



Vanadium Health Research Programme: Recent Published Literature

April - June 2017

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Introduction

This report presents the bibliographic details of papers identified as being published during the period April to June 2017.

The papers were selected because they address research areas that are considered of direct relevance to the health and environmental effects of Vanadium. In order to aid review, the papers are presented under the following categories; it should be noted however, that when considered appropriate, some papers may appear in more than one section.

Section 1 – HUMAN EXPOSURE MEASUREMENT AND MODELLING: Papers relating to the measurement or modelling of environmental and occupational Vanadium exposure; the development of human biomarkers of exposure or effect.

Section 2 - HEALTH EFFECTS: Papers on the influence of Vanadium on health, disease and dysfunction; assessment of the influence of genetic and epigenetic factors on human susceptibility to the effects of Vanadium; development and implementation of new medical approaches to the treatment of excessive Vanadium exposure.

Section 3 – BIOLOGICAL MECHANISMS: Papers on the biochemical and toxicological mechanisms underlying the effects of Vanadium.

Section 4 – USES OF VANADIUM: Papers relating to the use of Vanadium in medical and dental devices, dietary supplements and as therapeutic agents.

Section 5 – ENVIRONMENTAL EFFECTS in PLANTS and SOIL: Papers relating to the effects following environmental exposure to Vanadium that are specific to plants and soil.

Section 6 – ENVIRONMENTAL EFFECTS in TERRESTRIAL ORGANISMS: Papers relating to the effects following environmental exposure to Vanadium that are specific to terrestrial organisms.

Section 7 – ENVIRONMENTAL EFFECTS in AQUATIC ORGANISMS: Papers relating to the effects following environmental exposure to Vanadium that are specific to aquatic organisms.

Section 8 – MISCELLANEOUS: Other papers considered of general interest or potential relevance to the study of the health effects of Vanadium that do not relate to the above categories.

1. HUMAN EXPOSURE MEASUREMENT AND MODELLING

Al Rawahi, W.A. & Ward, N.I. (2017) Field-based application of developed solid phase extraction with inductively coupled plasma mass spectrometry for vanadium speciation analysis of groundwaters from Argentina. *Talanta*, 165: 391-397.

Abstract:

High levels of vanadium have been reported in groundwater (< 0.05 - $5300 \mu\text{g L}^{-1}$ V) from different parts of Argentina, yet no detailed study of vanadium speciation has been performed. A highly selective strong anion exchange - solid phase extraction (SAX-SPE) method was used (in-situ) for vanadium speciation analysis of groundwater samples from La Pampa - LP (General San Martin and Eduardo Castex) and Buenos Aires - BA (San German) provinces in Argentina. In this method both vanadyl (V-IV) and vanadate (V-V) were trapped by the complexation with disodium ethylenediaminetetraacetic acid on a pre-conditioned SAX cartridge. In the laboratory, vanadium species were separated at different eluent pH levels. V-IV was eluted at pH 4 using methanol and tetrabutylammonium hydroxide. V-V was eluted at pH 8 using dihydrogen ammonium phosphate. The eluted species were analysed by inductively coupled plasma mass spectrometry (ICP-MS). This method was validated using an inter-analytical method comparison with HPLC-ICP-MS. A Paired t-test revealed that there was no significant difference (probability, $P < 0.05$) between the two methods. V-V was found to be predominate species in both sample collection areas (LP: 69 - 100%, BA: 33 - 89% of species) over the range of $158.0 - 4748.0 \mu\text{g L}^{-1}$ in LP and $88.5 - 504.0 \mu\text{g L}^{-1}$ in BA. V-IV was found at higher levels (29.0 - $301.0 \mu\text{g L}^{-1}$) in Buenos Aires compared to General San Martin groundwater ($4.4 - 161.0 \mu\text{g L}^{-1}$). The results enhance the potential knowledge of the speciation of vanadium in terms of water quality and human health.

Annangi, B., Bonassi, S., Marcos, R., et al. (2016) Biomonitoring of humans exposed to arsenic, chromium, nickel, vanadium, and complex mixtures of metals by using the micronucleus test in lymphocytes. *Mutation Research/Reviews in Mutation Research*, 770(Part A): 140-161. Available at: https://www.researchgate.net/profile/Dr_Balasubramanyam_Annangi/publication/296472618_Biomonitoring_of_humans_exposed_to_arsenic_chromium_nickel_vanadium_and_complex_mixtures_of_metals_by_using_the_micronucleus_test_in_lymphocytes/links/56e2abf308aebc9edb1b946a.pdf

Abstract:

Various metals have demonstrated genotoxic and carcinogenic potential via different mechanisms. Until now, biomonitoring and epidemiological studies have been carried out to assess the genotoxic risk to exposed human populations. In this sense, the use of the micronucleus assay in peripheral blood lymphocytes has proven to be a useful tool to determine increased levels of DNA damage, as a surrogate biomarker of cancer risk. Here we review those biomonitoring studies focused on people exposed to arsenic, chromium, nickel, vanadium and complex mixtures of metals. Only those studies that used the frequency of micronuclei in binucleated (BNMN) cells have been taken into consideration, although the inclusion of other biomarkers of exposure and genotoxicity are also reflected and discussed. Regarding arsenic, most of the occupational and environmental biomonitoring studies find an increase in BNMN among the exposed individuals. Thus, it seems conclusive that arsenic exposure increases the risk of exposed human populations. However, a lack of correlation between the level of exposure and the increase in BNMN is also common, and a limited number of studies evaluated the genotype as a risk modulator. As for chromium, a BNMN increase in occupationally exposed subjects and a correlation between level of exposure and effect is found consistently in the available literature. However, the quality score of the studies is only medium-low. On the other hand, the studies evaluating nickel and vanadium are scarce and lacks a correct characterization of the individual exposure, which difficult the building of clear conclusions. Finally, several studies with medium-high quality scores evaluated a more realistic scenario of exposure which takes into account a mixture of metals. Among them, those which correctly characterized and measured the exposure were able to find association with the level of BNMN. Also, several

genes associated with DNA damage repair such as OGG1 and XRCC1 were found to influence the exposure effect.

Chen, C.S., Yuan, T., Shie, R., et al. (2017) Linking sources to early effects by profiling urine metabolome of residents living near oil refineries and coal-fired power plants. *Environment International*, 102: 87-96.

Abstract:

Background This study aims at identifying metabolic changes linking external exposure to industrial air toxics with oxidative stress biomarkers. Methods We classified 252 study subjects as 111 high vs. 141 low exposure subjects by the distance from their homes to the two main emission sources, oil refineries and coal-fired power plants. We estimated individual's external exposure to heavy metals and polycyclic aromatic hydrocarbons (PAHs) by dispersion and kriging models, respectively. We measured urinary levels of heavy metals and 1-hydroxypyrene (1-OHP) as biomarkers of internal exposure, and 8-OHdG, HNE-MA, 8-isoPGF2 α , and 8-NO2Gua as biomarkers of early health effects. We used two-dimensional gas chromatography time-of-flight mass spectrometry to identify urine metabolomics. We applied "meet-in-the-middle" approach to identify potential metabolites as putative intermediate biomarkers linking multiple air toxics exposures to oxidative stress with plausible exposures-related pathways. Results High exposure subjects showed elevated ambient concentrations of vanadium and PAHs, increased urine concentrations of 1-OHP, vanadium, nickel, copper, arsenic, strontium, cadmium, mercury, and thallium, and higher urine concentrations of all four urine oxidative stress biomarkers compared to low exposure subjects. We identified a profile of putative intermediate biomarkers that were associated with both exposures and oxidative stress biomarkers in participants. Urine metabolomics identified age-dependent biological pathways, including tryptophan metabolism and phenylalanine metabolism in children subjects (aged 9–11), and glycine, serine, and threonine metabolism in elderly subjects (aged > 55), that could associate multiple exposures with oxidative stress. Conclusion By profiling urine biomarkers and metabolomics in children and elderly residents living near a petrochemical complex, we can link their internal exposure to oxidative stress biomarkers through biological pathways associated with common complex chronic diseases and allergic respiratory diseases. The internal exposure may possibly be traced to multiple air toxics emitted from specific sources of oil refineries and coal-fired power plants.

Day, P.L., Eckdahl, S.J., Maleszewski, J.J., et al. (2017) Establishing human heart chromium, cobalt and vanadium concentrations by inductively coupled plasma mass spectrometry. *Journal of Trace Elements in Medicine and Biology: Organ of the Society for Minerals and Trace Elements (GMS)*, 41: 60-65.

Abstract:

OBJECTIVE: Chromium, cobalt, and vanadium are used in metallic joint prosthesis. Case studies have associated elevated heart tissue cobalt concentrations with myocardial injury. To document the long term heart metal ion concentrations, a validated inductively coupled plasma mass spectroscopy (ICP-MS) method was needed. METHOD: The method utilized a closed-vessel microwave digestion system to digest the samples. An ICP-MS method utilizing Universal Cell Technology was used to determine our target analyte concentrations. Accuracy was verified using reference materials. Precision, sensitivity, recovery and linearity studies were performed. This method was used to establish a reference range for a non-implant containing cohort of 80 autopsy human heart tissues RESULTS: This method demonstrated an analytic measurement range of 0.5-100ng/mL for each element. Accuracy was within +/-10% of target value for each element. Within-run precision for each element was below 20% CV. The chromium, vanadium and cobalt concentrations (mean+/-SD) were 0.1523+/-0.2157mug/g, 0.0094+/-0.0211mug/g and 0.1039+/-0.1305mug/g respectively in 80 non-implant containing human heart tissue samples. CONCLUSIONS: This method provides acceptable recovery of the chromium, cobalt and vanadium in heart tissue; allowing assessment of the effects of metallic joint prosthesis on myocardial health.

Filler, G., Kobrzynski, M., Sidhu, H.K., et al. (2017) A cross-sectional study measuring vanadium and chromium levels in paediatric patients with CKD. *BMJ Open*, 7(5): e014821-2016-014821. Available at: <http://bmjopen.bmj.com/content/7/5/e014821.full.pdf>

Abstract:

OBJECTIVES: Although many secondary effects of high levels of vanadium (V) and chromium (Cr) overlap with symptoms seen in paediatric patients with chronic kidney disease (CKD), their plasma V and Cr levels are understudied. **DESIGN:** Ancillary cross-sectional study to a prospective, longitudinal, randomised controlled trial. **SETTING:** Children's Hospital of Western Ontario, London Health Sciences Centre, London, Ontario, Canada. **PARTICIPANTS:** 36 children and adolescents 4-18 years of age with CKD. **INTERVENTIONS:** 1-6 trace element measurements per patient. Cystatin C (CysC) estimated glomerular filtration rate (eGFR) was calculated using the Filler formula. Plasma V and Cr levels were measured using high-resolution sector field inductively coupled mass spectrometry. Anthropomorphic data and blood parameters were collected from our electronic chart programme. Water Cr and V data were obtained from the Ontario Water (Stream) Quality Monitoring Network. **PRIMARY AND SECONDARY OUTCOME MEASURES:** Primary outcomes: plasma Cr and V. **SECONDARY OUTCOMES:** age, season, CysC, CysC eGFR, and Cr and V levels in environmental water. **RESULTS:** The median (IQR) eGFR was 51 mL/min/1.73 m² (35, 75). The median V level was 0.12 microg/L (0.09, 0.18), which was significantly greater than the 97.5th percentile of the reference interval of 0.088 microg/L; 32 patients had at least one set of V levels above the published reference interval. The median Cr level was 0.43 microg/L (0.36, 0.54), which was also significantly greater than the established reference interval; 34 had at least one set of Cr levels above the published reference interval. V and Cr levels were moderately correlated. Only some patients had high environmental exposure. **CONCLUSIONS:** Our study suggests that paediatric patients with CKD have elevated plasma levels of V and Cr. This may be the result of both environmental exposure and a low eGFR. It may be necessary to monitor V and Cr levels in patients with an eGFR <30 mL/min/1.73 m². **TRIAL REGISTRATION NUMBER:** NCT02126293; HC#172241.

Gürkan, R., Tamay, A. & Ulusoy, H.İ. (2017) Speciative determination of total V and dissolved inorganic vanadium species in environmental waters by catalytic-kinetic spectrophotometric method. *Arabian Journal of Chemistry*, 10(Supplement 1): S13-S22.

Abstract:

Abstract A kinetic determination of V(V) as a catalyst was spectrophotometrically performed by using the indicator reaction of Gallamine blue (GB+) and bromate at pH 2.0. The reaction was followed by measuring absorbance change for a fixed-time of 3 min at 537 nm. The variables such as reagent concentration, pH, buffer concentration, ionic strength and temperature were optimized to improve the selectivity and sensitivity. Under the optimized conditions, the determination of V(V) was performed in the range 1–100 µg L⁻¹ with limits of detection and quantification of 0.31 and 0.94 µg L⁻¹. The developed kinetic method is sufficiently sensitive, selective and simple. It was successfully applied to the speciative determination of total V and inorganic dissolved vanadium species, V(V) and V(IV) in environmental water samples. The oxidizing property of permanganate is used to differentiate between V(IV) and V(V) species. The V(IV) content was found by subtracting the V(V) content from those of total V. The recovery is above 95% for V(V) spiked samples. Additionally, the accuracy was validated by analysis of a certified water sample, CRM TMDA-53.3, and the results were in good agreement with the certified value.

Kostic, A.Z., Kaluderovic, L.M., Dojcinovic, B.P., et al. (2017) Preliminary investigation of mineral content of pollen collected from different Serbian maize hybrids - is there any potential nutritional value? *Journal of the Science of Food and Agriculture*, 97(9): 2803-2809.

Abstract:

BACKGROUND: Bee pollen has already proved to be a good supplement rich in iron and zinc. Studies on the application of flower pollen in the food industry and medicine have begun. Bearing in mind the prevalence of maize as a crop culture, its pollen will be easily available. The mineral composition of pollen of seven Serbian maize hybrids was analyzed in order to establish its nutritional value and the benefits of its implementation in the human diet using the inductively coupled plasma method. **RESULTS:** The presence of twenty four different macro- (nine) and micronutrients (fifteen) was detected. The most common minerals were phosphorus and potassium, while arsenic, cobalt, lead, nickel and molybdenum were found in some samples. **CONCLUSION:** Comparing the results obtained with recommended or tolerable dietary intake references for adults, it was found that maize pollen can be used as

a very good source of zinc, iron, chromium and manganese for humans. With regard to selenium content, pollen samples proved to be moderately good source of this important micronutrient. Contents of some elements (Fe, Zn, Mn, Cr, Se, Al and V) showed significant differences depending on hybrid type. In some samples increased concentrations of aluminum and vanadium were recorded, which may pose a potential problem due to their toxicity. © 2016 Society of Chemical Industry.

Liu, X., Zhang, Y., Piao, J., et al. (2017) Reference values of 14 serum trace elements for pregnant Chinese women: A cross-sectional study in the China nutrition and health survey 2010-2012. *Nutrients*, 9(3): 309. Available at: <http://www.mdpi.com/2072-6643/9/3/309/pdf>

Abstract:

The development of reference values of trace elements is recognized as a fundamental prerequisite for the assessment of trace element nutritional status and health risks. In this study, a total of 1400 pregnant women aged 27.0 ± 4.5 years were randomly selected from the China Nutrition and Health Survey 2010-2012 (CNHS 2010-2012). The concentrations of 14 serum trace elements were determined by high-resolution inductively coupled plasma mass spectrometry. Reference values were calculated covering the central 95% reference intervals (P2.5-P97.5) after excluding outliers by Dixon's test. The overall reference values of serum trace elements were 131.5 (55.8-265.0 $\mu\text{g/dL}$ for iron (Fe), 195.5 (107.0-362.4) $\mu\text{g/dL}$ for copper (Cu), 74.0 (51.8-111.3) $\mu\text{g/dL}$ for zinc (Zn), 22.3 (14.0-62.0) $\mu\text{g/dL}$ for rubidium (Rb), 72.2 (39.9-111.6) $\mu\text{g/L}$ for selenium (Se), 45.9 (23.8-104.3) $\mu\text{g/L}$ for strontium (Sr), 1.8 (1.2-3.6) $\mu\text{g/L}$ for molybdenum (Mo), 2.4 (1.2-8.4) $\mu\text{g/L}$ for manganese (Mn), 1.9 (0.6-9.0) ng/L for lead (Pb), 1.1 (0.3-5.6) ng/L for arsenic (As), 835.6 (219.8-4287.7) ng/L for chromium (Cr), 337.9 (57.0-1130.0) ng/L for cobalt (Co), 193.2 (23.6-2323.1) ng/L for vanadium (V), and 133.7 (72.1-595.1) ng/L for cadmium (Cd). Furthermore, some significant differences in serum trace element reference values were observed between different groupings of age intervals, residences, anthropometric status, and duration of pregnancy. We found that serum Fe, Zn, and Se concentrations significantly decreased, whereas serum Cu, Sr, and Co concentrations elevated progressively compared with reference values of 14 serum trace elements in pregnant Chinese women. The reference values of serum trace elements established could play a key role in the following nutritional status and health risk assessment. © 2017 by the authors. Licensee MDPI, Basel, Switzerland.

López-Rodríguez, G., Galván, M., González-Unzaga, M., et al. (2017) Blood toxic metals and hemoglobin levels in Mexican children. *Environmental Monitoring and Assessment*, 189(4): 179.

Abstract:

Metal toxicity can cause hematologic abnormalities and hemolysis. To evaluate the relationship of anemia with metal contamination in children, the following elements were quantified in dry blood: silicon, chromium, lead, titanium, vanadium, nickel, arsenic, manganese, and cadmium. A total of 88 samples of anemic children and 208 of non-anemic children aged 6-12 years were analyzed. Lead (35.1%), chromium (24.3%), vanadium (24.3%), nickel (45.6%), and silicon (48.6%) were identified in the samples, with titanium only detected in anemic children. The average level of arsenic was higher in anemic than non-anemic children (0.041 ± 0.11 wt% vs 0.014 ± 0.05 wt%, $p < 0.05$) and correlated with the concentration of hemoglobin ($r = -0.441$, $p < 0.01$). In conclusion, heavy metals, which confer a health risk, were detected in the dry blood of the children evaluated, and the levels of arsenic and titanium were found to be related to anemia. © 2017, Springer International Publishing Switzerland.

Mauriello, M.C., Sbordone, C., Montuori, P., et al. (2017) Biomonitoring of toxic metals in incinerator workers: A systematic review. *Toxicology Letters*, 272: 8-28.

Abstract:

Exposure to chemicals released during urban waste disposal and treatment is increasingly regarded as a potential occupational health issue. Indeed, several toxic metals emitted by an incinerator, including As, Be, Cd, Cr, Pb, Mn, Hg, Ni and V, have potentially toxic properties and their exposure, therefore, may be of concern for the health of the workers involved. The levels of exposure should therefore be carefully measured. Environmental

monitoring, however, may be unable, alone, to assess true exposure, due to its intrinsic limitations mainly concerning its inability to assess oral and dermal absorption. In these cases biological monitoring may represent a fundamental supplementary tool for the definition of the workers' true occupational exposure and for the prevention of the related health effects. There is, therefore, an increasing interest in developing and using, in these workers, sensitive and specific biomarkers for health risk assessment, particularly at low or even very low levels of exposure. Despite the large number of original and review articles present in the literature on the biomonitoring of workers exposed to metals, the data on subjects employed in waste treatment activities are scattered and results are sometimes inconsistent. This is the first systematic review, performed according to PRISMA methodology, of the major studies investigating the levels of different toxic metals measured in the main biological matrices (blood, urine, hair) of incinerator workers. The results show that the levels of metals measured in incinerators' workers are generally low, with some notable exceptions for Cd and Pb. These results, though, can be affected by several confounders related either to non-occupational exposure, including diet, area of residence and others, and/or by a number of methodological limitations, as we found in the reported studies. Future work should focus on an integrated approach, using ideally both biological and environmental monitoring. A particular emphasis should be given to the measurement of the different granulometric fractions of the dust containing metals, i.e. inhalable, thoracic, respirable and ultrafine fractions. Moreover, an accurate description of the work tasks and the characteristics and levels of non-occupational exposure should always be provided.

Nahan, K.S., Walsh, K.B., Adeoye, O., et al. (2017) The metal and metalloprotein profile of human plasma as biomarkers for stroke diagnosis. *Journal of Trace Elements in Medicine and Biology*, 42: 81-91.

Abstract:

Stroke, a major cause of disability and mortality, affects someone in the United States every 40 s. Stroke biomarkers, including those that could be used as a blood test for diagnosis of stroke, have been particularly elusive. We performed a double blind study to identify human plasma biomarkers for the diagnosis of stroke, including acute ischemic stroke (AIS) and intracerebral hemorrhage (ICH). We utilized a three-track approach based on the total metal profile, the metal cofactor levels among metalloproteins, and the identification of stroke-related metalloproteins. The study included 14 case-control pairs of AIS and 23 case-control pairs of ICH. Controls were matched to cases based on gender, ethnicity, and age (± 5 years). AIS cases were statistically higher from their respective controls for protein bound co-factors Se and Cd, while unique correlations of metal cofactor concentrations among metalloproteins were identified between Pb-W, Sr-W, Pb-V, and Cu-V. ICH cases were statistically higher from their respective controls for Se and Co cofactors, whereas Cd and Pb were statistically lower. Unique correlations between metal cofactors for ICH cases were identified between Pb-W, Sr-W, Pb-V, and Cu-V. Stroke-related metalloproteins were identified, including calpain-15, protein-activated inward rectifier potassium channel 1, tau-tubulin kinase 1, and voltage-dependent L-type calcium channel subunit beta-3. Linear discriminant analysis (LDA) was able to classify patients between stroke cases or controls with 93% accuracy as well as classify patients with one of the four stroke groups with 85% accuracy. Additionally, this study found utmost importance in vanadium (V) and tungsten (W) correlations for both bound and total metal concentrations, suggestive of binding to transferrin or inhibition of oxidoreductases. Future work in stroke patients will seek to quantify varying selenoproteins, including selenoprotein P and glutathione peroxidase and identified zinc finger tissue leakage proteins, and further explore the role of trace metal fluctuations with transferrin. © 2017 Elsevier GmbH.

Nisse, C., Tagne-Fotso, R., Howsam, M., et al. (2017) Blood and urinary levels of metals and metalloids in the general adult population of Northern France: The IMEPOGE study, 2008-2010. *International Journal of Hygiene and Environmental Health*, 220(2 Part B): 341-363.

Abstract:

Background: The assessment of human chemical risks related to occupational or environmental exposure to pollutants requires the use of both accurate exposure indicators and reference values. The objective of this study was to evaluate the blood and urinary levels of various metals and metalloids in a sample of adults aged 20-59 years of the general population of Northern France, a formerly heavily industrialised area that retains some

industrial activity. Methods: A cross-sectional study was conducted between 2008 and 2010, enrolling 2000 residents of Northern France. The quota method was used to guarantee the representativeness of the participants on a sex, age, social category and smoking status basis, according to the census done by the French National Institute of Statistics and Economic Studies. The levels of 14 metals: aluminium (Al), antimony (Sb), total arsenic (As), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), thallium (Tl), vanadium (V) and zinc (Zn) were quantified by ICP-MS in urine and blood samples. Results: A total of 982 men and 1018 women participated, allowing the analysis of 1992 blood and 1910 urine samples. Some metal(loid)s were detected in over 99% of the blood (Cd, Co, Mn, Ni, Pb) and urine (As, Co, Pb, Zn) samples and the remaining metals in 84-99% of the samples, with the exception of blood V (19%), blood Be (57%) and urine Be (58%). Mean blood levels of Pb and Zn were significantly higher in men, and Mn, Co and Cr in women. In urine, mean Pb, Tl and Sb concentrations were significantly higher in men, and Al and Co in women. Current smokers had significantly higher mean levels of blood Cd and Pb and lower blood Co, Mn and Hg. In urine (adjusted on urinary creatinine), the smokers had higher mean levels of Cd, Pb, V and Zn and lower mean levels of As, Co, and Hg. Overall, the mean urinary levels of most metal(loid)s found in the general population of Northern France were higher than those found in the French national survey for the same period except for urinary V. Mean blood lead level was markedly less than that of the French national population. Conclusion: This first biomonitoring survey of a large number of metal(loid)s in the general population of Northern France provides useful information on exposure levels to toxic elements and highlights the specificity of the regional environment. These data could be used, in complement to the national human biomonitoring reference values, for the interpretation of biomonitoring results. © 2016 Elsevier GmbH.

Sanna, D., Ugone, V., Serra, M., et al. (2017) Speciation of potential anti-diabetic vanadium complexes in real serum samples. *Journal of Inorganic Biochemistry*, 173: 52-65.

Abstract:

Abstract In this work the speciation in real serum samples of five VIVO complexes with potential application in the therapy of diabetes was studied through EPR spectroscopy as a function of V concentration (45.4, 90.9 and 454.5 μM) and time (0–180 min). $[\text{VO}(\text{dhp})_2]$, $[\text{VO}(\text{ma})_2]$, $[\text{VO}(\text{acac})_2]$, $[\text{VO}(\text{pic})_2(\text{H}_2\text{O})]$, and $[\text{VO}(\text{mepic})_2]$, where Hdhp indicates 1,2-dimethyl-3-hydroxy-4(1H)-pyridinone, Hma maltol, Hacac acetylacetonate, Hpic picolinic acid, and Hmepic 6-methylpicolinic acid, were examined. The distribution of VIVO^{2+} among the serum bioligands was calculated from the thermodynamic stability constants in the literature and compared with the experimental results. EPR results, which confirm the prediction, depend on the strength of the ligand L and geometry assumed by the bis-chelated species at physiological pH, cis-octahedral or square pyramidal. With dhp, the strongest chelator, the system is dominated by $[\text{VO}(\text{dhp})_2]$ and/or cis- $\text{VO}(\text{dhp})_2(\text{Protein})$; with intermediate strength chelators, i.e. maltolate, acetylacetonate and picolinate, by cis- $\text{VO}(\text{ma})_2(\text{Protein})$, $[\text{VO}(\text{acac})_2]$ or $[\text{VO}(\text{pic})(\text{citrH}-1)]_3^-/[\text{VO}(\text{pic})(\text{lactH}-1)]^-$ (citr = citrate and lact = lactate) when the V concentration overcomes 100–200 μM and by $(\text{VO})(\text{hTf})/(\text{VO})_2(\text{hTf})$ when concentration is lower than 100 μM ; with the weakest chelator, 6-methylpicolinate, $(\text{VO})(\text{hTf})/(\text{VO})_2(\text{hTf})$, $(\text{VO})(\text{HSA})(\text{hTf})$ (hTf = human serum transferrin and HSA = human serum albumin), and $\text{VO}(\text{mepic})(\text{Protein})(\text{OH})$ are the major species at concentration higher than 100–200 μM , whereas hydrolytic processes are observed for lower concentrations. For $[\text{VO}(\text{dhp})_2]$, $[\text{VO}(\text{ma})_2]$, $[\text{VO}(\text{acac})_2]$ and $[\text{VO}(\text{pic})_2(\text{H}_2\text{O})]$, the EPR spectra remain unaltered with elapsing time, while for mepic they change significantly because the hydrolyzed VIVO species are complexed by the serum bioligands, in particular by lactate. The rate of oxidation in the serum is $[\text{VO}(\text{dhp})_2] > [\text{VO}(\text{ma})_2] > [\text{VO}(\text{acac})_2]$ and reflects the order of $E_{1/2}$ values.

Skalny, A.V., Kaminskaya, G.A., Krekesheva, T.I., et al. (2017) The level of toxic and essential trace elements in hair of petrochemical workers involved in different technological processes. *Environmental Science and Pollution Research*, 24(6): 5576-5584.

Abstract:

The objective of the investigation is comparative analysis of hair trace element content in workers of different departments of petrochemical plant. A total of 75 men working in office

(engineers), and departments 1 (D1), 3 (D3), and 4 (D4) of the petrochemical plant, as well as occupationally non-exposed persons, were examined. Hair trace element levels were analyzed using inductively coupled plasma mass spectrometry. The office workers were characterized by the highest hair As, Hg, Sn, I, and Si content as compared to the workers of other departments, whereas the level of those elements did not differ significantly from the control values. It is notable that hair Be levels in all employees of petrochemical plant were significantly lower, whereas Se content was significantly higher than that in unexposed controls. Hair toxic trace element content in workers directly involved in industrial processes did not differ significantly or was lower than that in the control group. At the same time, the highest levels of essential trace elements (Cr, Fe, and I) were observed in employees working in primary oil refining (D1). Hair levels of Co, I, and Li were maximal in persons of sulfur and bitumen-producing division (D4). The lowest levels of both essential and toxic trace elements in hair were detected in employees involved in production of liquefied gas, kerosene, and diesel fuel (D3). The obtained data demonstrate that involvement in different technological processes in petrochemical complex differentially affect hair trace element content in workers. © 2016 Springer-Verlag Berlin Heidelberg.

Wang, J., Zhou, H., Guo, G., et al. (2017) A functionalized surface modification with vanadium nanoparticles of various valences against implant-associated bloodstream infection. *International Journal of Nanomedicine*, 12: 3121-3136. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5402895/pdf/ijn-12-3121.pdf>

Abstract:

Bloodstream infection, especially with implants involved, is an often life-threatening condition with high mortality rates, imposing a heavy burden on patients and medical systems. Herein, we firstly deposited homogeneous vanadium metal, V₂O₃, VO₂, and V₂O₅ nanofilms on quartz glass by magnetron sputtering. Using these platforms, we further investigated the potential antimicrobial efficiency of these nano-VO_x films and the interactions of human erythrocytes and bacteria (methicillin-resistant *Staphylococcus aureus* and *Pseudomonas aeruginosa*) with our samples in a novel cell-bacteria coculture model. It was demonstrated that these nano-VO_x precipitated favorable antibacterial activity on both bacteria, especially on *S. aureus*, and this effect increased with higher vanadium valence. A possible mechanism accountable for these results might be elevated levels of vanadium-induced intracellular reactive oxygen species. More importantly, based on hemolysis assays, our nano-VO_x films were found to be able to kill prokaryotic cells but were not toxic to mammalian cells, holding the potential for the prevention of implant-related hematogenous infections. As far as we know, this is the first report wherein such nano-VO_x films have assisted human erythrocytes to combat bacteria in a valence-dependent manner. Additionally, vanadium ions were released from these nano-VO_x films in a sustained manner, and low-valence films possessed better biocompatibility with human fibroblasts. This work may provide new insights for biomedical applications of inorganic vanadium compounds and attract growing attention in this field. From the perspective of surface modification and functionalization, this study holds promise to avail the prophylaxis of bloodstream infections involving implantable biomedical devices.

Zhang, X., Cui, X., Lin, C., et al. (2017) Reference levels and relationships of nine elements in first-spot morning urine and 24-h urine from 210 Chinese children. *International Journal of Hygiene and Environmental Health*, 220(2 Part A): 227-234.

Abstract:

Abstract Toxic elements have caused great concern due to their adverse health effects. Biological monitoring is generally considered to be a useful tool to assess human exposure to these elements during risk assessment. To better interpret the biological monitoring data, elemental reference values are critical. The major objectives of this study were to clarify whether first-spot morning urine can serve as a surrogate for 24-h urine and to determine the concentration reference interval of some elements in Chinese children's urine. In total, 259 first-spot morning urine samples and 24-h urine samples were collected from 210 2- to 12-year-old healthy children in China and analyzed for creatinine, aluminum, barium, manganese, titanium, cerium, scandium, vanadium, yttrium, and arsenic. The results showed that the creatinine-adjusted concentrations of aluminum, barium, manganese, titanium, cerium, scandium, vanadium, yttrium, and arsenic in the first-spot urine were

significantly correlated with those in the 24-h urine. This showed that first-spot morning urine is a favored matrix for monitoring element exposure due to its easy collection and low collection cost. The reference interval using ng/mg creatinine as the unit for Chinese children's urine was 1.63–2653 for aluminum, 3.71–116.8 for barium, 0.67–91.77 for titanium, 0.20–53.42 for arsenic, 1.36–25.29 for manganese, 0.24–8.59 for vanadium, 0.02–2.27 for cerium, 0.01–0.65 for yttrium, and 0.002–0.483 for scandium. These reference intervals may provide reference levels to assess Chinese children's exposure to these elements.

2. HEALTH EFFECTS

Adebiyi, O.E., Olopade, J.O. & Olayemi, F.O. (2017) Vanadium-Induced Behavioral and Cognitive Impairments: The Protective Role of *Grewia carpinifolia* Extract. *The Toxicologist: Supplement to Toxicological Sciences*, 15(1): 36. Abstract presented at the 56th Annual Meeting of the Society of Toxicology, Baltimore, Maryland, March 12–16, 2017.

Abstract:

Vanadium (V) has been reported to induce central nervous system toxicity characterized by production of reactive oxygen species causing neurodegeneration and various behavioural impairments. Oil exploration has further led to an increase discharge to the environment. Recently, natural products have been the target for discovery of new pharmaceuticals. This study investigated the possibility of *Grewia carpinifolia* ethanolic extract in preventing behavioural alterations following acute vanadium toxicity. Sixty Swiss mice (25–27 g) were randomized into 5 groups (A–E) of 12 animals each. The control Group A received distilled water, group B; vitamin E (500 mg/kg b.w. every 72 hours), orally along with a daily dose of sodium metavanadate (NaVO₃) i.p. for 7 days, groups C and D; *Grewia carpinifolia* leaf extract at 100 and 200 mg/kg b.w orally respectively along with NaVO₃ i.p. for 7 days while Group E received NaVO₃ i.p. only for 7 days. Behaviour, anxiety, motor function and memory were analysed by the open field, negative geotaxis, hanging wire tests and Morris water maze respectively. Co-treatment with *Grewia carpinifolia* extract significantly reduced the number of grooming, stretched attend posture and freezing time and also enhanced vestibular functions. In addition, time spent on the hanging wire in groups simultaneously administered with the extract and NaVO₃ compared favourably ($\alpha > 0.05$) with the control groups but a decrease in latent time was observed in the NaVO₃ only group. In the Morris water maze, concurrent administration of the extract significantly attenuated spatial learning deficits better than the standard group (α -tocopherol) as indicated by a significant reduction ($\alpha \leq 0.05$) in escape latency in the acquisition trials and a reduction in swimming time in the target quadrant during the probe trial. Thus, *Grewia carpinifolia* may act as a protective agent against acute vanadium-toxicity with a better result at 200 mg/kg b.w.

Furrow, E., McCue, M.E. & Lulich, J.P. (2017) Urinary metals in a spontaneous canine model of calcium oxalate urolithiasis. *Plos One*, 12(5). Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5415176/pdf/pone.0176595.pdf>

Abstract:

Calcium oxalate urolithiasis is a common and painful condition in people. The pathogenesis of this disease is complex and poorly understood. Laboratory animal and in vitro studies have demonstrated an effect of multiple trace metals in the crystallization process, and studies in humans have reported relationships between urinary metal concentrations and stone risk. Dogs are a spontaneous model of calcium oxalate urolithiasis, and the metal content of canine calcium oxalate stones mirrors that of human stones. The aim of this study was to test for a relationship between urinary metals and calcium oxalate urolithiasis in dogs. We hypothesized that urinary metals would differ between dogs with and without calcium oxalate urolithiasis. Urine from 122 dogs (71 cases and 51 stone-free controls) was analyzed for calcium and 12 other metals. The cases had higher urinary calcium, copper, iron, and vanadium and lower urinary cobalt. Higher urinary vanadium in the cases was associated with being fed a therapeutic stone-prevention diet. Urinary calcium had a strong positive correlation with strontium and moderate positive correlations with chromium, nickel, and zinc. The results of this study complement the findings of similar human studies and suggest a potential role of trace metals in calcium oxalate urolithiasis. Further investigation into how trace metals may affect stone formation is warranted. © 2017 Furrow et al. This is

an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Jiang, P., Ni, Z., Wang, B., et al. (2017) Acute toxicity, twenty-eight days repeated dose toxicity and genotoxicity of vanadyl trehalose in kunming mice. *Regulatory Toxicology and Pharmacology*, 85: 86-97.

Abstract:

A new trend has been developed using vanadium and organic ligands to form novel compounds in order to improve the beneficial actions and reduce the toxicity of vanadium compounds. In present study, vanadyl trehalose was explored the oral acute toxicity, 28 days repeated dose toxicity and genotoxicity in Kunming mice. The Median Lethal Dose (LD50) of vanadyl trehalose was revealed to be 1000 mg/kg body weight in fasted Kunming mice. Stomach and intestine were demonstrated to be the main target organs of vanadyl trehalose through 28 days repeated dose toxicity study. And vanadyl trehalose also showed particular genotoxicity through mouse bone marrow micronucleus and mouse sperm malformation assay. In brief, vanadyl trehalose presented certain, but finite toxicity, which may provide experimental basis for the clinical application. (C) 2017 Elsevier Inc. All rights reserved.

Jung, K.H., Torrone, D., Lovinsky-Desir, S., et al. (2017) Short-term exposure to PM2.5 and vanadium and changes in asthma gene DNA methylation and lung function decrements among urban children. *Respiratory Research*, 18(1): 63-017-0550-9. Available at:

<https://respiratory-research.biomedcentral.com/track/pdf/10.1186/s12931-017-0550-9?site=respiratory-research.biomedcentral.com>

Abstract:

BACKGROUND: Both short and long-term exposure to traffic-related air pollutants have been associated with asthma and reduced lung function. We hypothesized that short-term indoor exposure to fine particulate matter <2.5 μm (PM2.5) and vanadium (V) would be associated with altered buccal cell DNA methylation of targeted asthma genes and decreased lung function among urban children in a nested subcohort of African American and Dominican children. **METHODS:** Six day integrated levels of air pollutants were measured from children's homes (age 9-14; n = 163), repeated 6 months later (n = 98). Buccal samples were collected repeatedly during visits. CpG promoter loci of asthma genes (i.e., interleukin 4 (IL4), interferon gamma (IFN γ), inducible nitric oxide synthase (NOS2A), arginase 2 (ARG2)) were pyrosequenced and lung function was assessed. **RESULTS:** Exposure to V, but not PM2.5, was associated with lower DNA methylation of IL4 and IFN γ . In exploratory analyses, V levels were associated with lower methylation of the proinflammatory NOS2A-CpG+5099 among asthmatic overweight or obese children but not nonasthmatics. Short-term exposure to PM2.5, but not V, appeared associated with lower lung function (i.e., reduced z-scores for forced expiratory volume in one second (FEV1, FEV1/forced vital capacity [FEV1/FVC] and forced expiratory flow at 25-75% of FVC [FEF25-75]). **CONCLUSIONS:** Exposure to V was associated with altered DNA methylation of allergic and proinflammatory asthma genes implicated in air pollution related asthma. However, short-term exposure to PM2.5, but not V, appeared associated with decrements in lung function among urban children.

Wilk, A., Wiszniewska, B., Szypulska-Koziarska, D., et al. (2017) The Concentration of Vanadium in Pathologically Altered Human Kidneys. *Biological Trace Element Research*, DOI 10.1007/s12011-017-0986-2. Available at: <https://link.springer.com/content/pdf/10.1007%2Fs12011-017-0986-2.pdf>

Abstract:

Vanadium has a unique and beneficial effect on both humans and animal organisms; however, excessive amount of the above-mentioned metal can cause many alterations in tissues and organs, including the kidneys. The aim of the study was to determine the concentration of vanadium (V) in the kidneys removed from patients due to lesions of various etiologies, including the rejection of the transplanted kidneys. Additionally, we determined

the influence of selected biological and environmental factors on the V concentration. The study material consisted of the kidneys with tumor lesions (n = 27) and extracted kidney grafts (n = 10) obtained from patients from the north-western Poland. The V concentrations were assessed by atomic absorption spectrophotometry emission in inductively coupled argon plasma and expressed in concentrations in dry weight (dw). Statistically significant differences were observed for V concentrations in the renal medulla between the kidneys with tumors and renal grafts, where the lowest concentration of V was observed. The kidneys in more advanced stages of the tumor (T3 + T4) contained more vanadium than the kidneys of T1 + T2 stages and medians were 2.07 and 1.51, respectively. We also compared the V concentration in the kidneys between the renal grafts (K2) and the kidneys with tumor (K1) in two stages of advancement: T1 with T2 (K11 + 2) and T3 with T4 (K13 + 4). Statistically significant differences were noted between the renal medullae of the above-mentioned groups of kidneys. According to the previous studies on the concentrations of other heavy metals, renal grafts accumulate less vanadium than cancerous kidneys, what can be associated with the immunosuppressive drugs taken by patients after the transplantation.

3. BIOLOGICAL MECHANISMS

Cervantes-Yépez, S. & Fortoul Van Der Goes, T.I. (2017) Histological Alterations and in Connexin 43 Expression Induced by the Inhalation of Vanadium Pentoxide in a Mouse Model. *The Toxicologist: Supplement to Toxicological Sciences*, 15(1): 36. Poster presented at the 56th Annual Meeting of the Society of Toxicology, Baltimore, Maryland, March 12–16, 2017. Available at: <https://www.toxicology.org/pubs/docs/Tox/2017Tox.pdf>

Abstract:

Vanadium (V) is a transition metal adhered to suspended particles in the air of cities with high atmospheric pollution such as Mexico City. The eye is directly exposed to the atmosphere, as well as to the elements that enter into lung and further are distributed through the systemic circulation. However, in our murine model of V inhalation, it has been reported Central Nervous System damage induced by V generated oxidative stress. The retina could be an oxidative stress target because of its high metabolic activity, high oxygen consumption, low antioxidant capacity, continuous light exposure and a large surface of phospholipid bilayer. In our model, it has been reported that V decreases connexin 43 (Cx43) expression in various organs as a consequence of oxidative stress and retinal edema has been observed. GAP junctions play a pivotal role in retinal physiology; one of the most abundant connexin is Cx43. Altogether, the findings mentioned above suggest retinal GAP junctions' disruption as a consequence of V inhalation. It was hypothesized that V inhalation would alter the retinal layers organization and Cx43 expression; therefore the objective was to study the effect of V exposure on retinal histology and Cx43 expression and localization. Male CD-1 mice were exposed to V pentoxide [0.02M] inhalation 1 h at 24 h and twice/week for 1, 4 and 8 week time period. It was observed that V inhalation generates disruption in nuclear layers organization, number of nuclei variation and changes in layer's thickness; the anterior region of the retina was affected the most. On the contrary, changes in the ganglionic layer were not noticed. This suggests retinal damage induced by V inhalation is region and layer dependent. Cx43 expression decreased at 24 h, 1 and 4 weeks but at 8 week exposure time, it reached values similar to controls. Given that Cx43 is found in the retina in cell types involved in the blood-retinal barrier, it would be of interest to study the barrier integrity and GAP intercellular communication.

Ryan, L.K. & Diamond, G. (2017) Effects of Vanadium on Innate Immune Responses Induced by Streptococcus pneumonia, Staphylococcus aureus, IL-1-beta, and LPS in Mouse Airway Epithelial Cells. *The Toxicologist: Supplement to Toxicological Sciences*, 15(1): 229. Poster presented at the 56th Annual Meeting of the Society of Toxicology, Baltimore, Maryland, March 12–16, 2017. Available at: <https://www.toxicology.org/pubs/docs/Tox/2017Tox.pdf>

Abstract:

V2O5-containing air pollutant particulates in the lung are extensively studied but the effect on innate immune molecules such as antimicrobial peptides (AMP) remains to be elucidated. AMPs secreted by airway epithelial cells are part of the initial response to inhaled

microorganisms. AMPs, including β -defensins, kill microorganisms and modulate the initial local immune response in the airway. We showed that in vitro, air pollutant particulate matter (ROFA) containing vanadium (VV) inhibited this response in human airway epithelial cells at noncytotoxic levels. Specifically, V2O5 and VOSO4 suppress β -defensin-2 responses to LPS and IL- β in a dose-dependent manner in primary bovine and human airway epithelial cells. We hypothesized that mouse airway epithelial cells would respond similarly. Differentiated primary epithelial cells derived from tracheas (TEC) of C57BL/6 mice (WT), mice lacking the β -defensin-1 gene (KO) and a mouse alveolar type II epithelial cell line (MLE15) were used to model innate immune responses. Triplicate cultures were treated with 10 μ g/ml V2O5 or VOSO4 for 6 hr, washed, then stimulated with medium alone, 100 ng/ml LPS, 100 ng/ml IL-1 β or 1000:1 bacteria:cell for 24 hr. QRT-PCR assessed mBD-3, mBD-14, KC, IL-6 and CCL2 mRNA. In WT and KO mouse TEC, LPS and IL-1 β increased mBD-3 and mBD-14 mRNA, although responses in KO mice were much lower than WT. V2O5 inhibited induction of mBD-14 but not mBD-3 in WT TEC by IL-1 β ; it had no effect on their induction by LPS. V2O5 enhanced LPS-induced mBD-3 but had no effect on LPS-induced mBD-14 in WT TEC. VOSO4 induced mBD-3 and mBD-14, yet inhibited *S. pneumoniae*-induced mBD-3. IL-1 β and *S. aureus*-induced mBD-14 was enhanced by VOSO4, but KC induction was not affected. In KO TEC, V2O5 did not inhibit IL-1 β induction of mBD-3 and mBD-14 but induced mBD-3 and -14 in WT TEC and only mBD-14 in KO TEC. In MLE15 cells, no mBD-3 was expressed and LPS had no effect on mBD-14, but basal levels of mBD-14 were inhibited by V2O5. Thus, mouse and human primary airway epithelium are similar only with respect to V2O5 suppression of IL-1 β -induced β -defensins, whereas the responses of MLE15 cells do not resemble the responses of human A549 cells. In addition, it appears that the mBD-1 gene coordinates with mBD-3 and mBD-14 in innate immunity. (Funded by NIEHS 1R03ES016851 +S1).

Sanchez-Gonzalez, C., Moreno, L., Lopez-Chaves, C., et al. (2017) Effect of vanadium on calcium homeostasis, osteopontin mRNA expression, and bone microarchitecture in diabetic rats. *Metalomics : Integrated Biometal Science*, 9(3): 258-267.

Available

at:

https://www.researchgate.net/profile/Juan_Llopis/publication/313318773_Effect_of_vanadium_on_calcium_homeostasis_osteopontin_mRNA_expression_and_bone_microarchitecture_in_STZ-induced_diabetic_rats/links/58ae9e7945851503be9200bd/Effect-of-vanadium-on-calcium-homeostasis-osteopontin-mRNA-expression-and-bone-microarchitecture-in-STZ-induced-diabetic-rats.pdf

Abstract:

The aim of this study was to examine whether alterations caused by diabetes in calcium homeostasis, expression of osteopontin and the microarchitecture of bone are corrected by exposure to vanadium. Four study groups were examined over a period of five weeks: control (C), diabetic (DM), diabetic treated with 1 mg V per d (DMV), and diabetic treated with 3 mg V per d (DMVH). Vanadium was supplied in drinking water as bis(maltolato)oxovanadium(IV). Calcium was measured in the food, faeces, urine, serum, kidneys, liver, muscles, and femur. Osteopontin gene expression was determined in the liver, and the bone microarchitecture was studied with the aid of micro-computed tomography. In the DM group, food intake as well as calcium absorbed and retained and liver osteopontin mRNA increased, while Ca in the serum and femur decreased, and the bone microarchitecture worsened, in comparison with the control. In the DMV group, the amount of Ca absorbed and retained was similar to DM rats. Although the Ca content in the femur increased and osteopontin mRNA decreased, there were no significant changes in the bone microarchitecture, in comparison to the DM rats. In the DMVH group, the amount of Ca absorbed and retained, and the serum and femur content were equivalent to the control. The levels of osteopontin mRNA decreased and bone mineralization improved, compared to the DM group. We conclude that treatment with 3 mg V per d of the glucose lowering agent bis(maltolato)oxovanadium(IV) causes a decrease in osteopontin mRNA, which could favour the normalization of changes in Ca homeostasis and bone microarchitecture, both at the cortical and trabecular levels, caused by diabetes.

4. USES OF VANADIUM

Basu, A., Bhattacharjee, A., Samanta, A., et al. (2016) An oxovanadium(IV) complex protects murine bone marrow cells against cisplatin-induced myelotoxicity and DNA damage. *Drug and Chemical Toxicology*, 40(3): 359-367.

Abstract:

Cisplatin (CDDP) is one of the first-line anticancer drugs that has gained widespread use against various forms of human malignancies. But, the therapeutic outcome of CDDP therapy is limited due to its adverse effects including myelotoxicity and DNA damage which may lead to the subsequent risk of developing secondary cancer. Hence, in search of a suitable cytoprotectant, this study investigated the probable protective efficacy of an oxovanadium(IV) complex, namely oxovanadium(IV)-L-cysteine methyl ester complex (VC-IV) against CDDP-induced myelosuppression and genotoxic damage in the bone marrow cells of Swiss albino mice. CDDP was administered intraperitoneally (5 mg/kg b.w.) and VC-IV was administered orally (1 mg/kg b.w.) in concomitant and 7 d pretreatment schedule. Treatment with VC-IV in CDDP-treated mice significantly ($p < 0.01$) enhanced bone marrow cell proliferation and inhibited cell death in the bone marrow niche indicating improvement of CDDP-induced myelotoxicity. The organovanadium compound also significantly ($p < 0.01$) reduced the percentage of chromosomal aberrations, the frequency of micronuclei formation, and the extent of DNA damage. The observed chemoprotective effect of VC-IV was attributed to its anti-oxidant efficacy which significantly ($p < 0.01$) attenuated CDDP-induced generation of free radicals, and restored ($p < 0.01$) the levels of oxidized and reduced glutathione. Hence, VC-IV may serve as a promising candidate for future development to decrease the deleterious effects of CDDP in the bone marrow cells of cancer patients and associated secondary complications. © 2016 Informa UK Limited, trading as Taylor & Francis Group.

Basu, A., Bhattacharjee, A., Baral, R., et al. (2017) Vanadium(III)-l-cysteine enhances the sensitivity of murine breast adenocarcinoma cells to cyclophosphamide by promoting apoptosis and blocking angiogenesis. *Tumour Biology: The Journal of the International Society for Oncodevelopmental Biology and Medicine*, 39(5): 1010428317705759.

Abstract:

Various epidemiological and preclinical studies have already established the cancer chemopreventive potential of vanadium-based compounds. In addition to its preventive efficacy, studies have also indicated the abilities of vanadium-based compounds to induce cell death selectively toward malignant cells. Therefore, the objective of the present investigation is to improve the therapeutic efficacy and toxicity profile of an alkylating agent, cyclophosphamide, by the concurrent use of an organovanadium complex, vanadium(III)-l-cysteine. In this study, vanadium(III)-l-cysteine (1 mg/kg body weight, per os) was administered alone as well as in combination with cyclophosphamide (25 mg/kg body weight, intraperitoneal) in concomitant and pretreatment schedule in mice bearing breast adenocarcinoma cells. The results showed that the combination treatment significantly decreased the tumor burden and enhanced survivability of tumor-bearing mice through generation of reactive oxygen species in tumor cells. These ultimately led to DNA damage, depolarization of mitochondrial membrane potential, and apoptosis in tumor cells. Further insight into the molecular pathway disclosed that the combination treatment caused upregulation of p53 and Bax and suppression of Bcl-2 followed by the activation of caspase cascade and poly (ADP-ribose) polymerase cleavage. Administration of vanadium(III)-l-cysteine also resulted in significant attenuation of peritoneal vasculature and sprouting of the blood vessels by decreasing the levels of vascular endothelial growth factor A and matrix metalloproteinase 9 in the ascites fluid of tumor-bearing mice. Furthermore, vanadium(III)-l-cysteine significantly attenuated cyclophosphamide-induced hematopoietic, hepatic, and genetic damages and provided additional survival advantages. Hence, this study suggested that vanadium(III)-l-cysteine may offer potential therapeutic benefit in combination with cyclophosphamide by augmenting anticancer efficacy and diminishing toxicity to the host.

Hong, X-L., Zeng, M-H., Liu, L-J., et al. (2017) Synthesis, characterization and in vitro antitumor behavior of a vanadium(V) complex with 4'-(3-methoxyphenyl)-2,2':6'2"-terpyridine. *Journal of Coordination Chemistry*, 70(8): 1438-1450.

Abstract:

A dioxovanadium(V) complex, [VO₂(moptpy)](ClO₄) (1, moptpy = 4'-(3-methoxyphenyl)2,2':6'2"-terpyridine), was synthesized and characterized by elemental analysis, ESI-MS, UV-vis, IR, and ¹H, ¹³C, and ⁵¹V NMR. The cytotoxicity in vitro of 1 was evaluated against cancer cell lines HepG-2 (hepatocellular carcinoma), SGC-7901 (gastric carcinoma), SiHa (cervical cancer), BEL-7402 (hepatocellular), and rat PC-12 (pheochromocytoma) by the MTT method. The results demonstrated that 1 exhibits superior anticancer activity in vitro with much lower values of 50% inhibitive concentration (IC₅₀) against the selected cell lines than cisplatin, and 1 shows the highest cytotoxic activity toward SGC-7901 cells (IC₅₀ = 1.3 ± 0.1 μM) among the selected cell lines. A series of cellular morphological and staining experiments were carried out, and the results indicated that 1 can effectively induce apoptosis of SGC-7901 cells through a ROS-mediated mitochondrial dysfunction pathway. In addition, cellular incorporation and cell cycle analysis were also performed, and it was concluded from the experimental observations that 1 can efficiently enter into the cell nuclei, and the complex inhibits cell growth in SGC-7901 cell at G₀/G₁ phase. © 2017 Informa UK Limited, trading as Taylor & Francis Group.

Inamdar, P. & Angappan, S. (2017) DNA binding behaviour of mixed ligand vanadium(V) complex based on novel tridentate hydrazone and benzhydroxamic acid ligand systems. *Applied Organometallic Chemistry*, 31(3): UNSP e3573.

Abstract:

Novel tridentate ONO hydrazone ligand (HL) and the corresponding vanadium(V) complex, [VO(HL)(Benz)], based on the ligand and benzhydroxamic acid, were synthesized and characterized using UV-visible, Fourier transform infrared, NMR and mass spectral studies. In order to assess the binding efficacy of the synthesized complex with DNA, UV absorption spectral titrations, fluorescence displacement assays using ethidium bromide and acridine orange dyes, circular dichroism, viscosity and molecular docking studies were carried out. Based on the results obtained, it is evident that the complex shows significant intercalating ability almost comparable to that of the standard intercalator drug cisplatin. The binding affinity values for the [VO(HL)(Benz)] complex and cisplatin were found to be (3.84 ± 0.08) × 10⁴ M⁻¹ and (4.27 ± 0.012) × 10⁴ M⁻¹. In addition, the cytotoxicity of [VO(HL)(Benz)] was also assessed by MTT assay against the MCF-7 cell line.

Kazemi, Z., Amiri Rudbari, H., Mirkhani, V., et al. (2017) Self-recognition of the racemic ligand in the formation of homochiral dinuclear V(V) complex: In vitro anticancer activity, DNA and HSA interaction. *European Journal of Medicinal Chemistry*, 135: 230-240.

Abstract:

The reaction of a racemic mixture of Schiff base tridentate ligand with vanadium(V) affords homochiral vanadium complex, (VO(R-L))₂O and (VO(S-L))₂O due to ligand "self-recognition" process. The formation of homochiral vanadium complex was confirmed by ¹H NMR, ¹³C NMR and X-ray diffraction. The HSA- and DNA-binding of the resultant complex is assessed by absorption, fluorescence and circular dichroism (CD) spectroscopy methods. Based on the results, the HSA- and DNA-binding constant, K_b, were found to be 8.0 × 10⁴ and 1.9 × 10⁵ M⁻¹, respectively. Interestingly, in vitro cytotoxicity assay revealed the potent anticancer activity of this complex on two prevalent cancer cell lines of MCF-7 (IC₅₀ value of 14 μM) and HeLa (IC₅₀ value of 36 μM), with considerably low toxicity on normal human fibroblast cells. The maximum cell mortality of 12.3% obtained after 48 h incubation of fibroblast cells with 100 μM of the complex. Additionally, the specific DNA- and HSA-binding was also shown using molecular docking method. The synthesized complex displayed high potential for biomedical applications especially for development of novel and efficient anticancer agents.

Kazemi, Z., Amiri Rudbari, H., Mirkhani, V., et al. (2017) Self-recognition of the racemic ligand in the formation of homochiral dinuclear V(V) complex: In vitro anticancer activity, DNA and HSA interaction. *European Journal of Medicinal Chemistry*, 135: 230-240.

Abstract:

The reaction of a racemic mixture of Schiff base tridentate ligand with vanadium(V) affords homochiral vanadium complex, (VO(R-L))₂O and (VO(S-L))₂O due to ligand "self-

recognition" process. The formation of homochiral vanadium complex was confirmed by ^1H NMR, ^{13}C NMR and X-ray diffraction. The HSA- and DNA-binding of the resultant complex is assessed by absorption, fluorescence and circular dichroism (CD) spectroscopy methods. Based on the results, the HSA- and DNA-binding constant, K_b , were found to be 8.0×10^4 and $1.9 \times 10^5 \text{ M}^{-1}$, respectively. Interestingly, *in vitro* cytotoxicity assay revealed the potent anticancer activity of this complex on two prevalent cancer cell lines of MCF-7 (IC₅₀ value of 14 μM) and HeLa (IC₅₀ value of 36 μM), with considerably low toxicity on normal human fibroblast cells. The maximum cell mortality of 12.3% obtained after 48 h incubation of fibroblast cells with 100 μM of the complex. Additionally, the specific DNA- and HSA-binding was also shown using molecular docking method. The synthesized complex displayed high potential for biomedical applications especially for development of novel and efficient anticancer agents.

Kumar, A., Pant, I., Dixit, A., et al. (2017) Terpyridyl oxovanadium(IV) complexes for DNA crosslinking and mito-targeted photocytotoxicity. *Journal of Inorganic Biochemistry*, 174: 45-54.

Abstract:

Oxovanadium(IV) complexes $[\text{VO}(\text{L}_1/\text{L}_2)\text{Cl}_2]_n + (1,2)$ of (anthracenyl)terpyridine (An-tpy as L1 in 1, $n = 0$) and triphenylphosphonium-appended (anthracenyl)terpyridine (An-tpy-TPP+ as L2 in 2, $n = 1$) were synthesized, characterized and their DNA crosslinking ability, photocytotoxicity in visible light and cellular localization in cancer cells studied. The bromide derivative of 2, viz. $[\text{VO}(\text{An-tpy-TPP})\text{Br}_2]\text{Br}$ (3) is structurally characterized. The structure showed trans disposition of two halides in the coordination sphere and the TPP+ unit is a pendant to the terpyridyl ligand. The DNA melting and comet assay studies on the complexes suggest the formation of DNA crosslinks. Complexes 1 and 2 displayed ~ 10 fold increase in cytotoxicity on exposure to visible light (400–700 nm) when compared to those in dark in HeLa and MCF-7 cells. FACScan (Fluorescence Associated Cell Sorter Scan) analysis showed cellular apoptosis when treated with the complex in visible light in comparison to their dark controls. Fluorescence microscopic studies using complex 2 revealed its mitochondrial localization within the cancer cells.

Mal, S.K., Chattopadhyay, T., Fathima, A., et al. (2017) Synthesis and structural characterization of a vanadium(V)-pyridylbenzimidazole complex: DNA binding and anticancer activity. *Polyhedron*, 126: 23-27.

Abstract:

Synthesis and structural characterization of a new pyridylimidazole based vanadyl compound $[\text{VO}_2(\text{L})(\text{L}^-)]$ (1) [$\text{L} = 2$ -(2-pyridyl)benzimidazole] (1) are reported. It crystallizes in $P 1 -$ space group. The molecular geometry of 1 around vanadium(V) is found to be distorted octahedron. 1 interacts with DNA in an intercalative fashion. Hypochromism of the absorption band of the complex with increasing concentration of DNA and the steady increase in DNA viscosity with increasing concentration of 1 indicates intercalative mode of binding. The binding constant is calculated as $2.76 \times 10^5 \text{ M}^{-1}$. 1 also shows cytotoxicity against human breast cancer, human lung cancer and human keratinocyte cancer cell lines.

Nahari, G., Reyman, L., Vendier, L., et al. (2017) Cytotoxic Vanadium Complexes of Branched [ONNO]-Type Diamine Bis(phenolato) Ligands. *European Journal of Inorganic Chemistry*, (12): 1807-1811.

Abstract:

Vanadium complexes are attractive potential alternatives to platinum-based anticancer drugs. Two vanadium(V) complexes, based on a common chelating tetradentate diaminebis(phenolato) ligand featuring a branched connectivity but differing in their labile ligands, were synthesized and characterized. Whereas the isopropoxido complex was obtained as a mixture of cis and trans isomers with regard to the orientation of the labile group vs. the amine sidearm, the salicylato-containing complex was obtained as a single trans isomer. X-ray structures of the complexes featured octahedral geometry for both. The two complexes exhibited high cytotoxic activity toward different cancer cells, often higher than that of cisplatin, including toward cisplatin-resistant ovarian cancer cells. These complexes demonstrated rapid hydrolysis, releasing the labile ligand within several minutes, with no indications of release of free chelating ligand after water exposure, suggesting that polynuclear hydrolysis products are involved in the cellular activity.

Niu, X., Xiao, R., Wang, N., et al. (2016) The Molecular Mechanisms and Rational Design of Anti-Diabetic Vanadium Compounds. *Current Topics in Medicinal Chemistry*, 16(8): 811-822.

Abstract:

Vanadium compounds are promising anti-diabetic agents. Although BEOV was not able to succeed in phase II clinical trial, great progresses have been made in the past three decades on the discovery and development of anti-diabetic vanadium compounds. A vast of knowledge has been obtained on the molecular mechanisms of both the pharmacological and toxicological effects of vanadium complexes. It has been revealed that vanadium compounds exert insulin enhancement effects and cell protection via a multiple mechanism involving inhibition of PTP1B, activation of PPARs- AMPK signaling, regulation of unfolded protein responses (UPRs), and stimulation of antioxidant enzymes, while vanadium-induced oxidative stress and inflammatory response could primarily be attributed to vanadium toxicity. Based on the present results concerning the relationship between structures, biological activities and biochemical properties, the rationale for future design of anti-diabetic vanadium compounds has been discussed.

Rozzo, C., Sanna, D., Garribba, E., et al. (2017) Antitumoral effect of vanadium compounds in malignant melanoma cell lines. *Journal of Inorganic Biochemistry*, 174: 14-24.

Abstract:

In this study we evaluated the anticancer activity against malignant melanoma (MM) of four different vanadium species: the inorganic anion vanadate(V) (indicated with VN), and three oxidovanadium(IV) complexes, [VIVO(dhp)₂] where dhp⁻ is the anion 1,2-dimethyl-3-hydroxy-4(1H)-pyridinonate (indicated with VS2), [VIVO(mpp)₂] where mpp⁻ is 1-methyl-3-hydroxy-4(1H)-pyridinonate (indicated with VS3), and [VIVO(ppp)₂] where ppp⁻ is 1-phenyl-2-methyl-3-hydroxy-4(1H)-pyridinonate (indicated with VS4). The antitumor effects of these compounds were studied against two different MM cell lines (A375 and CN-mel) and a fibroblast cell line (BJ) as normal control. All tested V compounds exert antiproliferative activity on MM cells in a dose dependent manner (IC₅₀ ranges from 2.4 μM up to 14 μM) being A375 the most sensitive cell line. VN and VS2 were the two most active compounds against A375 (IC₅₀ of 4.7 and 2.6 μM, respectively), causing apoptosis and cell cycle block. The experimental data indicate that the cell cycle arrest occurs at different phases for the two V species analyzed (G2 checkpoint for VN and G0/G1 for VS2), showing the importance of the chemical form in determining their mechanism of action. These results add more insights into the landscape of vanadium versatility in biological systems and into its role as a potential cancer therapeutic agent.

Sinha, A., Banerjee, K., Banerjee, A., et al. (2017) Induction of apoptosis in human colorectal cancer cell line, HCT-116 by a vanadium- Schiff base complex. *Biomedicine & Pharmacotherapy*, 92: 509-518.

Abstract:

Vanadium compounds are well known for their therapeutic interventions against several diseases. Various biochemical attributes of vanadium complexes inspired us to evaluate the cancer cell killing efficacy of the vanadium complex, viz., vanadyl N-(2-hydroxyacetophenone) glycinate [VO(NG)₂]. Previously we showed that VO(NG)₂ is an effective anticancer agent in in vitro and in vivo cancer models and imposed miniscule side effects. Herein we report that VO(NG)₂ is significantly cytotoxic to various cancer cell lines. Furthermore, this redox active vanadyl complex altered the redox homeostasis of many human cancer cell lines significantly. VO(NG)₂ actuates programmed cell death in human colorectal carcinoma cells(HCT-116) through mitochondrial outer membrane permeabilization but in caspase independent manner, possibly by altering cellular redox status and by inflicting DNA damage. Thus, the present work is an attempt to provide many evidences regarding the potent and selective chemotherapeutic efficacy of the novel VO(NG)₂.

Tesmar, A., Wyrzykowski, D., Kruszyński, R., et al. (2017) Characterization and cytotoxic effect of aqua-(2,2',2''-nitriлотriacetato)-oxo-vanadium salts on human osteosarcoma cells. *Biometals*, 30(2): 261-275. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5352783/pdf/10534_2017_Article_1.pdf

Abstract:

The use of protonated N-heterocyclic compound, i.e. 2,2'-bipyridinium cation, [bpyH⁺], enabled to obtain the new nitrilotriacetate oxidovanadium(IV) salt of the stoichiometry [bpyH][VO(nta)(H₂O)]H₂O. The X-ray measurements have revealed that the compound comprises the discrete mononuclear [VO(nta)(H₂O)]⁻ coordination ion that can be rarely found among other known compounds containing nitrilotriacetate oxidovanadium(IV) moieties. The antitumor activity of [bpyH][VO(nta)(H₂O)]H₂O and its phenanthroline analogue, [phenH][VO(nta)(H₂O)](H₂O)_{0.5}, towards human osteosarcoma cell lines (MG-63 and HOS) has been assessed (the LDH and BrdU tests) and referred to cis-Pt(NH₃)₂Cl₂ (used as a positive control). The compounds exert a stronger cytotoxic effect on MG-63 and HOS cells than in untransformed human osteoblast cell line. Thus, the [VO(nta)(H₂O)]⁻-containing coordination compounds can be considered as possible antitumor agents in the osteosarcoma model of bone-related cells in culture. © 2017 The Author(s).

Velescu, B.S., Anuta, V., Aldea, A., et al. (2017) Evaluation of Protective Effects of Quercetin and Vanadyl Sulphate in Alloxan Induced Diabetes Model. *Farmacia*, 65(2): 200-206.

Abstract:

Various vanadium compounds demonstrated decreasing blood sugar levels in different diabetes animal models, and are considered to be promising antidiabetic agents. Oxovanadium(IV) complexes with flavonoid ligands, with beneficial effects in diabetic pathology, like the complex di- μ -hydroxobis(quercetinatooxovanadium)(IV), proved to decrease the elevated blood sugar levels and the total cholesterol, without impact on the insulin levels in alloxan induced diabetic rats. The aim of the study was to evaluate the effect of quercetin and vanadyl sulphate on rats exposed to alloxan, as diabetogenic agent. The rats' treatment consisted in daily oral administered doses of 0.01 mmol/kg b.w. of vanadyl sulphate, 0.02 mmol/kg b.w. of quercetin and respectively 0.01/0.02 mmol/kg b.w. of vanadyl sulphate - quercetin mixture, over a 4 weeks period. The experimental results pointed out protective effects of quercetin and vanadyl sulphate in alloxan exposed rats on the induced diabetic onset, rats' glycaemia and impaired lipid metabolism.

Wu, J.X., Hong, Y.H. & Yang, X.G. (2016) Bis(acetylacetonato)-oxidovanadium(IV) and sodium metavanadate inhibit cell proliferation via ROS-induced sustained MAPK/ERK activation but with elevated AKT activity in human pancreatic cancer AsPC-1 cells. *Journal of Biological Inorganic Chemistry : JBIC : A Publication of the Society of Biological Inorganic Chemistry*, 21(8): 919-929.

Abstract:

In this study, the antiproliferative effect of bis(acetylacetonato)-oxidovanadium(IV) and sodium metavanadate and the underlying mechanisms were investigated in human pancreatic cancer cell line AsPC-1. The results showed that both exhibited an antiproliferative effect through inducing G2/M cell cycle arrest and can also cause elevation of reactive oxygen species (ROS) levels in cells. Moreover, the two vanadium compounds induced the activation of both PI3K/AKT and MAPK/ERK signaling pathways dose- and time-dependently, which could be counteracted with the antioxidant N-acetylcysteine. In the presence of MEK-1 inhibitor, the degradation of Cdc25C, inactivation of Cdc2 and accumulation of p21 were relieved. However, the treatment of AKT inhibitor did not cause any significant effect. Therefore, it demonstrated that the ROS-induced sustained MAPK/ERK activation rather than AKT contributed to vanadium compounds-induced G2/M cell cycle arrest. The current results also exhibited that the two vanadium compounds did not induce a sustained increase of ROS generation, but the level of ROS reached a plateau instead. The results revealed that an intracellular feedback loop may be against the elevated ROS level induced by vanadate or VO(acac)₂, evidenced by the increased GSH content, the unchanged level at the expression of antioxidant enzymes. Therefore, vanadium compounds can be regarded as a novel type of anticancer drugs through the prolonged activation of MAPK/ERK pathway but retained AKT activity. The present results provided a proof-of-concept evidence that vanadium-based compounds may have the potential as both antidiabetic and antipancreatic cancer agents to prevent or treat patients suffering from both diseases.

5. ENVIRONMENTAL EFFECTS in PLANTS and SOIL

Cao, X., Diao, M., Zhang, B., et al. (2017) Spatial distribution of vanadium and microbial community responses in surface soil of Panzihua mining and smelting area, China. *Chemosphere*, 183: 9-17.

Abstract:

Spatial distribution of vanadium in surface soils from different processing stages of vanadium-bearing titanomagnetite in Panzihua mining and smelting area (China) as well as responses of microbial communities including bacteria and fungi to vanadium were investigated by fieldwork and laboratory incubation experiment. The vanadium contents in this region ranged from 149.3 to 4793.6 mg kg⁻¹, exceeding the soil background value of vanadium in China (82 mg kg⁻¹) largely. High-throughput DNA sequencing results showed bacterial communities from different manufacturing locations were quite diverse, but Bacteroidetes and Proteobacteria were abundant in all samples. The contents of organic matter, available P, available S and vanadium had great influences on the structures of bacterial communities in soils. Bacterial communities converged to similar structure after long-term (240 d) cultivation with vanadium containing medium, dominating by bacteria which can tolerate or reduce toxicities of heavy metals. Fungal diversities decreased after cultivation, but Ascomycota and Ciliophora were still the most abundant phyla as in the original soil samples. Results in this study emphasize the urgency of investigating vanadium contaminations in soils and provide valuable information on how vanadium contamination influences bacterial and fungal communities.

Du, C., Liu, E., Chen, N., et al. (2017) Factorial kriging analysis and pollution evaluation of potentially toxic elements in soils in a phosphorus-rich area, South Central China. *Journal of Geochemical Exploration*, 175: 138-147.

Abstract:

Identifying spatial variations of potentially toxic elements at different spatial scales and their contamination conditions is important for soil management and remediation. Utilizing a 1 km × 1 km sampling grid, a total of 615 soil samples were collected from a phosphorus-rich area of South Central China and determined for arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), vanadium (V), and zinc (Zn) concentrations. Factorial kriging analysis (FKA), enrichment factor (EF), and potential ecological risk (RI) were used to examine scale-dependent correlations between the elements, identify factors of multi-scale spatial variations, and assess pollution status, respectively. The results indicate that only the mean concentrations of As, Cd, and Pb exceeded the background levels. Based on EF method, the pollution levels of As, Cd, and Pb were assessed as middle or high, and according to the RI values, 11.2% of the study area was under considerable potential ecological risk. Through linear model of co-regionalization (LMC) fitting, spatial multi-scale variations of elements could be modeled as the sum of a nugget effect, an exponential structure (3 km), and a spherical structure (15 km). At the short-range scale, spatial variations of Co, Cr, Cu, Ni, and V were controlled by parent materials, whereas that of As, Pb, Cd, and Zn were related to human influence, such as phosphorus-related industrial activities and river pollution. At the long-range scale, parent materials were the dominant factors regulating the spatial variations of all elements.

Nickel, S., Schröder, W., Wosniok, W., et al. (2017) Modelling and mapping heavy metal and nitrogen concentrations in moss in 2010 throughout Europe by applying Random Forests models. *Atmospheric Environment*, 156: 146-159.

Abstract:

Objective: This study explores the statistical relations between the concentration of nine heavy metals (HM) (arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), vanadium (V), zinc (Zn)), and nitrogen (N) in moss and potential explanatory variables (predictors) which were then used for mapping spatial patterns across Europe. Based on moss specimens collected in 2010 throughout Europe, the statistical relation between a set of potential predictors (such as the atmospheric deposition calculated by use of two chemical transport models (CTM), distance from emission sources, density of different land uses, population density, elevation, precipitation, clay content of soils) and concentrations of HMs and nitrogen (N) in moss (response variables) were evaluated by the use of Random Forests (RF) and Classification and Regression Trees (CART). Four spatial

scales were regarded: Europe as a whole, ecological land classes covering Europe, single countries participating in the European Moss Survey (EMS), and moss species at sampling sites. Spatial patterns were estimated by applying a series of RF models on data on potential predictors covering Europe. Statistical values and resulting maps were used to investigate to what extent the models are specific for countries, units of the Ecological Land Classification of Europe (ELCE), and moss species. Results: Land use, atmospheric deposition and distance to technical emission sources mainly influence the element concentration in moss. The explanatory power of calculated RF models varies according to elements measured in moss specimens, country, ecological land class, and moss species. Measured and predicted medians of element concentrations agree fairly well while minima and maxima show considerable differences. The European maps derived from the RF models provide smoothed surfaces of element concentrations (As, Cd, Cr, Cu, N, Ni, Pb, Hg, V, Zn), each explained by a multivariate RF model and verified by CART, and thereby more information than the dot maps depicting the spatial patterns of measured values. Conclusions: RF is an eligible method identifying and ranking boundary conditions of element concentrations in moss and related mapping including the influence of the environmental factors.

6. ENVIRONMENTAL EFFECTS in TERRESTRIAL ORGANISMS

Wang, J.P., He, K.R., Ding, X.M., et al. (2017) Effect of Feeding and Withdrawal of Vanadium and Vitamin C on Egg Quality and Vanadium Residual Over Time in Laying Hens. *Biological Trace Element Research*, 177(2): 367-375.

Abstract:

This experiment examined the egg quality of hens fed vanadium (V) and vitamin C (VC) during storage, as well as the V and VC withdrawal on egg quality and V residual in egg. A total of 360 laying hens (31 weeks old) were randomly allotted into a 3 x 2 factorial arrangement treatments (6 replicates and 10 chicks per replicate) with three levels of dietary V (0, 5, and 10 mg/kg) and two levels of VC (0 and 100 mg/kg) for 19 weeks (feeding V and VC 12 weeks, recovery 7 weeks). The V residual in eggs at 4, 8, and 12th weeks were increased (linear effect, $P \leq 0.01$) as V levels increased and was not detected in albumen at 7th week after V withdrawal. Followed by 12-week feeding period, albumen height and Haugh unit of eggs during 2-week storage were decreased (linear and quadratic effect, $P < 0.01$) by dietary V supplementation. Lightness value was increased (linear effect, $P < 0.01$), whereas redness and yellowness value of the eggshell were lowered (linear effect, $P < 0.01$) in V-containing diet. During 7-week withdrawal period, eggs from groups pre-feeding 5 and 10 mg/kg V had lower (linear effect, $P < 0.01$) overall albumen height and Haugh unit. The reducing effect on albumen height and HU continued to be observed until the seventh week, whereas the bleaching effect on eggshell color disappeared after 1-week withdrawal. The results indicated that feeding 5 or 10 mg/kg V increases egg V residual and reduces egg albumen quality and bleached the shell color, and the impaired albumen quality induced by 10 mg/kg of V lasted at least 6 weeks after changing to no V supplementation diet. The addition of VC did not show to affect egg quality during storage or recovery phase.

7. ENVIRONMENTAL EFFECTS in AQUATIC ORGANISMS

ISLAM, M.K., BISWAS, F.B., RIPON, R.I., et al. (2017) Oxidation of Vanadium(III) to Vanadium(IV) by Thioredoxin and L-Serine Contemplating the in vitro Redox Behavior of Vanadium in the Vanadocyte of Ascidians. *Asian Journal of Chemistry*, 29(2): 403-408.

Abstract:

Ascidians are known to accumulate high levels of vanadium from sea water, in their blood cells, called vanadocytes. To evaluate the fact the total accumulation process of vanadium by ascidians are redox or not, and to justify the subsistence of trace extent of whethervanadium(IV) with large extent of vanadium(III) in the vanadocyte of ascidians. The

oxidation behaviour of vanadium(III) to vanadium(IV) followed by series of amino acids and thioredoxin were investigated. UV-visible and electron spin resonance (ESR) spectroscopy revealed that thioredoxin and only serine (L-Ser) assist very fast oxidation having adoption the physiological pH (4.0-5.5) region relevant to vanadocyte. Specially, amino acids favour the oxidation of vanadium(III) which have the low stability constant with vanadium(III) and larger stability constant with vanadium(IV), i.e., $\log K_1$ and $\log K_2 > 10$. ABSTRACT FROM AUTHOR]; Copyright of Asian Journal of Chemistry is the property of Asian Journal of Chemistry and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use. This abstract may be abridged. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material for the full abstract. (Copyright applies to all Abstracts.).

Ogunola, O.S., Onada, O.A. & Falaye, A.E. (2017) Ecological Risk Evaluation of Biological and Geochemical Trace Metals in Okrika Estuary. *International Journal of Environmental Research*, 11(2): 149-173.

Abstract:

Concentrations of heavy metals, aluminium (Al), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), vanadium (V) and zinc (Zn) were analysed in the tissues of two estuarine fish species; Tilapia (*Sarotherodon melanotheron*) and silver catfish (*Chrysichthys nigrodigitatus*) and also in the surface sediments from Okrika estuary in the Niger Delta area of Nigeria. The sampling was conveyed in two seasons, October/November, 2015 and January/February, 2016, representing the climax of both wet and dry seasons, respectively. The levels of the metals in the fish species and surface sediments were analysed by inductively coupled plasma-atomic emission spectroscopy (ICP-AES). The sequence of the metal accumulations in Tilapia was; Fe > Al > Zn > Cu > Cr > V > Ni, in silver catfish; Fe > Al > Zn > Cu > Cr > Ni > V and for sediment; Al > Fe > Zn > Cr > V > Ni > Cu. Levels of the metals in the fish species and sediment were higher than the international permissible limits based on the criteria or application of relevant pollution indices and standards. This indicates that the two fish species were not fit for human consumption. A two-way analysis of variance was used to test the difference in metal concentrations in the fish tissues and sediment. Mean differences were separated by the use of t test. Although, some degree of pollution was found in the reference or control site because Niger-Delta is strongly localised and congested with oil-refining and other industrial activities thereby making it difficult to get a clean estuary. In comparison to the metal accumulations in the tissues of the fish species from oil-impacted creeks (Ekerekana, Okari and Ogoloma) and less oil-impacted counterpart (control site), higher levels ($p < 0.05$) of the metals were observed in the impacted than the less impacted creek. For most of the metals, *S. melanotheron* had higher concentrations than the *C. nigrodigitatus*. Seasonal variations reflected that there was higher accumulation of the metals in the two fish species in the rainy season than the dry season. For sediment, there was significant difference for most of the metals between these two creeks except for Al. The multivariate tools of principal component analysis, Pearson correlation analysis and the use of vanadium/nickel ratio were used to confirm the possible source of the metals in the environmental matrices from oil pollution. Therefore, it is mandatory and expedient to ensure regular monitoring of the trace element loadings in these creeks and to take appropriate measures to alleviate the incident to safeguard the health of the public. © 2017, University of Tehran.

Telfeyan, K., Breaux, A., Kim, J., et al. (2017) Arsenic, vanadium, iron, and manganese biogeochemistry in a deltaic wetland, southern Louisiana, USA. *Marine Chemistry*, 192: 32-48.

Abstract: Geochemical cycling of the redox-sensitive trace elements arsenic (As) and vanadium (V) was examined in shallow pore waters from a marsh in an inter-distributary embayment of the lower Mississippi River Delta. In particular, we explore how redox changes with depth and distance from the Mississippi River affect As and V cycling in the marsh pore waters. Previous geophysical surveys and radon mass balance calculations suggested that Myrtle Grove Canal and the bordering marsh receive fresh groundwater, derived in large part from seepage of the Mississippi River, which subsequently mixes with brackish waters of Barataria Bay. Additionally, the redox geochemistry of pore waters in the wetlands is affected by Fe and S cycling in the shallow subsurface (0–20 cm). Sediments with high organic matter content undergo SO_4^{2-} reduction, a process ubiquitous in the shallow

subsurface but largely absent at greater depths (~ 3 m). Instead, at depth, in the absence of organic-rich sediments, Fe concentrations are elevated, suggesting that reduction of Fe(III) oxides/oxyhydroxides buffers redox conditions. Arsenic and V cycling in the shallow subsurface are decoupled from their behavior at depth, where both V and As appear to be removed from solution by either diffusion or adsorption onto, or co-precipitation with, authigenic minerals within the deeper aquifer sediments. Pore water As concentrations are greatest in the shallow subsurface (e.g., up to 315 nmol kg⁻¹ in the top ~ 20 cm of the sediment) but decrease with depth, reaching values < 30 nmol kg⁻¹ at depths between 3 and 4 m. Vanadium concentrations appear to be tightly coupled to Fe cycling in the shallow subsurface, but at depth, V may be adsorbed to clay or sedimentary organic matter (SOM). Diffusive fluxes are calculated to examine the export of trace elements from the shallow marsh pore waters to the overlying canal water that floods the marsh. The computed fluxes suggest that the shallow sediment serves as a source of Fe, Mn, and As to the surface waters, whereas the sediments act as a sink for V. Iron and Mn fluxes are substantial, ranging from 50 to 30,000 and 770 to 4300 nmol cm⁻² yr⁻¹, respectively, whereas As fluxes are much less, ranging from 2.1 to 17 nmol cm⁻² yr⁻¹. Vanadium fluxes range from 3.0 nmol cm⁻² yr⁻¹ directed into the sediment to 1.7 nmol cm⁻² yr⁻¹ directed out of the sediment.

8. MISCELLANEOUS

Alagappan, L.P., Shanmugasundaram, P., Ramachandra, B.L., et al. (2017) Fabrication of electrochemical biosensor with vanadium pentoxide nano-interface for the detection of methylglyoxal in rice. *Analytical Biochemistry*, 528: 19-25.

Abstract:

Increased consumption of raw and par-boiled rice results in the formation of methylglyoxal (MG) at higher concentration and leads to complications in diabetic patients. Highly sensitive electrochemical biosensor was developed using glutathione (GSH) as a co-factor with vanadium pentoxide (V₂O₅) as a nano-interface for MG detection in rice samples. The Pt/V₂O₅/GSH/Chitosan bioelectrode displayed two well-defined redox peaks in its cyclic voltammograms for MG reduction. This occurred as two electron transfer process where MG gained two electrons from oxidized glutathione disulfide and formed hemithioacetal. The current density response of the fabricated bioelectrode was linear towards MG in the concentration range of 0.1–100 μM with the correlation coefficient of 0.99, sensitivity of 1130.86 μA cm⁻² μM⁻¹, limit of detection of 2 nM and response time of less than 18 s. The developed bioelectrode was used for the detection of MG in raw and par-boiled rice samples.

Dhungana, N., Morris, C. & Krasowski, M.D. (2017) Operational impact of using a vanadate oxidase method for direct bilirubin measurements at an academic medical center clinical laboratory. *Practical Laboratory Medicine*, 8: 77-85. Available at: http://ac.els-cdn.com/S2352551716300610/1-s2.0-S2352551716300610-main.pdf?_tid=fb563ce8-52a7-11e7-9d31-00000aacb361&acdnat=1497626888_c8c5fa24660bb0bdf616b797aa544b4f

Abstract:

The aim of this study was to compare the operational impact of using vanadate oxidase versus diazo direct bilirubin assays for an academic medical center patient population. Design and methods Retrospective study was done over an approximately 3.5 year period. The main automated chemistry instrumentation was a Roche Diagnostics cobas 8000 line. The Roche Direct Bilirubin assay was compared to Diazyme Laboratories Direct Bilirubin Assay and Randox Laboratories Direct Bilirubin assay using manufacturer's guidelines for hemolysis index, lipemia index, and analytical measurement range (AMR). Results Retrospective data was analyzed for 47,333 serum/plasma specimens that had clinical orders for direct bilirubin. A total of 5943 specimens (12.6%) exceeded the hemolysis index limit for the Roche method compared to only 0.2% and 0.05% of specimens for the Diazyme and Randox methods, respectively. The impact was particularly large on patients less than 2 years old, for which 51.3% of specimens exceeded the hemolysis index for the Roche method. A total of 1671 specimens (3.5%) exceeded the lipemia index limit for the Roche method compared to less than 0.1% for the Randox method. Lastly, 988 (2.1%) of specimens had direct bilirubin concentrations exceeding the upper AMR limit of 10 mg/dL

[171 µmol/L] for the Roche assay compared to less than 1% of specimens for the vanadate oxidase methods. Conclusions Vanadate oxidase direct bilirubin methods offer advantages over diazo methods in terms of less interference by hemolysis and lipemia, as well as wider AMR. The advantages are particularly evident for neonatal and infant populations.

Fierros-Romero, G., Wrosek-Cabrera, J.A., Gomez-Ramirez, M., et al. (2017) Expression Changes in Metal-Resistance Genes in *Microbacterium liquefaciens* Under Nickel and Vanadium Exposure. *Current Microbiology*, 74(7): 840-847.

Abstract:

Microbacterium liquefaciens MNSH2-PHGII-2 is a nickel-vanadium-resistant bacterium isolated from mine tailings located in Guanajuato, Mexico. In PHGII liquid media, *M. liquefaciens* has the ability to remove 29.5 ppm of Ni and 168.3 ppm of V. The present study reports, for the first time in *M. liquefaciens*, the presence of the genes *nccA* (Ni-Co-Cd resistance), *hant* (high-affinity nickel transporter), *smtA*, a metal-binding protein gene, and *VAN2* (V resistance), which showed an increased expression under exposure to 200 ppm of Ni and 200 ppm of V during the logarithmic growth phase of the microorganism in PHGII liquid media. Data about the expression profile of genes conferring metal resistance to *M. liquefaciens* can improve the knowledge of those mechanisms involved in the processes of Ni-V resistance and probably in Ni-V removal processes. Based on our data, we can suggest that *M. liquefaciens* has the potential to be used in the biological treatment of toxic wastes with high Ni and V content.

Nesbitt, J.A. & Lindsay, M.B. (2017) Vanadium Geochemistry of Oil Sands Fluid Petroleum Coke. *Environmental Science & Technology*, 51(5): 3102-3109.

Abstract:

Vanadium has previously been linked to elevated toxicity of leachates derived from oil sands petroleum coke. However, geochemical controls on V mobility within coke deposits remain poorly constrained. Detailed examinations of pore-water and solid-phase V geochemistry were, therefore, performed on oil sands fluid petroleum coke deposits in Alberta, Canada. Sample collection focused on both active and reclaimed deposits, which contained more than 3 x 10⁷ m³ of fluid petroleum coke. Dissolved V concentrations were highest (up to 3.0 mg L⁻¹) immediately below the water table, but decreased rapidly with increasing depth. This trend corresponded to a transition from mildly acidic (pH 6-7) and oxic conditions to mildly alkaline (pH 7-8.5) and anoxic conditions. Scanning electron microscopy (SEM), electron microprobe analysis (EMPA) and micro-X-ray fluorescence (microXRF) mapping revealed coke particles exhibited an internal structure characterized by successive concentric layers. The outer margins of these layers were characterized by elevated V, Fe, Si, and Al concentrations, indicating the presence of inorganic phases. Micro-X-ray absorption near-edge structure (µXANES) spectroscopy revealed that V speciation was dominated by V(IV) porphyrins except at outer margins of layers, where octahedrally-coordinated V(III) was a major component. Minor to trace V(V) was also detected within fluid petroleum coke particles.

Zhao, Y., Zeng, F., Liang, H., et al. (2017) Chromium and vanadium bearing nanominerals and ultra-fine particles in a super-high-organic-sulfur coal from Ganhe coalmine, Yanshan Coalfield, Yunnan, China. *Fuel*, 203: 832-842.

Abstract:

The Late Permian coal of the Ganhe coalmine (Ganhe coal) from Yanshan coalfield, Yunnan, southwestern China, is a super-high-organic-sulfur (SHOS) coal that has a total sulfur content of 9.3–12.4% (dry basis) and an organic sulfur content of 7.4–10.5% (dry basis). Compared with average trace elemental abundances of ordinary Chinese coals and worldwide hard coals, the Ganhe coal is remarkably rich in chromium (Cr, 389 µg/g) and vanadium (V, 554 µg/g) (on the whole coal basis), which show negative correlations with ash yield. The result from statistical analysis seems to imply predominately the organic association of Cr and V in the Ganhe coal. Furthermore, Cr and/or V were identified in association with Al-Si (muscovite, illite, and pyrophyllite), Fe (pyrite, jarosite, Fe-S-Cr particle, and Fe-Cr-Au particles), and Ti (Ti-oxides) nanominerals in maceral components through further nanoscale mineralogical examination using high resolution transmission electron microscopy (HR-TEM) and scanning transmission electron microscopy (STEM)

coupled with energy-dispersive X-ray spectrometry (EDS). Furthermore, compared with Fe-bearing nanominerals in two medium-organic sulfur coals from northeast India (Ribeiro et al., 2010), more types of nanominerals (Al-Si, Fe, Ti nanominerals) are found in the Ganhe SHOS coal. Additionally, in these nanominerals, nano Ti-oxides are associated with the largest proportions of Cr and V. The origin and association mechanism of Cr and/or V bearing nanominerals still need further investigation. © 2017 Elsevier Ltd.