

## Potential biological applications of vanadium compounds

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### Abstract

Vanadium has a cosmopolitan distribution in almost all plant and animal cells in sub milligram quantity. But up to what extent it is important for living organisms is still not well examined. On the other hand, vanadium has turned into progressively more significant ecological metal. When vanadium compounds are used in limited quantity they show a great biological potential towards a number of diseases such as for the treatment of diabetes, can be used as biomaterials in implants, having cardio protective potential and more recently used for the treatment of neurodegenerative diseases. This biological potential of vanadium is one side of the coin, on the other side vanadium compounds are also having toxicological effects on the other cells of the body which depends upon the type of the vanadium compound and amount. This feature of the toxic effects can be utilized for the synthesis of anticancerous drugs. In this short review, the author reviewed recent information regarding the potential biological applications of vanadium compounds with respect to diabetes, biomaterial implants, cancer treatment and treatment of the neurodegenerative diseases.

Keywords: cardio protective, anticancerous drugs, vanadium compounds, neurodegenerative diseases, implants, biomaterials

### Introduction

Vanadium is present in sub-milligram quantities in natural systems and is prevalent in the natural surroundings. Oil deposits are the richest source of vanadium on the other hand water, rocks and soil are the poor sources of vanadium. Vanadium is positioned in first transition series and it is having valenceies III, IV, and V due to which it can form compounds with these valencies. In the presence of oxygen and at neutral pH vanadium (III) is not stable. It is found about vanadium that there is very easy oxidation of vanadium (IV) to vanadium (V) in natural conditions. Another oxidation state of vanadium i.e. vanadium

(V) occur as vanadate anions. Employees who come in direct contact with vanadium are in danger because respiring vanadium particulates can go through into lungs and there is a study which shows the relationship between vanadium inhalation and lung cancer (1, 2). There are no much evidence on how vanadium is involved in toxicity and carcinogenicity but inspite of this vanadium is used in a number of biologically important areas:

Growth-factor-mediated signaling can be controlled with the help of vanadium nanoparticles, encourage cell renovation, put forth inhibitory effect on definite enzymatic pathways, and reduce cell-cell attachment (3–5). Vanadium compounds were also found as one of the reason of direct DNA smash up such as strand rupture and results in introduction of hydroxyl groups in dG residues (6). The capability of cells to retain genomic integrity is very important for cell's continued existence and propagation. Absence of reliability in DNA duplication and preservation can leads to deadly alterations in DNA sequences, leading to cell loss or, can lead to different types of cancer (7). Cell cycle succession and stability of DNA, when the DNA is damaged by chemicals solely depends upon cell signaling pathways.

Cell-cycle control points regulate the start of DNA duplication and cell division so as to make sure the reliability of the complete hereditary information (8, 9). it was reported in the earliar reports that sodium vanadate results in G2/M seize and phosphorylation of Rb to a less than normal extent in T98 glioma cells (10), indicating that the G2/M sieze caused by a peroxovanadium compound which was interrelated to the decreased activity of p34cdc2 and prohibition of Cdc25C (11). It was reported that when myeloma cells continuously exposed for 2 hours to sodium vanadate results in the lowering the concentration of cyclin D (12). In some additional reports it was specified that vanadate leads to cell division in CSV3-1 cells which was connected with the stimulation of hyperactivity of protooncogenes, , *c-jun* and *jun B*, two most important factors of the AP-1 transcription factor (13).

It has been also reported that programmed cell death can be promoted with the help of vanadate by the generation of hydrogen peroxide (14).

There are other fields in which we can use vanadium nanoparticles:

Vanadium oxide is expansively used as catalyst in a number of industries

It can also be used to make laser crystals

In the synthesis of nanowires and nanofibers

But in this review we are much focused on the biological applications of vanadium nanoparticles(15).

### **Use of vanadium alloy in implants**

The mixture of Ti-6 Aluminum-4 Vanadium and Titanium (Ti) are mainly used in implants but beta type alloys are having the very good potential for making biomaterials as this provide very good mechanical strength. In this paper (16) have reported that different titanium and vanadium combination, in vitro as well as in vivo prove their great prospective in biological applications. They used different combinations of metals e.g. (CpTi); G2-Ti-6Al-4V alloy; G3-Ti-13 Niobium-13 Zirconium alloy; G4-Ti-35 Niobium alloy; G5-Ti-35 Niobium-7 Zirconium-5 Tantalum alloy, and stem cells of bone of newborn cat calvaria were plated on these different combinations. They examined the ingrowth of bone after 2-4 weeks of plating.

It was demonstrated that nanocomposite-coated Ti-6Al-4V helps in the induction of attachment between cells and cell propagation, and ultimately results in the development of new bone cell. On the whole, these nanocomposite coatings have potential orthopedic applications for efficient biomimic bone renewal (16).

### **Use of vanadium compounds in treatment of diabetes**

Diabetes mellitus is a severe metabolic disease, which is primarily distinguished by high level of sugar in blood, in addition to it inappropriate digestion of carbohydrates, lipids and proteins. The marvelous significance of this ailment can be returned in about 366 million sugar patients imagined in the globe by 2030 (17). There are two most important types of human diabetes. Type I diabetes which is also known as insulin dependent diabetes (diabetes incipendus), this is the type of diabetes in which insulin which is a very important hormone which is a type of protein helps in controlling adequate amount of glucose in the blood which is

mainly released by pancreatic beta cells. Other type of diabetes is type 2 which is also known as non insulin dependent diabetes mellitus, in this type faulty insulin is produced by beta cells of pancreas as a result of this, level of insulin increased in the blood ultimately leads to insulin resistance. (18) The broad-spectrum management in non insulin dependent diabetes mellitus of NIDDM is largely supported by nutrition, workout control, and drug analysis (19). Management of diabetes by nutrition and workout can be done upto certain level but cannot be substituted with medicines.

A range of medicines having unique mechanism with which it act in the cell has been medically used (20). On the other hand, treatment of non insulin dependent diabetes generally not controlled by taking medicines orally. So in order to control the disease patients are given insulin injections (21). No doubt insulin effects Although insulin effects proficient in a number of patients, regrettably, the regular use of these insulin injections have a number of bad effects on the patients. This is the main cause for the improvement of novel medicines for the management of diabetes mellitus. Vanadium, which is a transition metal occupying central position in the periodic table with atomic number 23, is an element which is present in very minute quantity, broadly dispensed in natural surroundings, and it can form a number of polyvalent compounds as it is polyvalent in nature and each of the vanadium compound show a great biological potential (22). Initially vanadium was used by scientists in 2006 for the management of diabetes mellitus roughly a century ago(23). polyvalent compounds of vanadium also having the potential of for curing the ailments which are caused by protozoan, harmful cancers and different types of infections caused by bacteria and virus (24). Sodium vanadate was used as antidiabetic agent and he had administered this vanadium compound in rats in which diabetes was induced by streptozotocin and he has reported decreased amount of sugar in the blood, in addition to this there heart health was also not affected due to diabetes and from this finding, there was a generation of huge interest in this field (25). In consequent time, this discovery catch the attention of a number of researchers, who performed a significant number of works on the potential importance of vanadate in the improvement of symptoms connected with high sugar level in the blood (26). Furthermore, additional explorations demonstrated that when vanadium is used in the type of vanadyl (pIV) was also efficient in reducing the appearance of high sugar level in the rat (27). Because this treatment did not enhance the amount of internal insulin, it was imagined that vanadium most probably could straightly take action on insulin marked tissues (28). On account of wonderful measure of hopeful announcements on the feasible utilization of vanadium compounds in the management of diabetes which was induced by conducting experiment on rats, on the basis of this study, in

1990s scientists developed an interest in finding out whether vanadium compound treatment is helpful in treating human diabetes or not and scientists started to do work on how vanadium compounds interact in the cell, how these compounds helps in metabolism of glucose what is the mechanism of action in the cell along with this they also have assessed the possible risks associated with the use of vanadium compounds for the treatment of diabetes (29).

## **Vanadium and Cancer**

Chemotherapy is the way to treat cancer that uses drugs to kill cancer cells or is the use of drugs to harm disease causing micro-organism without any damage to the patient. This description consequently covers all the chemical agents that can kill bacteria, virus and any cancer causing mediator. In case of bacterial and viral, diseases causing organisms and the patient is clearly different from each other but in cancer, cancer causing cells and organism are not stringently unlike but the management of this disease has a general aim of the removal abnormal cells, as in cancer organisms own body cells propagate abnormally. Because of this, such chemical drugs are synthesized which can provoke permanent cytotoxic effect. The best success in the area of using chemicals in treatment of cancer is the introduction of cisplatin (30) and carboplatin (31). The appropriate task of using metals with cisplatin for the treatment of cancer is a trial product. Nevertheless, the progress of compounds with configurations analogous to that of the cisplatin has manufactured numerous potential composites. Every direct constructional analogs of cisplatin fabricate a very parallel outcome on target DNA and they provoke same biological reactions. Consequently, it is found that the synthesis of materials of different metals which are having different structure form cisplatin can give rise to novel pharma drugs which may have different property to treat the disease.

A number of experiments have been performed on animal models and different types of cancerous cell lines in order to investigate the anticancerous properties of vanadium compounds. Vanadium possess anticancerous property which is investigated by the mechanism of its action in which vanadium inhibits cell cycle or cause death of tumor cell. This hypothesis is strongly supported by the verification that the vanadium compounds results in hindering the action of PTPases and formation of reactive oxygen species as a result of this a number of cell constituents are damaged and due to ROS, oxidative stress leads to DNA damage. PTPases are the enzymes which controls a number of cell signaling pathways but inhibition of this enzyme leads to programmed cell death, sieze of cell cycle, modification of proteins which are there in abnormal growth activity of cancerous cells. Alternatively, the interface of vanadium with cancer causing materials (i.e. alkyl drugs), can result in chemopreventive action. This activity has

been holded by experiments mentioned in prior evidences. Propagation of the human cancerous cells (HTB-14), hematopoietic mouse cells (MDAY-D2) and endothelial mouse cells (EDMA) was hindered by 5 - 50  $\mu\text{M}$  of sodium orthovanadate. It has been also reported that the cells in an active propagation situation were more susceptible to the inhibitory action of vanadium [32].

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