATION

Desalting and increasing concentration of the samples
Solid phase extraction (SPE)

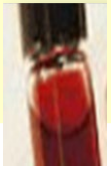


Analysis using LC/ESI/MS-MS
TSQ Vantage, LTQ Orbitrab

Examination – workers + controls

- Questionnaire
- Occupational history – years of exposure, daily exposure, PPE, latency since last shift,
- Personal history - diseases, medication, smoking, alcohol intake, regular physical activity,
- Diet, last meal, last smoking.
- Family history
- Physical examination, temperature,
- Body mass index
- Blood pressure,
- Spirometry
- Monitoring local data of environmental pollution (SO_2, CO, NOx, $PM_{2.5}$, PM_{10})

Markers measured in EBC, urine, plasma (2016-2018)
LC-ESI-MS/MS analysis


- **aldehydes C_6-C_{12}**
- **malondialdehyde (MDA)**
- **4-hydroxy-trans-hexenal (HHE)** **oxidation of lipids**
- **4-hydroxy-trans-nonenal (HNE)**
- **8-isoProstaglandin $F_{2\alpha}$ (8-isoprostane)**
- **8-hydroxy-2-deoxyguanosine (8-OHdG)**
- **8-hydroxyguanosine (8-OHG)** **oxidation of nucleic acids**
- **5-hydroxymethyl uracil (5-OHMeU)**
- **o-tyrosine (o-Tyr)**
- **3-chloro-tyrosine (3-Cl-Tyr)** **oxidation of proteins**
- **nitrotyrosine (3-NO-Tyr)**
- leukotrienes LTB_4, LTC_4, LTD_4, LTE_4 markers of inflammation
- *tumor necrosis factor (TNF)*
- *FeNO – fractional exhaled nitric oxide - inflammation*

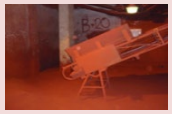




Aerosol Measurement at the workplace

- 3-8 hours shifts measurements, background measurements
- **Berner Low-Pressure Cascade Impactor** (BLPI) - separation into the size fractions and chemical analysis,
- Scanning Mobility **Particle Sizer** (SMPS),
- Aerodynamic **Particle Sizer** (APS),
- Condensation **Particle Counter** (CPC)
- Optical Particle Sizer (OPS).
- Personal nanoparticle samplers (Pluto Technology Taiwan) 2019, 2020

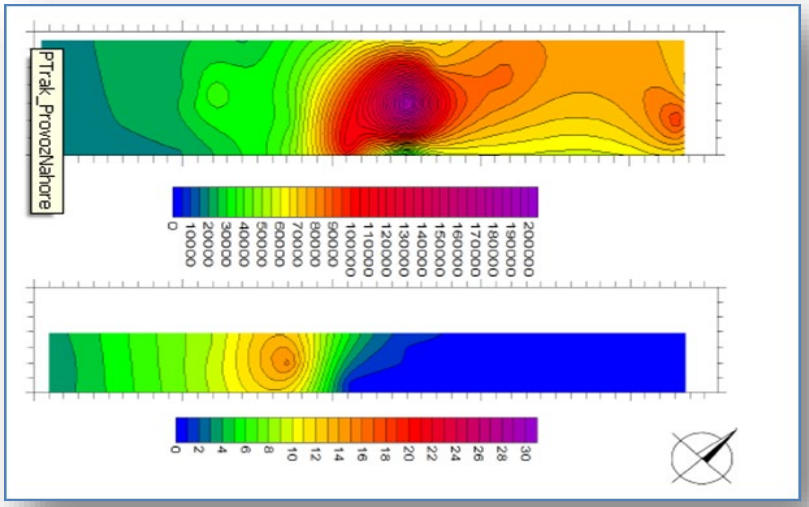
Exposure and Groups of Workers

	N	Age	Proportion of nano particles	Exposure time/day	Median Mass Concentration mg/m^3	Median Particles number /cm^3
TiO_2 2012* 	20	34±8	80%	7.5 h	0.65	19 800
TiO_2 2013* 	14	34±5	80%	7.5 h	0.40	23 200
TiO_2 2013 office 	22	44±4	80%	15 min	0.40	23 200
Fe-oxides 2013 	14	43±8	80%	7.5 h	0.083	66 800
Nanocomposites 2016-2020 	61	40±12	40-95%	3.0 h	0.12-1.84	48 000-540 000
Controls 2012-2020	Comparable number, age and gender			No nano- exposure		

Group 1 WORKERS IN PRODUCTION of TiO_2 pigments 2012 pre-shift, post-shift and 2013 post-shift

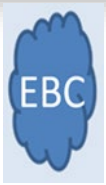
80 % nano size

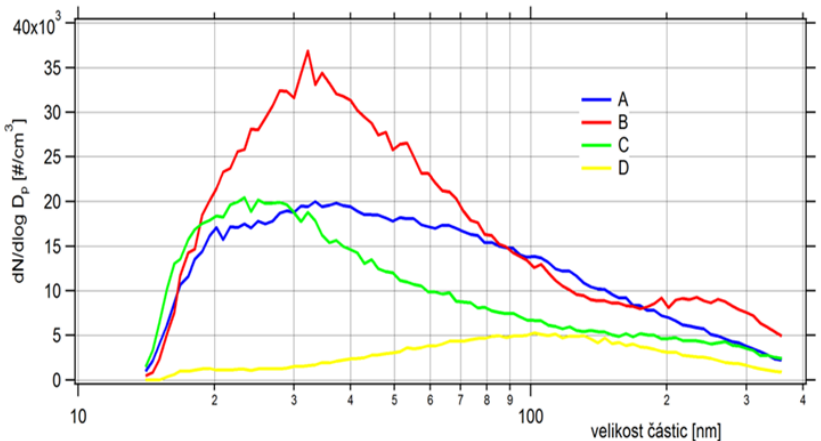
Ilmenite - iron titanium oxide, $FeTiO_3$



Titania – TiO_2

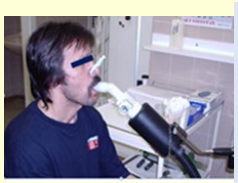
SMPS - scanning mobility particle sizer - particles from 15 to 350 nm





Pelclova D et al: Markers of oxidative stress are elevated in workers exposed to nanoparticles. NANOCON 2012 Proceedings, p. 654-658.

Raman microspectroscopy found TiO_2 in EBC

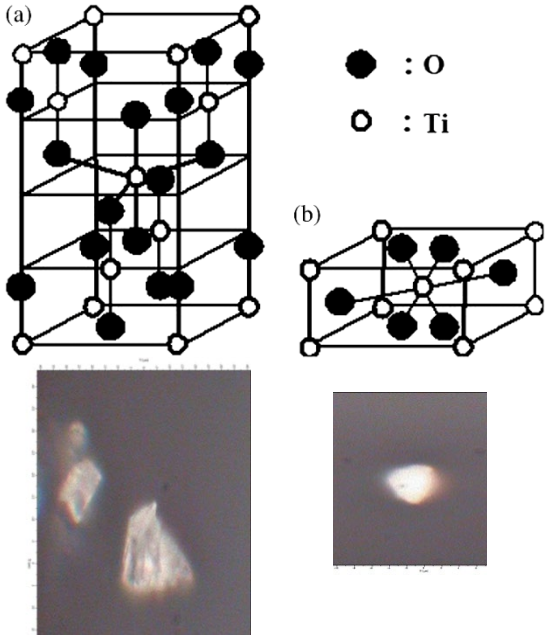


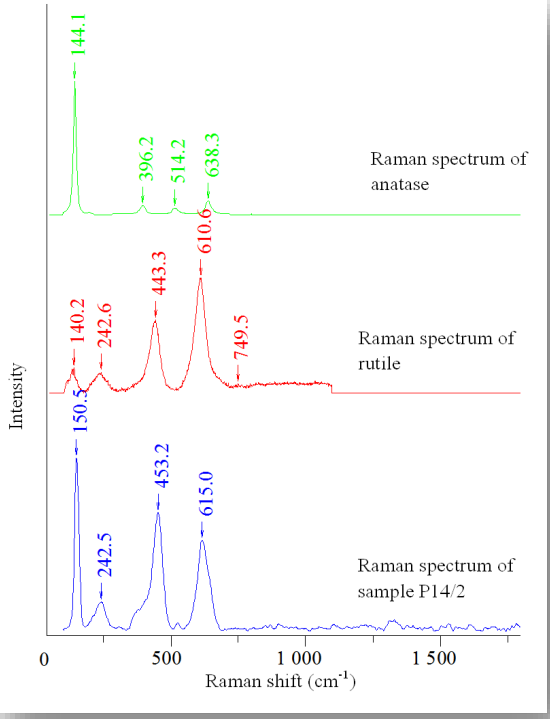
EBC

2012 **pre-shift in 40 % workers**

post-shift in 70 % workers

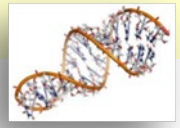
a) anatas b) rutile

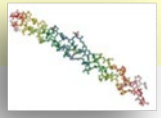


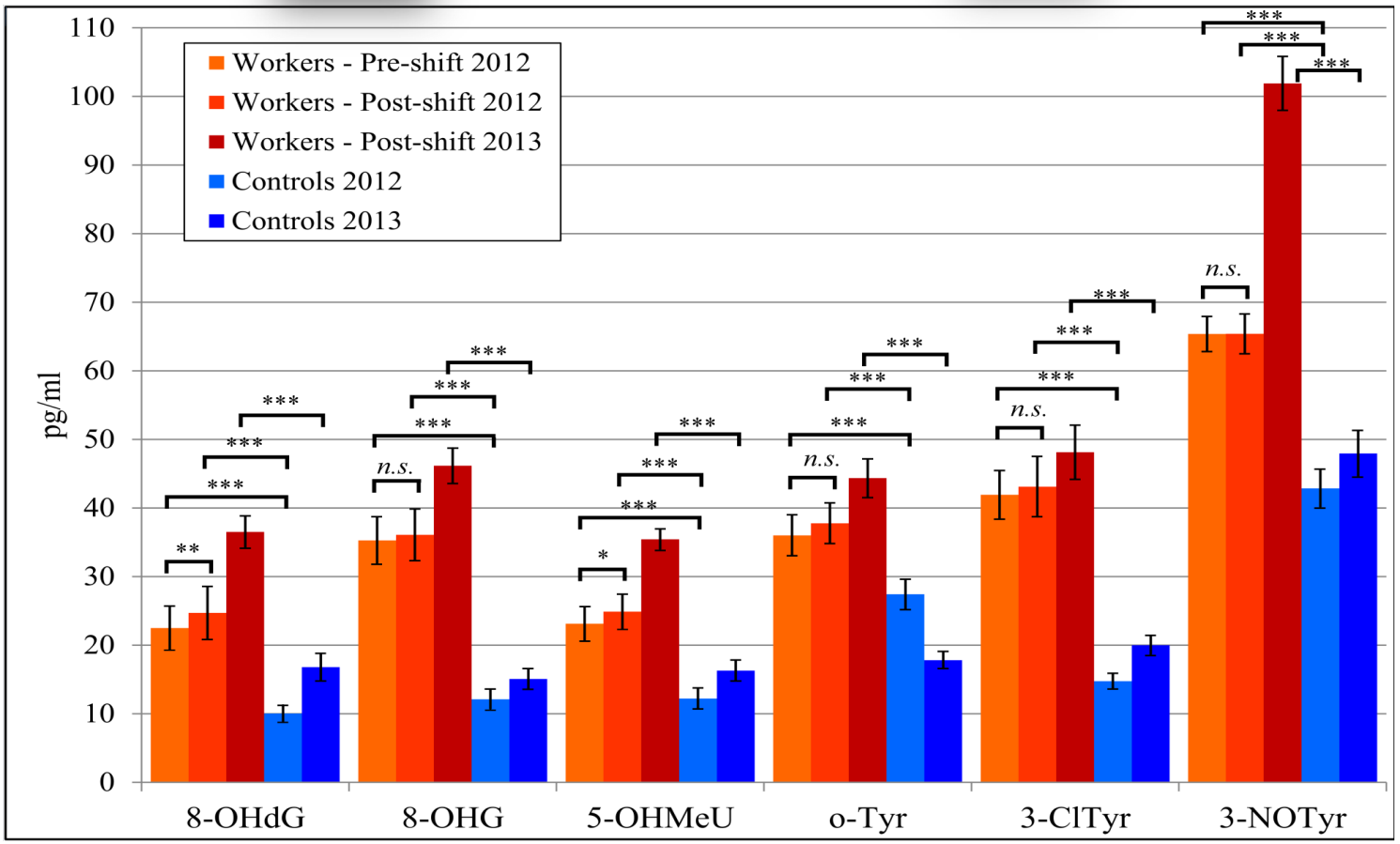


Pelclova D, Barosova H, Kukutschova J, Zdimal V, Navratil T, Fenclova Z, Vlckova S, Schwarz J, Zikova N, Kacer P, Komarc M, Belacek J, Zakharov S.: **Raman microspectroscopy of exhaled breath condensate and urine in workers exposed to fine and nano TiO_2 particles: a cross-sectional study.** ***J Breath Research 2015***

TiO_2 Production Workers 2012 and 2013 and Controls







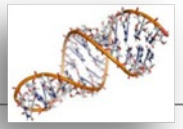
Pelclova D, Zdimal V, Fenclova Z, Vlckova S, Turci F, Corazzari I, Kacer P, Schwarz J, Zikova N, Makes O, Syslova K, Komarc M, Belacek J, Navratil T, Machajova M, Zakharov S. **Markers of oxidative damage of nucleic acids and proteins among workers exposed to TiO2(nano) particles.** ***Occup Environ Medicine 2016***

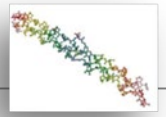
Multiple regression analysis – the job is the key (TiO_2)

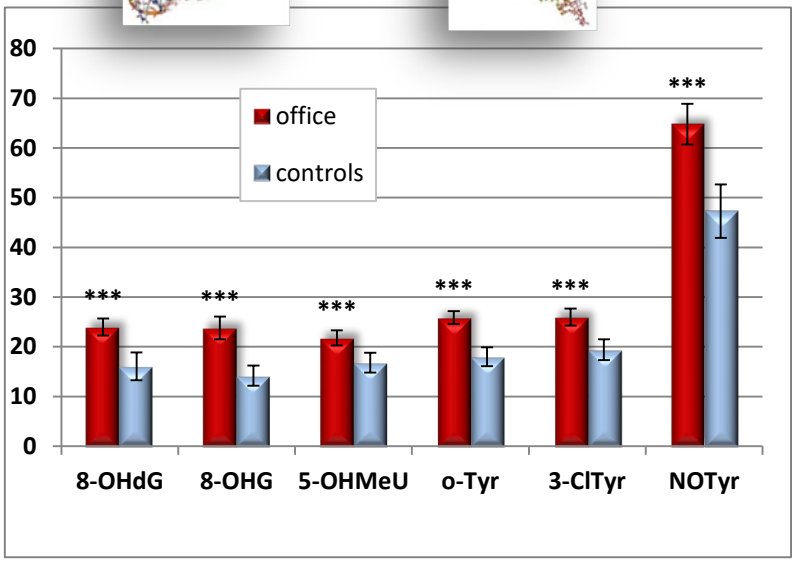
	8-OHdG (pg/ml)	8-OHG (pg/ml)	5-OHMeU (pg/ml)	o-Tyr (pg/ml)	3-ClTyr (pg/ml)	3-NOTyr (pg/ml)
TiO_2 Production exposure (Yes/No)	**19.20*** (14.75, 23.66)**	**30.37*** (26.75, 34.00)**	**19.35*** (16.30, 22.40)**	**28.95*** (25.51, 32.38)**	**28.43*** (23.71, 33.14)**	**51.68*** (44.31, 59.04)**
Age (years)	0.02 (-0.17, 0.21)	-0.02 (-0.17, 0.13)	0.06 (-0.06, 0.19)	-0.02 (-0.16, 0.13)	0.13 (-0.07, 0.32)	-0.06 (-0.36, 0.25)
Smoking (Yes/No)	-0.29 (-3.65, 3.07)	0.70 (-2.04, 3.43)	0.38 (-1.92, 2.69)	-0.46 (-3.05, 2.14)	-1.41 (-4.97, 2.14)	1.62 (-3.94, 7.17)
SO_2 ($\mu g/m^3$) (CO, NO_x) environmental	0.02 (-0.13, 0.17)	-0.02 (-0.14, 0.10)	-0.04 (-0.15, 0.06)	-0.13* (-0.24, -0.01)	-0.06 (-0.22, 0.10)	0.16 (-0.09, 0.41)

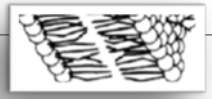
Pelclova D, Zdimal V, Fenclova Z, Vlckova S, Turci F, Corazzari I, Kacer P, Schwarz J, Zikova N, Makes O, Syslova K, Komarc M, Belacek J, Navratil T, Machajova M, Zakharov S. **Markers of oxidative damage of nucleic acids and proteins among workers exposed to TiO2(nano) particles**. ***Occup Environ Medicine 2016***

Group 2 Office employees TiO_2 and Controls (2013)









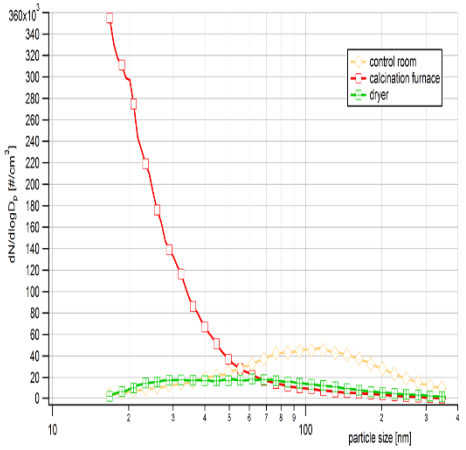
Pelclova D, Zdimal V, Kacer P, Vlckova S, Fenclova Z, Navratil T, Komarc M, Schwarz J, Zikova N, Makes O, Zakharov S. **Markers of nucleic acids and proteins oxidation among office workers exposed to air pollutants including (nano)TiO2 particles.** ***Neuro Endocrinol Lett. 2016***

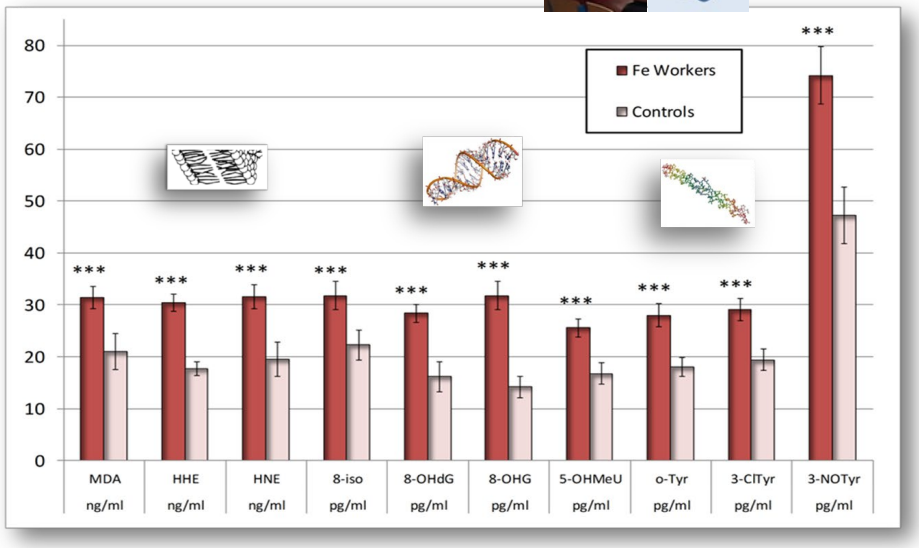
Pelclova D, Zdimal V, Kacer P, Komarc M, Fenclova Z, Vlckova S, Zikova N, Schwarz J, Makes O, Navratil T, Zakharov S, Bello D. **Markers of lipid oxidative damage among office workers exposed intermittently to air pollutants including nanoTiO2 particles.** ***Rev Environ Health 2017***

GROUP 3 Fe oxides (+nano) pigments production 2013

ilmenite $FeTiO_3$

80% particles in nano size





Oxidative stress markers are elevated in exhaled breath condensate of workers exposed to nanoparticles during iron oxide pigment production.

Pelclova D, Zdimal V, Kacer P, Fenclova Z, Vlckova S, Syslova K, Navratil T, Schwarz J, Zikova N, Barosova H, Turci F, Komarc M, Pelcl T, Belacek J, Kukutschova J, Zakharov S.

J Breath Res. 2016

Group 4 - NANOCOMPOSITES PRODUCING RESEARCH WORKERS IN 2016, 2017, 2018, 2019, 2020

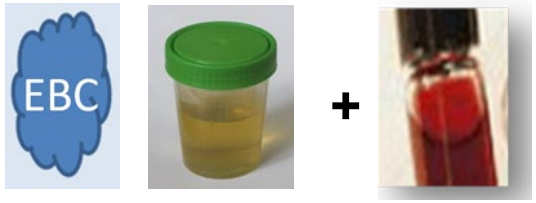
Examination of 61 workers pre-shift and post-shift

+ 62 controls

Research plant for **new resistant nanocomposites**

- metals and geopolymers (nano SiO_2 filler)

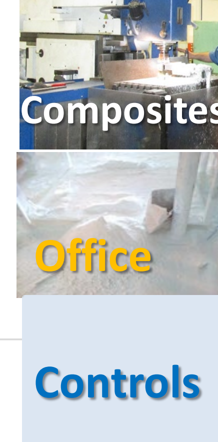
by welding and machining (grinding) technology.

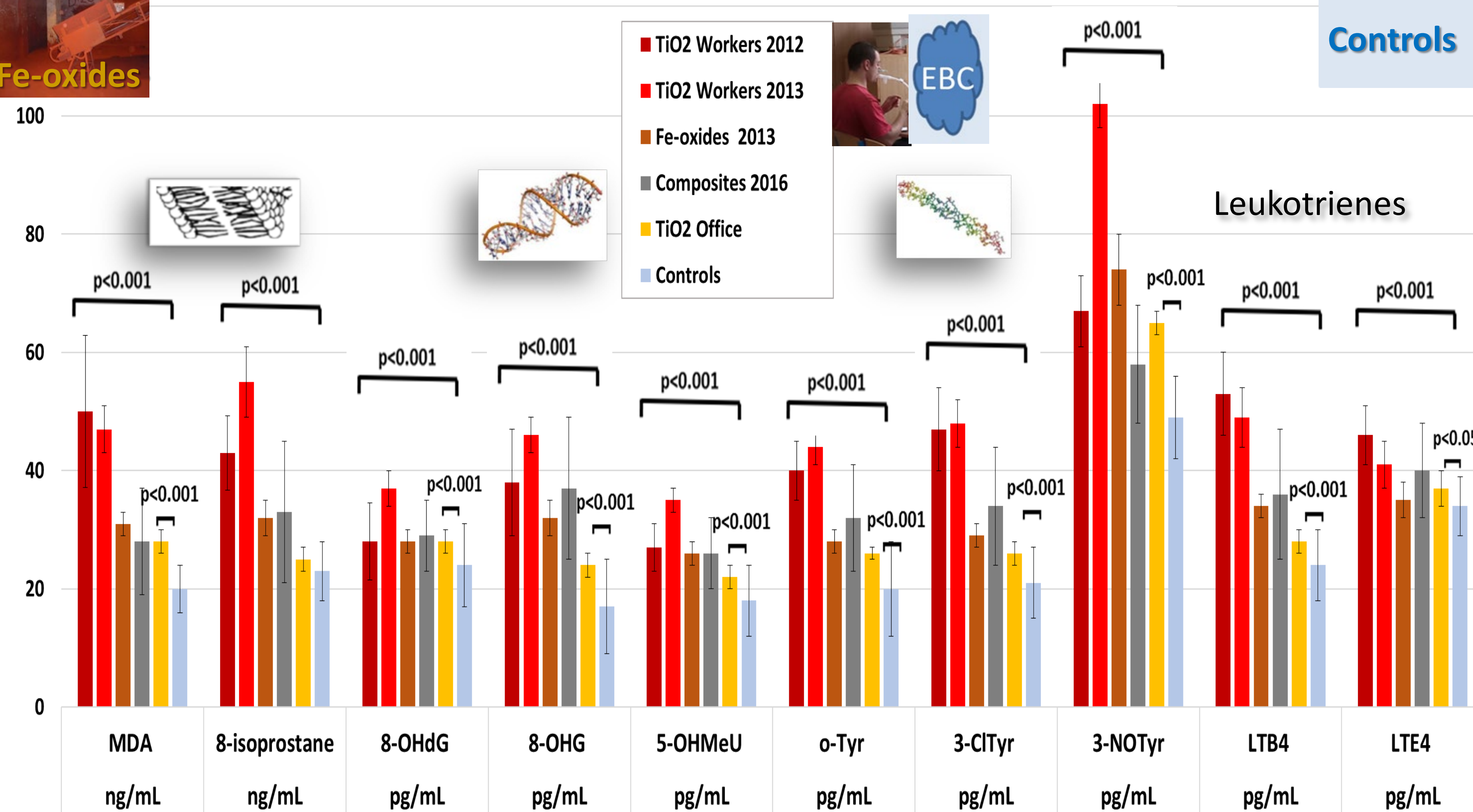


3 hours´ exposure

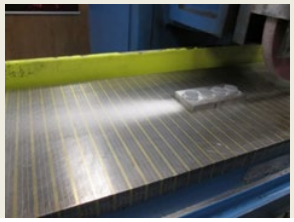
Proportion of nanoparticles at MACHINING up to 95 %

3 Metal oxides exposures and 6 groups of workers post-shift





LUNG FUNCTIONS



Chronic bronchitis more frequent:

4 (20%) nanocomposites, 0 % controls p=0.033*

Duration of exposure (but not age) correlated negatively with FEV1/FVC (p<0.05)

Post-shift decrease in the workers:

* p<0.05

LUNG FUNCTIONS	%FVC	%VCIN	%FEV1	FEV1/FVC	%PEF
Pre-shift	94.7±13.3	92.2±13.0	102.2±13.5	0.89±0.06	110.2±14.3
Post-shift	95.0±11.6	93.1±11.0	↓99.0±12.0*	↓0.86±0.06*	106.8±15.2
Controls	100.8±13.6	98.7±13.0	106.1±14.0	0.89±0.06	111.8±20.2

nanomaterials

MDPI

Article

Three-Year Study of Markers of Oxidative Stress in Exhaled Breath Condensate in Workers Producing Nanocomposites, Extended by Plasma and Urine Analysis in Last Two Years

2020

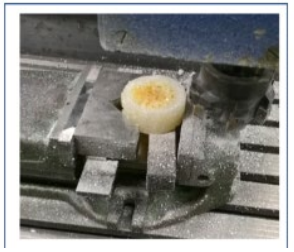
Daniela Pelclova [1,*], Vladimir Zdimal [2], Martin Komarc [3,4], Jaroslav Schwarz [2], Jakub Ondracek [2], Lucie Ondrackova [2], Martin Kostejn [2], Stepanka Vlckova [1], Zdenka Fenclova [1], Stepanka Dvorackova [5], Lucie Lischkova [1], Pavlina Klusackova [1], Viktoriia Kolesnikova [1], Andrea Rossnerova [6] and Tomas Navratil [7]

2016, 2017, 2018

WELDING

- EBC, urine and plasma samples
- in 2018 controls also examined twice - morning and afternoon samples

MACHINING

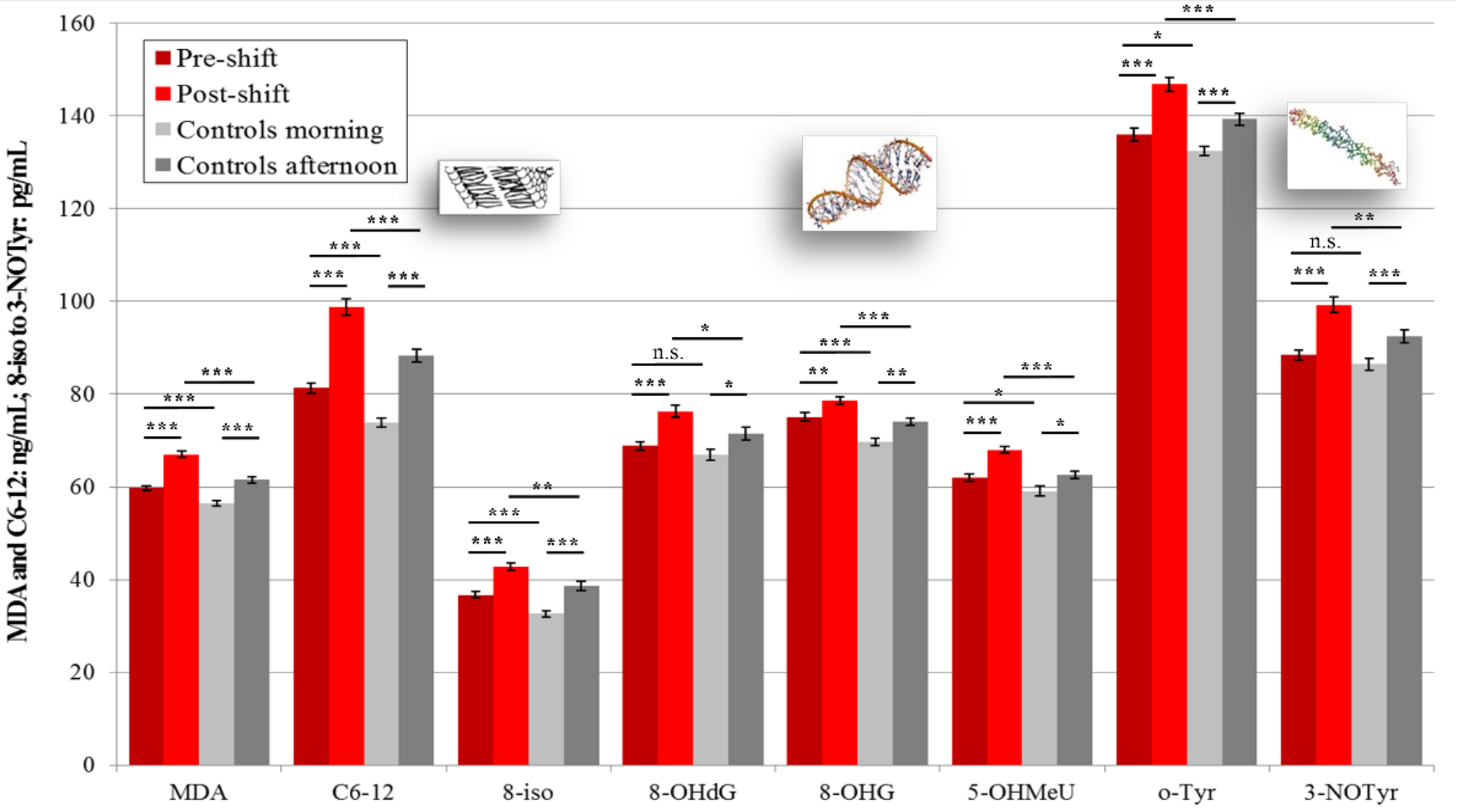


Plasma samples 2018

highest significance

75% pre-shift ↑ 100% shift effect ↑

100% postshift ↑ vs afternoon controls

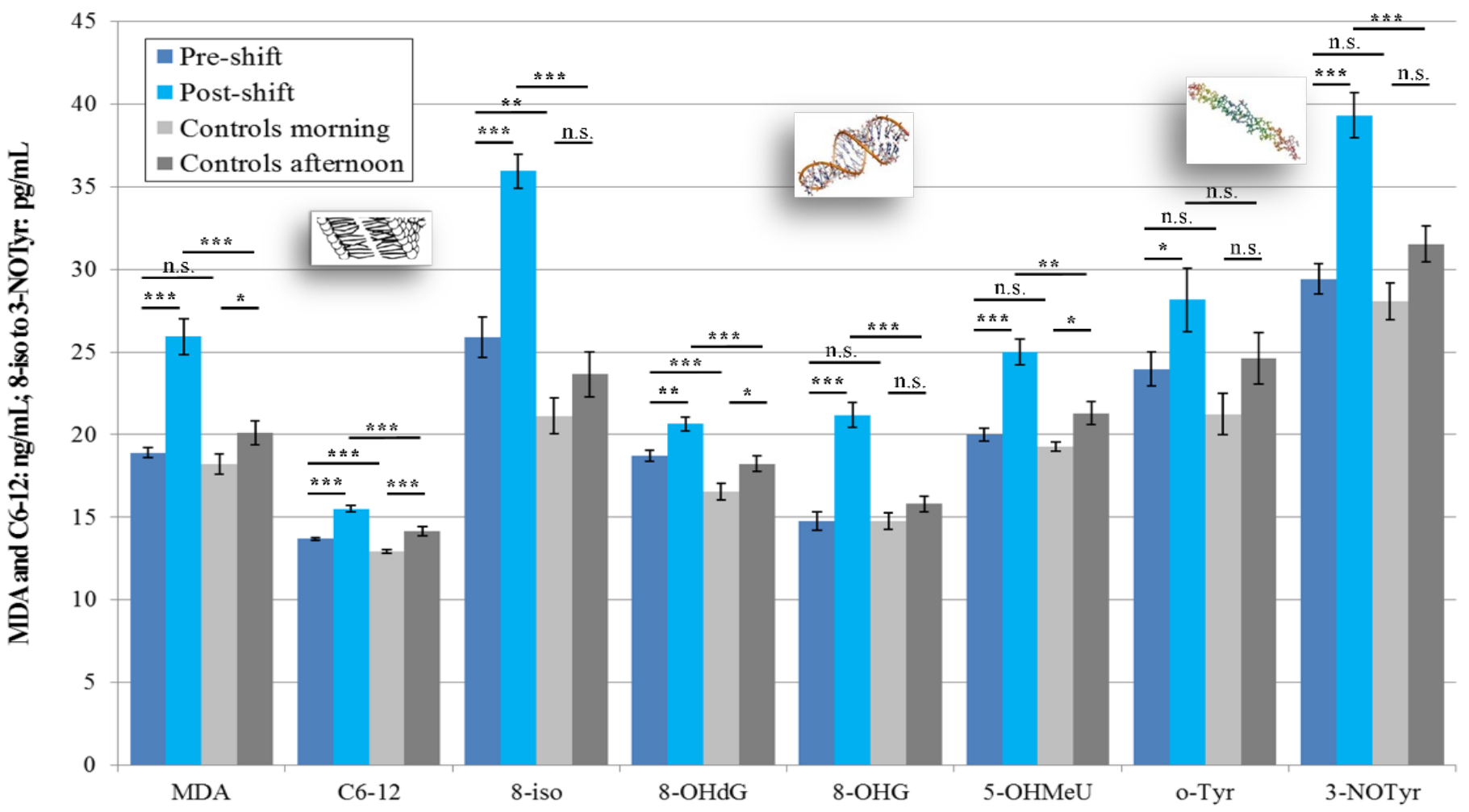


EBC markers 2018

high significance

38% pre-shift ↑ 100% shift effect ↑

88% postshift ↑ vs afternoon controls

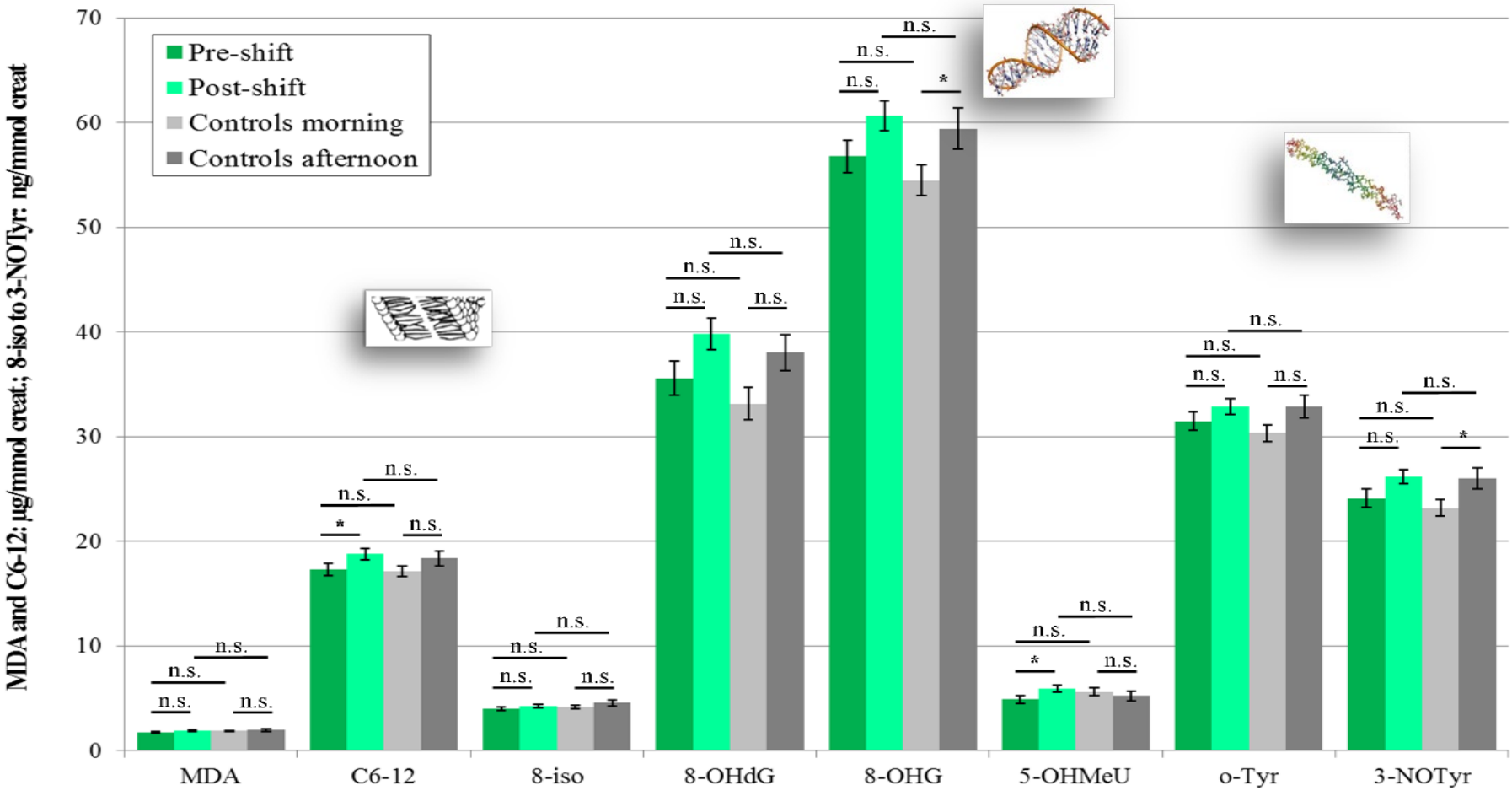


Urine samples 2018

same trends, less significance

0 pre-shift ↑ 0 shift effect ↑

25% post 3h shift ↑ vs afternoon controls



J Nanopart Res. 2015 Oct;17:413. Epub 2015 Oct 19.

Assessing the first wave of epidemiological studies of nanomaterial workers.

Liou SH[1], Tsai CS[2], Pelclova D[3], Schubauer-Berigan MK[4], Schulte PA[4].

Author information

[1]National Institute of Environmental Health Sciences, National Health Research Institutes, 35 Keyan Road, Zhunan, Miaoli County 35053, Taiwan, ROC.
[2]Department of Environmental and Radiological Health Science, Colorado State University, Fort Collins, CO, USA.
[3]Department of Occupational Medicine, First Faculty of Medicine, Charles University in Prague, Prague, Czech Republic.
[4]National Institute for Occupational Safety and Health, Cincinnati, OH, USA.

- **1 682 commercial products with nanoparticles**
- Price 10^{12} (trillions) USD
- **2015 Only 6 published occupational studies + 11 conference proceedings**
  EXPOSURES: Nanomaterials (Taiwan), TiO_2 (Czech Rep, China), carbon nanotubes (Russia, South Korea, Netherlands, Japan), Fe oxides (Czech Rep), $CaCO_3$ (China), nanoAg (Korea)
- SAMPLES: **blood serum** (Taiwan, Russia, Netherlands), **sputum** (China), **induced sputum** (Russia), **urine**, **EBC** (Czech Rep 2012, South Korea 2015)

- **2022 SEARCH in PubMed**
- **key words: NANO - EXPOSURE – INHALATION – WORKERS - BIOMARKERS**
- **ACTUALLY 33 HUMAN STUDIES (NOT REVIEWS)**

BIOMARKERS, 2016
http://dx.doi.org/10.3109/1354750X.2016.1160432

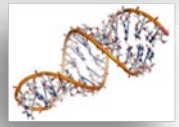
Taylor & Francis
Taylor & Francis Group

Liou 2016

RESEARCH ARTICLE

Increased levels of oxidative stress biomarkers in metal oxides nanomaterial-handling workers

Saou-Hsing Liou[a]#, Yu-Cheng Chen[b], Hui-Yi Liao[a]#, Chien-Jen Wang[a], Jhih-Sheng Chen[b] and Hui-Ling Lee[b]#



↑8-OHdG in plasma, ↑ 8-OHdG in urine, correlation between urine and plasma

130 workers 26xTiO_2, 31xSiO_2, 30xIndium Tin Oxide (*ITO* of display technologies, electroluminescent, and electro chromatic displays, touch screen technologies).
DNA damage, lipids peroxidation, ….

Contents lists available at ScienceDirect

Journal of Hazardous Materials

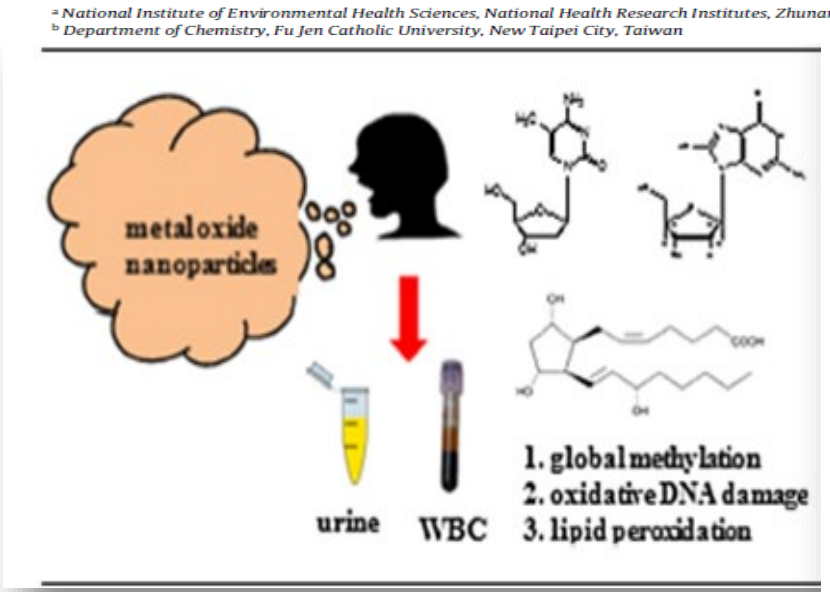
journal homepage: www.elsevier.com/locate/jhazmat

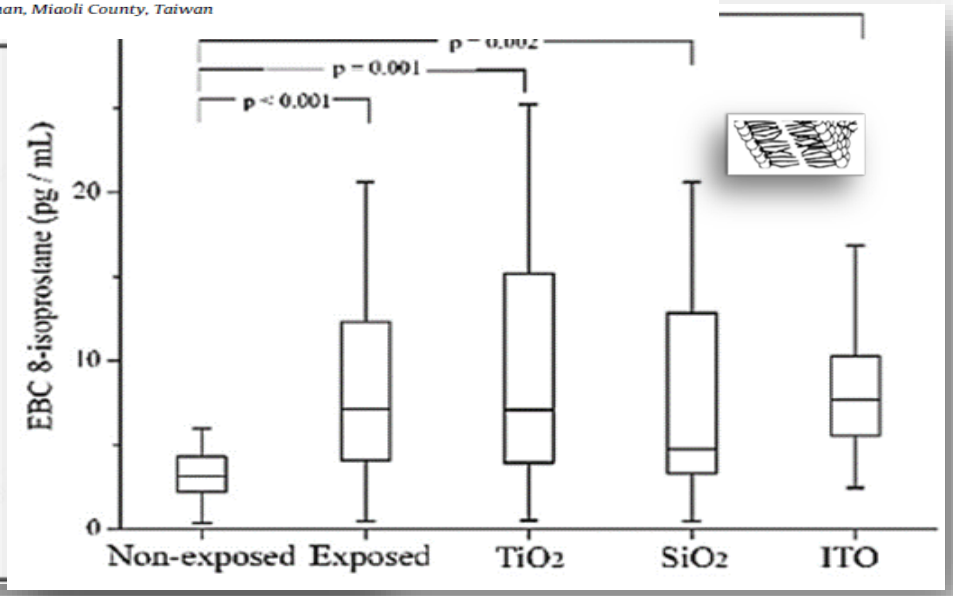
Liou 2017

Global DNA methylation and oxidative stress biomarkers in workers exposed to metal oxide nanoparticles

Saou-Hsing Liou [a], Wei-Te Wu [a], Hui-Yi Liao [a], Chao-Yu Chen [b], Cheng-Yen Tsai [b], Wei-Ting Jung [b], Hui-Ling Lee [b,*]

[a] National Institute of Environmental Health Sciences, National Health Research Institutes, Zhunan, Miaoli County, Taiwan
[b] Department of Chemistry, Fu Jen Catholic University, New Taipei City, Taiwan





↑ 8-OHdG in urine, ↑ 8-isoprostanes in exhaled breath condensate (EBC)

130 workers 26x TiO_2, 31x SiO_2, 30x Indium Tin Oxide

DNA damage, lipids peroxidation, DNA hypomethylation, and genomic instability – oncogenesis,….

NANOTOXICOLOGY, 2018
https://doi.org/10.1080/17435390.2018.1425502

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Cardiopulmonary effects induced by occupational exposure to titanium dioxide nanoparticles

Zhao 2018

Lin Zhao[a], Yifang Zhu[b], Zhangjian Chen[a], Huadong Xu[a], Jingwen Zhou[c], Shichuan Tang[d], Zhizhen Xu[d], Fanling Kong[e], Xinwei Li[c], Yifei Zhang[f], Xianzuo Li[f], Ji Zhang[c] and Guang Jia[a]

- TiO_2 production plant in China
- 85 TiO_2 packers 3.17 mg/m^3, 39% nano TiO_2
- Blood malondialdehyde (MDA), TNF, IL-10, ….
- Cardiovascular disease markers (cell adhesion molecules VCAM, ICAM)
- **Lung functions** impaired ($p < 0.05$)
- **X-ray** – 43% increased interstitial pattern in workers
- ***All markers associated with exposure to TiO_2***

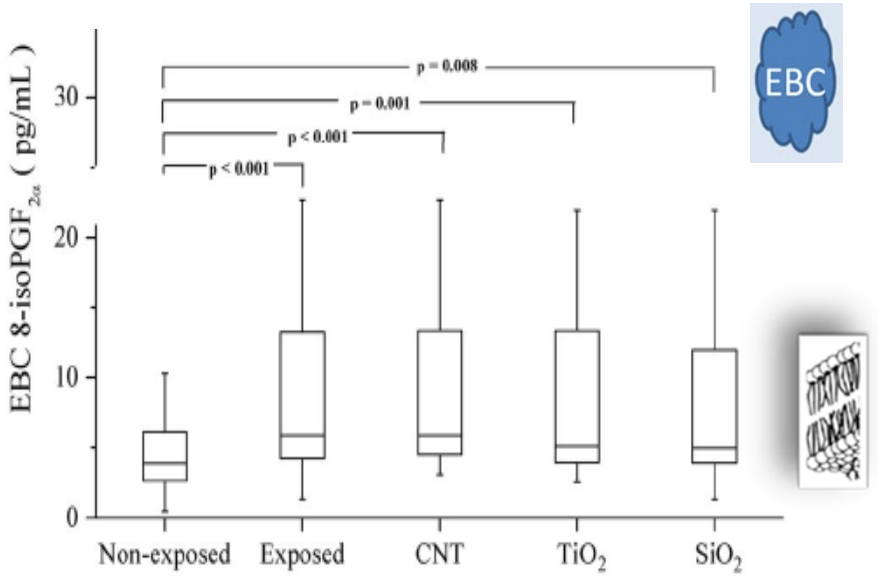
NANOTOXICOLOGY

Lipid peroxidation metabolites associated with biomarkers of inflammation and oxidation stress in workers handling carbon nanotubes and metal oxide nanoparticles

Wei-Te Wu, Wei-Ting Jung & Hui-Ling Lee

WU et al. 2021

- Confirmed a higher sensitivity of EBC, than urine 8-isoprostane markers for nanoTiO_2 - EBC recommended for biomonitoring as most sensitive



69 Non-exposed controls

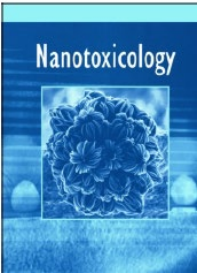
80 Exposed nanomaterials workers:

POST-SHIFT SAMPLES on Friday

22 carbon nanotubes (CNT)

30 nano-TiO_2

28 nano-SiO_2



NANOTOXICOLOGY
https://doi.org/10.1080/17435390.2021.1936254

Taylor & Francis
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REVIEW ARTICLE

Check for up

Shekaftik and Nasirzadeh 2021

8-Hydroxy-2′-deoxyguanosine (8-OHdG) as a biomarker of oxidative DNA damage induced by occupational exposure to nanomaterials: a systematic review

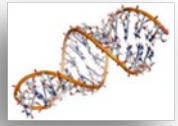
Soqrat Omari Shekaftik[a] and Nafiseh Nasirzadeh[b]

REVIEW

"biomarkers"+ "occupational exposure" + "nanomaterials."

- from 126 studies – 8 studies left (4 our studies)

- blood 8-OHdG and EBC level can be introduced as a biomarker for metal nanomaterials,



- but urinary 8-OHdG needs to be taken with caution.

Zhang, Bello et al. 2022

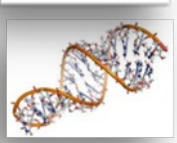
nanomaterials

MDPI

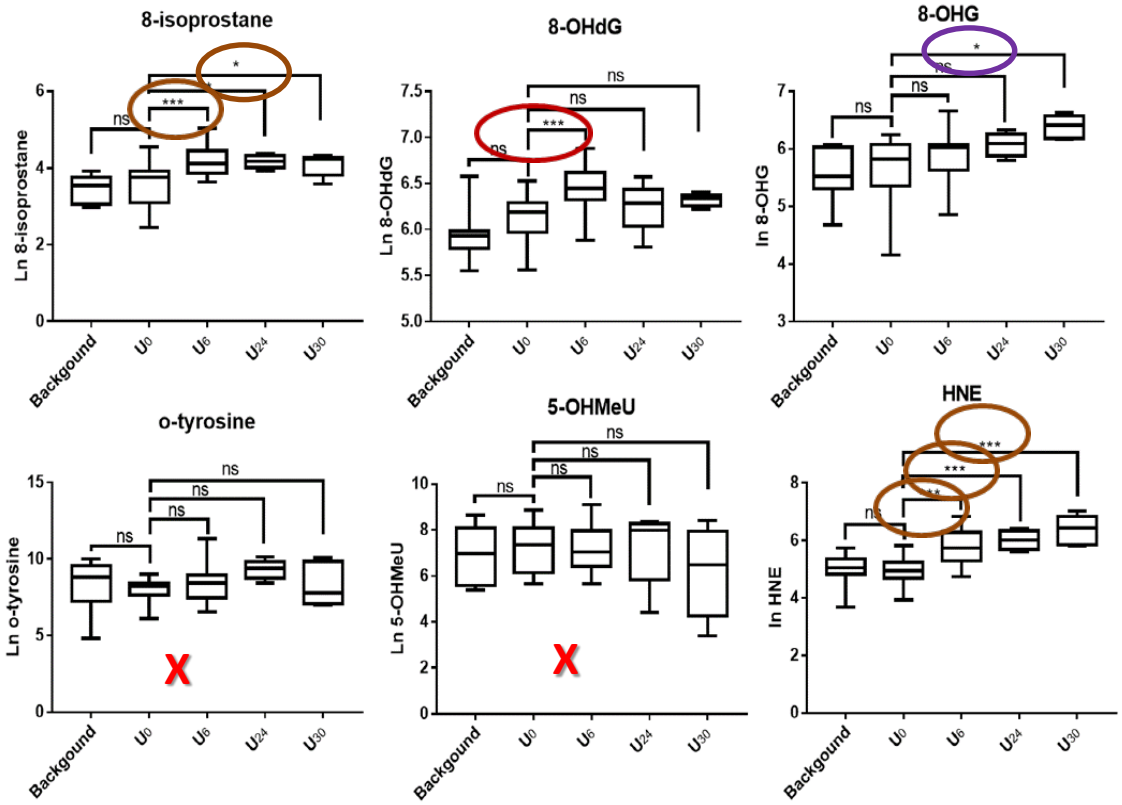
Article

Elevated Urinary Biomarkers of Oxidative Damage in Photocopier Operators following Acute and Chronic Exposures

Yipei Zhang [1], Anila Bello [2], David K. Ryan [1], Philip Demokritou [3] and Dhimiter Bello [3,4,*]



- ACUTELY 6 h in volunteers
- Nanoparticles from photocopiers induce systemic oxidative stress, lipid oxidation (8-isoprostanes, HNE),
- DNA (8-OHdG), RNA (OHG) in urine samples post exposure



9 healthy volunteers: urine

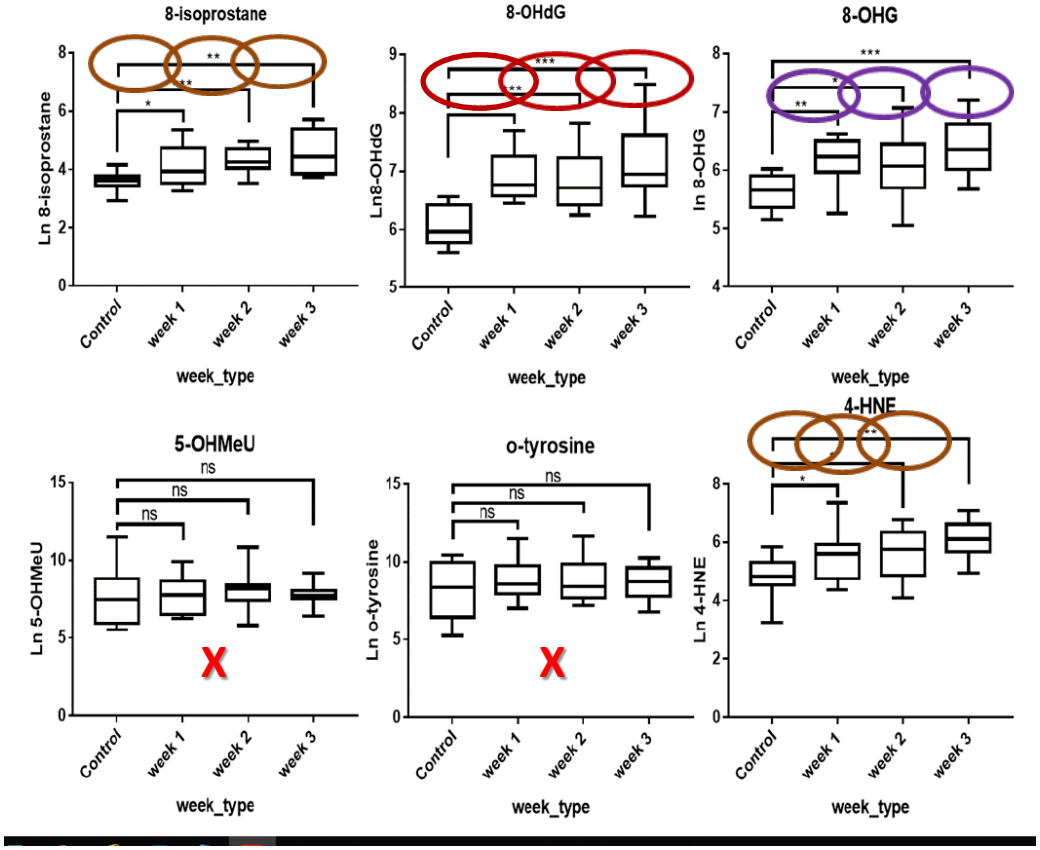
- background,
- pre-exposure,
- after 6 h exposure
- 24 h later,
- 36 h later

Longer latency: OHG and HNE increased with time

CHRONICALLY DURING 3 WEEKS IN OPERATORS

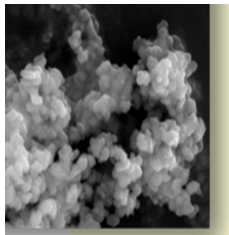
Zhang, Bello et al. 2022

Nanoparticles from photocopiers induce systemic oxidative stress, leading to lipid oxidation (8-isoprostanes, HNE), DNA (8-OHdG), RNA (OHG) in urine samples



6 Operators + 11 Controls
repeated 3x:
week 1, week 2, week 3

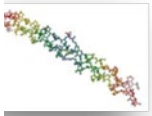
Stable results during weeks



Conclusions

- MONITORING IS NEEDED - results are consistent with oxidative stress hypothesis and a lung injury at the molecular level
- Group test – minimum 20 exposed workers
- Two body fluids from EBC, plasma, urine
- Several biomarkers – from all groups





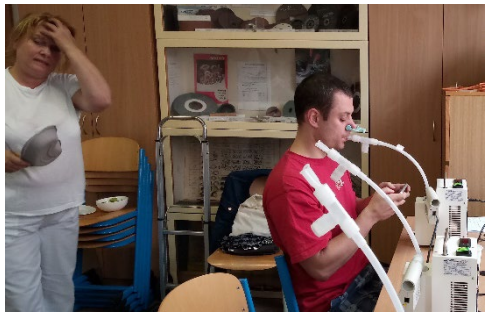
- Timing to reflect both chronic and acute effect
- EBC or plasma post-shift
- Urine - post-shift at the end of the week
- Control group – identical location - identical time
- Post-shift **spirometry** after higher exposures
- *X-ray after long-term intense exposure*


Further plans

- FOLLOW-UP is recommended - similarity of findings in EBC (8-isoprostane, MDA) in silicosis and asbestos-exposed patients
- 2019 and 2020 personal samplers also used – PENs, individual exposure data available
- Nanoparticles in the samples 2019-2020 by Raman method to be correlated with the markers
- Antioxidant capacity measured: GSH, ferric reducing antioxidant power (FRAP)
- We are open to cooperation

Hvala za pozornost!
Thank you

Charles University in Prague, Department of Occupational Medicine, and General University Hospital Prague, Czech Republic,
Technical University in Liberec, Faculty of Mechanical Engineering, Department of Machining and Assembly, Department of Material Science
Institute of Chemical Process Fundamentals of the CAS, v.v.i., Prague
Heyrovsky Institute of Physical Chemistry of the CAS, v.v.i., Prague



Project of the Charles University in Prague

daniela@pelclova.cz