EFFECT OF VANADIUM ON THE LEVELS OF NEUROTRANSMITTERS IN THE BRAIN AND MUSCLE TISSUES OF CHANNA PUNCTATUS

R.NIKITHA

STUDENT.

SAROJINI NAIDU VANITA MAHA VIDYALAYA

SHARON TRIVENI PRASAD

FACULTY MEMBER

SAROJINI NAIDU VANITA MAHA VIDYALAYA

NAMPALLY, HYDERABAD, INDIA.

Dr. C.MANJUSHA

SENIOR FACULTY MEMBER.

SAROJINI NAIDU VANITA MAHA VIDYALAYA

NAMPALLY, HYDERABAD, INDIA.

ABSTRACT

For thirty days, the fish are administered twenty-four parts per million of vanadium. Each of the three groups of five fish was put into its own tub. As an experiment, no compounds are put to Group 1. However, 20 and 40 ppm of substances are added to Groups 2 and 3, respectively. Every day, we eliminate chlorine by changing the water for these three fish species. The following methods will be used to assess 1. How to determine acetylcholine using the Histrin technique (1949) and 2. How to determine aspartate using the Marklegault and Roy method (1999). Two neurotransmitters, acetylcholine and aspartate, are declining with age, as shown in the study. In addition to a 30-day drop in these neurotransmitters, the study found behavioural changes in the fish, including very slow and listless movement, weak muscular tone, respiratory distress, overall mucus production, lacrimation, scale

detachment from the skin, and insufficient feeding. Following a comparison with the control, the data underwent statistical analysis. The data is shown by the average and standard deviation. The statistical investigations were carried out utilising one-way ANOVA analysis and the Microsoft Excel program. Data was subjected to statistical analysis after comparisons with the control group.

Key Words: Vanadium, Neurotransmitter, Acetylcholine, and Aspartate

INTRODUCTION

Symbolised as "V" and assigned the atomic number 23, vanadium Their level of oxidation determines the hue of the complexes they display. Consider the following set of integers: +2, +3, +4, +5. Each of these has a unique colour: II for purple, III for green, IV for blue, and V for brown or yellow (R. Wesset al., 1984). Due to its corrosion resistance, vanadium is ideal for use in the building of tubes and pipes; it accounts for about 85% of vanadium's use as an additive in steel and iron (Karlsson-Norrgran and Runn 1985). Indian waterways continue to be polluted, even though the country is less industrialised than wealthier ones. A greater number of toxic compounds are now recognised to be present in waterways. Khare and Singh released their results in 2002.

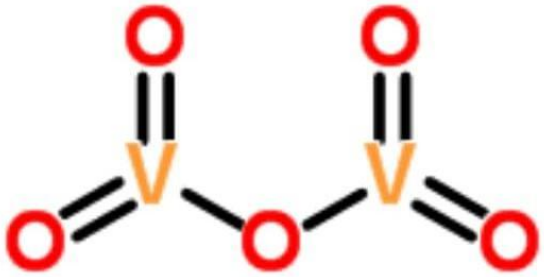


Fig.1.Structure of Vanadium

Companies' disposal of harmful chemicals and heavy metals into the environment is a major contributor to the degradation of aquatic ecosystems. (Woodling et al., 2001) and Gbem et al., 2001.. Vanadium is not only not physiologically necessary but also persistent, non-biodegradable, and perhaps most toxic among heavy metals. The gills, the skin, and the intestinal wall are the three primary pathways whereby metals in food may be absorbed by freshwater fish. The authors Karlsson-Norrgran and Runn state that in 1985. Toxic

consequences, including tissue damage and death, are caused by heavy metal exposure in fish over time. A study conducted by Ferrard et al. (1983) is cited. This suggests that transition metals contribute to long-term skeletal muscles of the Channa punctatus fish.

Neurotransmitters

Synapses allow chemical messengers called neurotransmitters to go from neurones to other cells. (Berk et al., 2000) is the cited work.

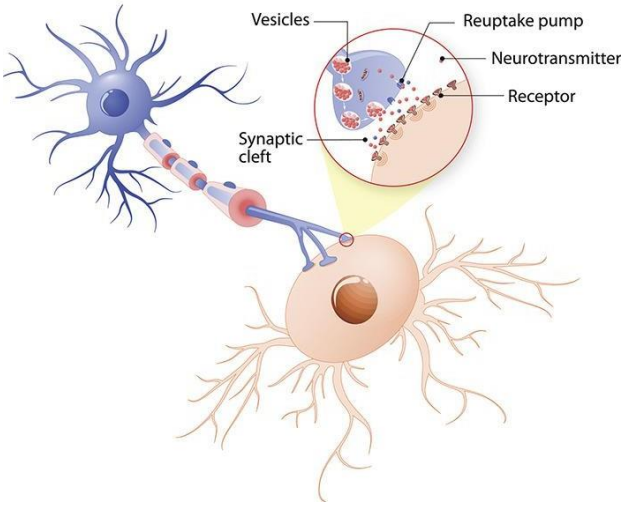


Fig.2.Structure of a typical chemical synapse

Among the over a hundred neurotransmitters in the brain, some of the most common are glutamate, glycine, acetylcholine, and GABA. (March 2019)—Cuevas et al. Neurotransmitters serve a variety of physiological purposes, including regulation of respiration and heart rate as well as learning, emotion regulation, fear management, pleasure perception, and happiness. They are crucial for maintaining brain function and for enhancing and balancing brain messages. (2021) (Guy-evnas et al.).

Chlorophyll (CH)

In 1921, a German researcher named Otto Loewi was the first to identify acetylcholine as a neurotransmitter. One kind of amine that is produced naturally is acetylcholine. Parasympathetic and central nervous system components are both capable of containing it. The principal function of this neurotransmitter is to facilitate learning, memory, and the activation of muscles via its association with motor neurones. This cholinergic system includes

two types of receptors namely **nicotinic receptors** that respond to the agonist nicotine and act as excitatory receptor that activates ligand-gated ion channel that opens a sodium channel causing depolarization of the cell membrane that increases the cell firing and **muscarinic receptors** that respond to muscarine, acts as an inhibitory receptor which activates G-protein that opens a potassium channel causing hyperpolarization of the cell membrane that reduces the cell firing. **(Knut Schmidt Neilsen et al., 1976).**

Low levels lead to paralysis and other symptoms include dry mouth, dry eyes, low muscle tone, memory problems, learning difficulties, depressed mood, Alzheimer's, and Parkinson's and high levels lead to cramps, increased salivation, lacrimation, paralysis, convulsions, blurred visions, and muscle weakening, muscular fasciculation, and diarrhea **(Richard.W.Hill et al., 1976).**

Aspartate

Mammals are able to produce aspartate on their own, making it a non-essential amino acid. The ventral spinal cord is where it is most often found. These are found in high concentrations in the brain and have powerful excitatory effects on neurons **(Edwin C Johnson et al., 2017).**

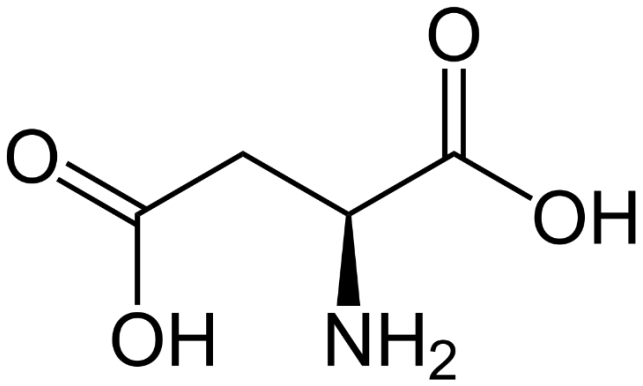


Fig.5. Structure of Aspartate

They help in strengthening Long-term potentiation (LTP), a neurological mechanism related to the creation of powerful memories, which occurs at synapses. **(Evelyn F. and William L. et al., 2015).** It must be synthesized in neurons in order to promote hormone synthesis, red blood cell production, immunological function, and tissue growth and repair **(J Victor Nadler et al., 2010).** When administered intravenously, certain types are

intended to lessen brain damage brought on by liver cirrhosis. **(J Victor Nadler et al., 2010).** Besides high levels have been linked to seizures and anxiety **(Robert H. Edwards and Roger A. Nicoll et al., 2015).**

Objectives for Study

1. To investigate how vanadium affects neurotransmitter levels in Channa punctatus brain and muscle tissues.

2. To compare the findings in brain and muscle tissues at the 1, 15, and 30 day marks.

DESIGN OF EXPERIMENT

Maintenance and collection of fish: We will purchase live Channa punctatus from a nearby market, place them in a plastic bag, and transport them to the laboratory for analysis. The fish will spend 20 minutes submerged in a 0.05% $KMnO_4$ solution in the lab to prevent skin diseases. To ensure that the fish are free of any lingering effects from prior chemical exposure, they will be acclimated for one week before the experiment begins (Pandey et al.,2009; Nwani et al.,2010). There will be three groups of fish: one will act as a control, while the other two will undergo experiments with varying concentrations of vanadium (20 ppm and 40 ppm, respectively). Daily water changes will keep these three groups healthy. Chlorine in water stresses out fish, kills cells, damages skin and gills, and may even cause respiratory problems. The water will be allowed to sit in the open for 24 hours to lower the chemical levels, which will avoid these issues, before being used the following day. In addition to changing the water every day, the vanadium concentrations of 20 and 40 ppm will be supplied to the water on a regular basis until the experiment ends on the 30th day.

METHODOLOGY

Channa punctatus

Fig.6.Scientific Classification of *Channa punctatus*

Scientific Classification	
Kingdom	Animalia
Phylum	Chordata
Class	Actinopterygii
Order	Anabantiformes
Family	Channidae
Genus	*Channa*
Species	*punctata*

Fig.7.*Channa punctatus*

Channa punctatus is a scientific name and is commonly called Spotted snakehead and locally called Murrel.

Identification Characters

Anatomically, it has a long, cylindrical body with a colour pattern that changes depending on its environment; the back is often yellowish to black while the underside is lighter. All around the body are many dark patches. The pectoral fin is located immediately above the pelvic fin, and the caudal fin is broad and rounded. There are huge scales and extremely tiny eyes positioned in front of the skull. The lower jaw protrudes somewhat.

Body length: Typically, it reaches a maximum of 15.0 cm, however, males have the potential to reach 31.0 cm (Pauly, Daniel et al., 2014). The natural environments in which it thrives include ponds, marshes, and brackish water systems. (Research conducted by Froese and

Rainer in 2014). These animals mostly consume carnivore prey, which includes insects, crustaceans, molluscs, and juvenile fish.

Spawning: The rainiest months of April through June are also good times to breed.

Evaluation In an effort to forestall any skin infections, fifteen fish were purchased and subjected to a twenty-minute treatment with KMnO4 solution. After that, the fish were left in fresh water for six days to become used to it. The fish were delivered into separate tubs in three groups of five. Two groups, one serving as a control and the other as an experimental set (20 and 40 ppm, respectively), are used in this study. Three intervals of one, fifteen, and thirty days after exposure to the Vanadium toxicant were used to conduct the toxicity analysis. Three groups had their brain and muscle tissue aspartate and acetylcholine concentrations measured to determine vanadium's impact. At each time point, one fish was sacrificed from each group, and the remaining six fish were utilised to observe behaviour.

Quantitative Evaluation

The average and standard deviation show the data. Statistical investigations were conducted using the Microsoft Excel program and one-way ANOVA analysis.

After comparing the outcomes to the control group, statistical analysis was performed on the data. The experiment will include dissecting the fish in order to get the necessary brain and muscle tissues for the assay of neurotransmitters, namely acetylcholine and aspartate. A mortar and pestle were used to homogenise the brain and muscle tissues in their respective solutions. Additional tests will be conducted on the control group. The experimental groups (20 and 40 ppm) will also undergo the same treatment.

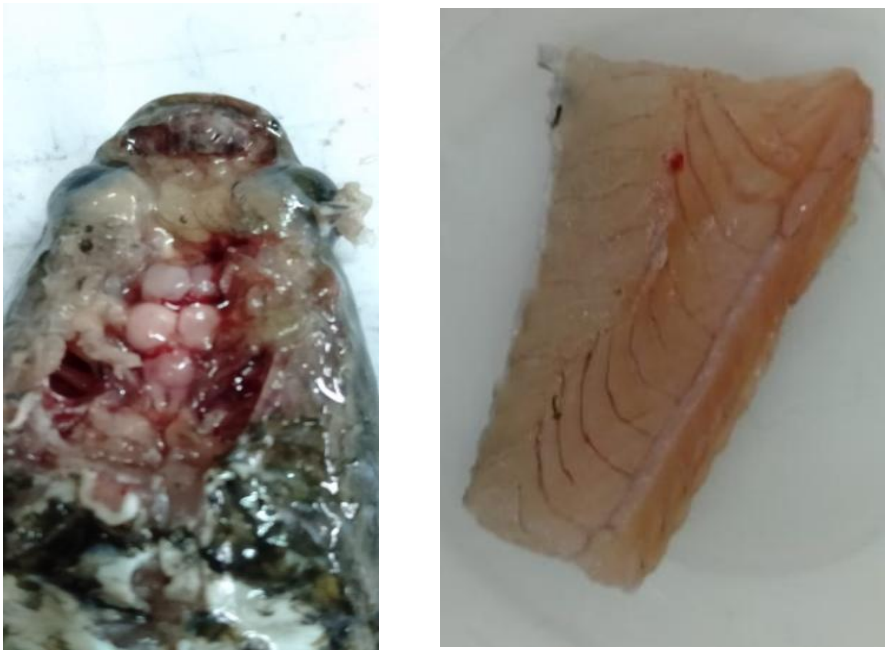


Fig.8.Brain and Muscle tissue

According to Hestrin (1949), acetylcholine levels in the brain and muscles may be estimated. Marklegault and Roy's (1999) approach is used to estimate aspartate in brain and muscle tissues.Histrin Method for the Determination of Acetylcholine Concentration (1949) 10 milligrammes of either brain or muscle tissue is weighed and homogenised with 1 millilitre of 3% perchloric acid before being spun at 1200 revolutions per minute for 10 minutes. Estimation was performed using the supernatant. Reagents 1 and 2 were mixed in equal quantities and left to incubate at room temperature for three hours to produce new hydroxylamine reagent. Prior to adding 1 ml of FeCl3 solution, 2 ml of alkaline hydroxylamine reagent was added to 1.0 ml of the supernatant. The pH was then corrected to 1.5 by adding 0.001 N HCl, and the mixture was well mixed by vortexing. We measured the optical density at 540 nm. To make a blank, combine 2 millilitres of hydroxylamine reagent with 1 millilitre of perchloric acid in a test tube. Add 1 millilitre of ferric chloride after adjusting the pH to 1.5 with a 0.001N HCl solution. Markle, Gault, and Roy's (1999) technique for estimating aspartate 10 milligrammes of brain or muscle tissue is weighed and homogenised with 1 millilitre of 3% perchloric acid. The mixture is then centrifuged at 1000 revolutions per minute for 10 minutes. The resulting supernatant is transferred to a new tube. To this, 2 millilitres of citrate buffer, 1 millilitre of 1% ninhydrin solution, and 1 millilitre of 1% SnC12 are added. The mixture is thoroughly mixed and then heated at 100 degrees Celsius for 15 minutes. Later, it is cooled on ice for 10 minutes in a dark room. Following

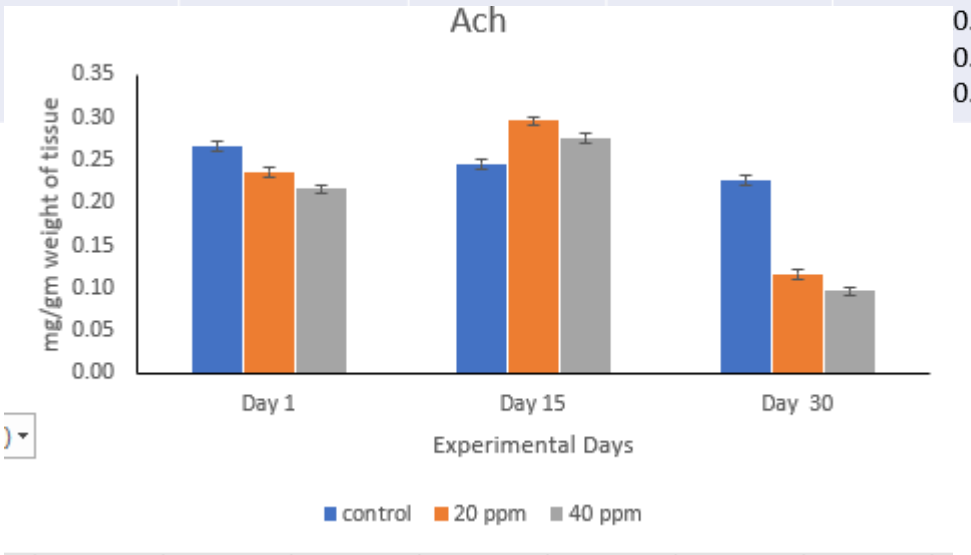
this, 6 millilitres of isobutyl alcohol was added, mixed well, and the alcohol layer was measured for optical density at 570 nanometres. The blank is prepared by taking 6 millilitres of isobutyl alcohol.

RESULTS

Brain Acetylcholine Levels: On days 1, 15, and 30, the following amounts of acetylcholine were found in the brain tissue of fish that were exposed to doses of 20 ppm and 40 ppm of vanadium:

Mean and standard deviation are the measures of data representation.

S. No	Tissue	Day	Control	Experimental	
				20 ppm	40 ppm
1					0.01 0.01 0.01



We may deduce from the data in the table above that the levels of acetylcholine in the brain tissue rose on the fifteenth day compared to the control group, and then progressively declined on the thirtyth day. In other words, the order is 1st < 15th > 30th day. What follows is a visual depiction of the data.

Fig.9.Graphical representation of Acetylcholine levels in the brain tissue

In Muscle:

The amount of Acetylcholine present in the muscle tissue of a fish exposed to 20ppm and 40ppm vanadium concentrations for the 1st, 15th, and 30th day is as follows:

The Data is represented by Mean and Standard Deviation.

Table.1.Acetylcholine levels in the muscle tissue

S. No	Tissue	Day	Control	Experimental	
				20 ppm	40 ppm
1	Muscle Tissue	1st 15th 30th	0.22±0.01 0.20±0.01 0.18±0.01	0.18±0.01 0.23±0.01 0.08±0.01	0.16±0.01 0.21±0.01 0.06±0.01

Based on the data shown in the table, it can be inferred that the levels of acetylcholine in the muscle tissue, as opposed to the control group, rose on the fifteenth day and then declined throughout the thirtyth day, in the following sequence: 1st < 15th > 30th day. Below you may see the data graphically represented.

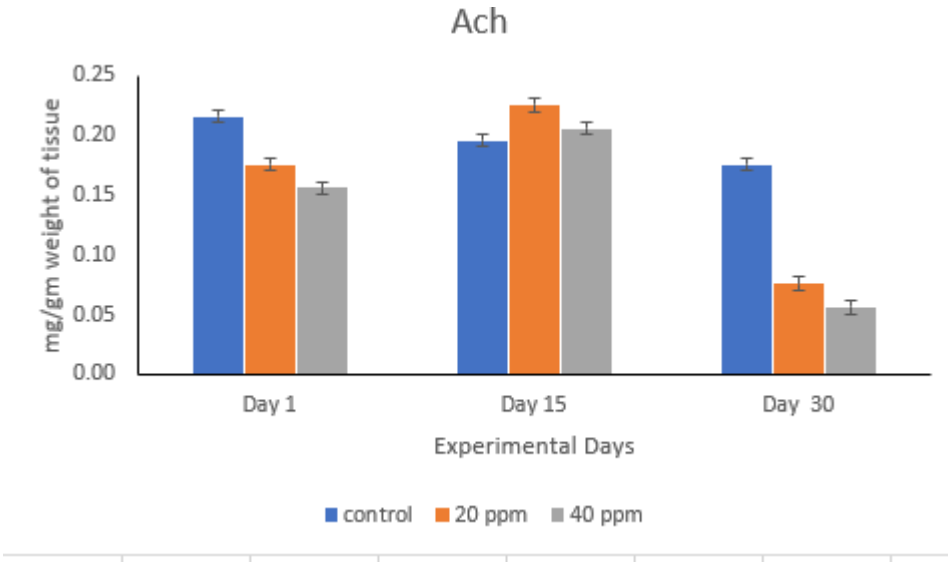


Fig.10. Graphical representation of Acetylcholine levels in the muscle tissue

Inside the Mind:

Here is the quantity of Aspartate found in the brain tissue of a fish that was exposed to 20

S. No	Tissue	Day	Control	Experimental	
				20 ppm	40 ppm
1	Brain	1st 15th 30th	0.24±0.01 0.22±0.01 0.20±0.01	0.20±0.01 0.15±0.01 0.10±0.01	0.18±0.01 0.10±0.01 0.06±0.01

ppm and 40 ppm of vanadium on the first, fifteenth, and thirtyth day: Mean and standard deviation show the data.Table 2.Aspartate levels in the brain tissue

The data in the table show that starting on day 1, aspartate levels in brain tissue declined progressively compared to the control group, with the decline being most pronounced on days 15 and 30. Below you may see the data graphically represented.

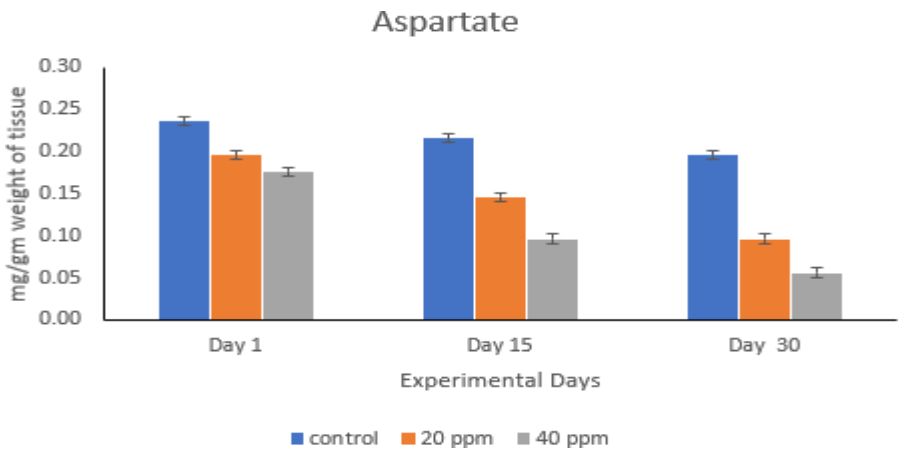


Fig.11. Graphical representation of Aspartate levels in the brain tissue

For the first, fifteenth, and thirtyth days after being exposed to 20 ppm and 40 ppm vanadium concentrations, the following amounts of aspartate were found in the fish's muscle tissue: Mean and standard deviation show the data.

Table.3. Aspartate levels in the muscle tissue

S. No	Tissue	Day	Control	Experimental	
				20 ppm	40 ppm
1	Muscle Tissue	1st 15th 30th	0.20±0.01 0.18±0.01 0.16±0.01	0.17±0.01 0.13±0.01 0.08±0.01	0.16±0.01 0.08±0.01 0.02±0.01

The data in the table show that over the first, fifteenth, and thirtyth days, there was a progressive drop in aspartate levels in the muscle tissue compared to the control group. Below you may see the data graphically represented.

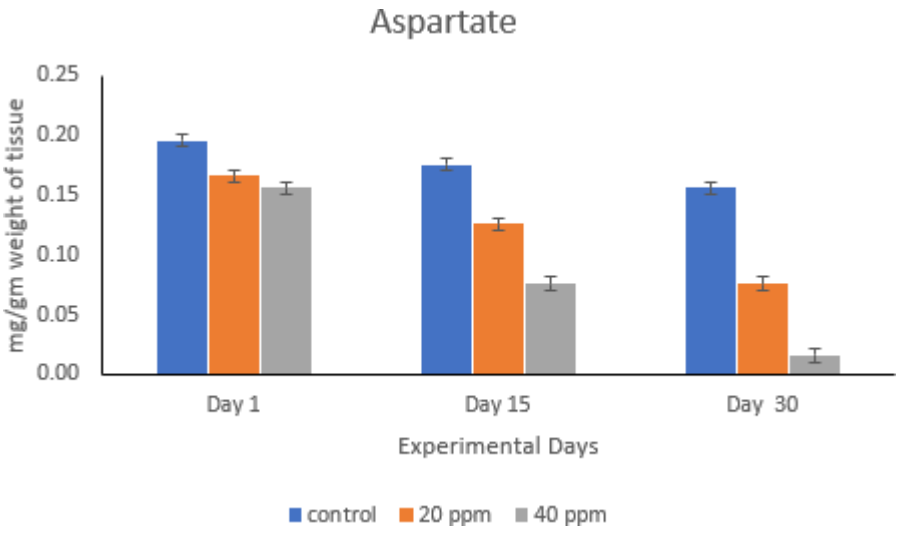


Fig.12. Graphical representation of Aspartate levels in the muscle tissue

DISCUSSION

Compared to the control group on days one and thirty, levels of the neurotransmitter acetylcholine rose on day fifteen in the current research. Acetylcholine levels mostly rose and fell gradually. At high enough doses, acetylcholine may cause morphological issues, such as the development of glands all over the body, the release of saliva, sluggish swimming, and behavioural disturbances in fish. Heavy metal toxicants impede AChE, which causes these acetylcholine level fluctuations . Consistent with previous research, this study found that toxicant exposure caused an initial rise in Ach levels followed by a steady fall, with the same symptoms as previously described (R. W. Hill et al., 1976). From the first to the thirty-first day, there is a notable and steady decline in the aspartate levels in the brain and muscle tissues. There was a lack of response from the fish, which manifested as sluggish swimming and the loss of scales. Vanadium intoxication might be the cause of these symptoms and alterations in aspartate levels. These findings are in line with those of a prior research that shown the critical role of this neurotransmitter in regulating energy metabolism, brain function, and the development and maintenance of healthy tissues (J Victor Nadler et al.,

2010). Disruptions in the release of neurotransmitters may be caused by exposure to very toxic metals (Richard.W.Hill et al., 1976).

CONCLUSION

Neurotransmitters acetylcholine and aspartate show a steady decline from day 1 through day 30, according to the research. Possible bioaccumulation of toxicants in fish tissues is responsible for these neurotransmitter release abnormalities. This changes the regular lives of fish, which has a lasting impact on them. In addition, the fish acts extremely clumsily and unresponsively, salivates excessively, produces mucus all over its body, causes respiratory distress, lacrimal discharge, weak muscles, poor eating, scale shedding, impaired tissue development and repair, and so on. A reduction in neurotransmitter levels and a possible association with neurodegenerative diseases are the pathophysiological consequences of vanadium that are being studied in this trial. More investigation, analysis, and assessment are required in this area.

REFERENCES

1. Weast, Robert (1984) - Environmental Toxicology; Vanadium accumulation and its effect on brain and skeletal muscle of zebra fish.
2. Karlson-norrgan and Runn (1985) - Heavy metal vanadium and its side effects:overview.
3. Ferrard James O.Olopade, R. Connor and Runn (2011) - Vanadium and Neurotoxicity: A review.
4. Knut Schmidt Neison (1976)- Animal Physiology 2nd edition.
5. Knut Schmidt Neison (1976) - Animal Physiology - Adaption snd environment, 4th edition.
6. J.Victor Nadler (2011) - Aspartate release and signalling in the hippocampus.
7. J.Victor and Richard.W.Hill (1976) - Role of acetylcholine and its significance: Animal physiology-2nd edition.
8. Edwin C.Johnson,Robert Edwards ,J. Victor, Nadler and Roger A.Nicoll (2017) - aspartate is an excitatory neurotransmitter.
9. Done, Valla Reddy Anantharamam, Huajun Jin (1979) - Vanadium exposure in an animal model of metal neurotoxicity.
10. Pyrzynska, and Weirzbicki(2004);and Woodling J.D Brinkman (2001) - Non uniform accumulation of vanadium in ecosystem.
11. Michael E. Hasselmo (2006) - The role of acetylcholine in learning and memory.

12. James O.Olopade and James R.Connor (2011) - Vanadium and Neurotoxicity: A review
13. Kausik Mondal, Sanjib Ghosh, Sama Haque (2018) - A review on contamination, Bioaccumulation and toxic effects of heavy metals on fresh water fishes.
14. Rajan, M.T. and Banerjee, T.K. (1991) - Histopathological changes induced by heavy metal toxicity in freshwater catfish Heteropneustesfossilis (Bloch). Ecotoxicology.
15. Satyanarayanan, D., Rao, and Prasad Reddy, B.R. (1985) - Trace metals in water and particulate matter.
16. Narayanan, K.R., Lyla.P. S. and Ajmal Khan, S. (1997) - Pattern of accumulation of heavy metals; Ecotoxicology.
17. Harper Collin's Publishers, New York (2011) - Neurosceince/Neurotransmitters.
18. Moore, J.W. and Ramamoorthy, S. (1984) - Heavy Metals in Natural Waters.
19. Braak H, Braak E.(2000) - Pathoanatomy of Parkinson's disease. J Neurol.
20. Nancy Hammond, M.D.Jennifer Berry (2019) – Toxins and pesticides increases acetycholine levels.
21. Olanrewaju I. Fatola, Funmilayo E. Olopade(2017)–Trends in Vanadium Neurotoxicity
22. Avila-Costa MR, Montiel Flores E, Colin-Barenque L, Ordonez JL, Gutierrez AL, Nino-Cabrera HG, Mussali-Galante P. Fortoul TI.(2004) - Nigrostriatal modifications after vanadium inhalation: an immunocytochemical and cytological approach.
23. Ansari KA, Johnson A. (1975) - Olfactory function in patients with Parkinson's disease
24. Some organs of carp, Cyprinuscarpio L in case of per os administration. Arch. Pol. Fish., 1: 61-66.
25. Astacuzartacus L. (Crustacea: Decapoda). Ecotoxicol. Environ. Safe.. 21: 137-156.
26. Moore, J.W. and Ramamoorthy, S. 1984. Heavy Metals in Natural Waters: Applied Monitoring and Impact Assessment. Springer Verlag, Tokyo, 1-268
27. Narayanan, K.R., Lyla.P. S. and Ajmal Khan, S. 1997. The pattern of accumulation of heavy metals (mercury, cadmium, and zinc) in the mud crab Scylla Serrata. J. Ecotoxicol. Environ. Monit., 7: 191-195.
28. Paul, V.I. and Banerjee, T.K. 1996. Analysis of ammonium sulphate toxicity: in the catfish Heteropneustesfossilis using leucocyte indexing. Pol. Arch, Hydrobiol., 43: 111-125.
29. Paul. VI. and Banerjee, T.K. 1997. Histopathological changes induced by ambient ammonia (ammonium sulphate) on the opercular linings of the live fish Heteropneustesfossilis (Bloch). Dis. Aquat. Org., 28: 15-161. Protasowicki, M. andChodyneicki, A. 1992. Bioaccumulation of cadmium in 47.
30. Rajan, M.T. and Banerjee, T.K. 1991. Histopathological changes induced by acute toxicity of mercuric chloride on the epidermis of freshwater catfish Heteropneustesfossilis (Bloch). Ecotoxicol. Environ. Safe, 22: 139-152. Rema. L..P. and Philip, B. 1997. Accumulation of an essential metal (zinc) and a non-essential metal (mercury) in different tissues of Orrockm mismossambicus (Peters). Ind. J. Exp. Biol., 35: 67-69
31. Satyanarayanan, D., Rao, I. M., and Prasad Reddy, B.R. 1985, Chemical oceanography of harbor and coastal environment of Visakhapatnam (Bay of Bengal). Part 1: Trace metals in water and particulate matter J. Mar. Sci., 14: 139-146.

32. Woodling. J. D., Brinkman.S. F. and Hom, B.J. 2001. Non-uniform accumulation of cadmium and copper in kidneys of wild brown trout Sa
33. http://what-when how.com/neuroscience/neurotransmitters-the lmotrutta populations. Arch. Environ. Contam Toxicol, 40: 381-385
34. Knut Schmidt Nielsen, Animal Physiology-Adaptation and environment, 4th edition, Cambridge University Press, U.K
35. Richard.W.Hill (1976) Animal Physiology, 2 edition
36. Harper Collin's Publishers, New York. http://www.sciencedaily.com/releases/2011/12/111205
37. http://www.columbia.edu/cu/psychology/courses/1010
38. /mangels/neuro/transmission/transmission.htm
39. http://www.chemistryexplained.com/NeNu/Neurotransmite html#b
40. Knut Schmidt Nielsen, Animal Physiology - Adaptation and environment, 4th edition, Cambridge University Press, U.K Richard.W.Hill (1976) Animal Physiology, 2nd edition, http://www.columbia.edu/cu/psychology/courses/1010
41. Harper Collin's Publishers, New York. § http://www.sciencedaily.com/releases/2011/12/1112 05 165907.htm/mangels/neuro/transmission/transmission.html http://www.chemistryexplained.com/NeNu/Neurotransmitters.html#b
42. https://www.webmd.com/vitamins/ai/ingredientmono - 749 / vanadium
43. https : //www.webmd . com / vitamins / ai /ingredientmono - 749 / vanadium
44. Badmaev, V., Prakash, S., and Majeed, M. Vanadium: a review of its potential role in the fight against diabetes. J Altern Complement Med 1999 ; 5 (3) : 273291.
45. Beliaeva, N. F., Gorodetskii, V. K., Tochilkin, A. I.Golubev, M. A., Semenova, N. V., and Kovel'man , I. R.[Vanadium compounds - a new class of therapeutic agents for the treatment of diabetes mellitus) .Vopr.Med Khim . 2000 ; 46 (4) : 344-360.
46. Bradley , R. , Oberg , E. B. , Calabrese , C. , and Standish ,L. J. Algorithm for complementary and alternativemedicine practice and research in type 2 diabetes . JAltern.Complement Med . 2007 ; 13 (1) : 159-175 .
47. Chakraborty, T. , Chatterjee , A. , Rana , A. , Rana , B. , Palanisamy , A. , Madhappan ,
48. R. , and Chatterjee , M.Suppression of early stages of neoplastic transformation in a two - stage chemical hepatocarcinogenesis model : supplementation of vanadium , a dietary micronutrient , limits cell
49. Adachi A, Asai K, Koyama Y, Matsumoto Y, Kobayashi T. Vanadium content of cigarettes. Bull Environ Contam Toxicol. 1998; 61:276-280. [PubMed: 9702367]
50. Afesch Ngwa H, Kanthasamy A, Anantharam V, Song C. Witte T, Houk R, Kanthasamy AG. Vanadium induces dopaminergic neurotoxicity via protein kinase Cdelta dependent oxidative signaling mechanisms: relevance to etiopathogenesis of Parkinson's disease. Toxicol Appl Pharmacol. 2009; 240:273-285. [PubMed: 19646462]
51. Allam MF, Del Castillo AS, Navajas RF. Parkinson's disease risk factors: genetic, environmental, or both? Neurol Res. 2005; 27-206-208. [PubMed: 15829184]
52. Amorim FA, Welz B, Costa AC, Lepri FG, Vale MG, Ferreira SL. Determination of vanadium in

petroleum and petroleum products using atomic spectrometric techniques. Talanta. 2007; 72:349 359. [PubMed: 19071624]

53. Anglade P. Vyas S, Hirsch EC, Agid Y. Apoptosis in dopaminergic neurons of the human substantia nigra during normal aging. Histol Histopathol. 1997; 12:603-610. [PubMed: 9225140]
54. Ansari KA, Johnson A. Olfactory function in patients with Parkinson's disease. J Chronic Dis. 1975; 28:493-497. [PubMed: 1176578]
55. Antunes MB, Bowler R, Doty RL. San Francisco/Oakland Bay Bridge Welder Study: olfactory function. Neurology. 2007; 69:1278-1284. [PubMed: 17875916]
56. Aschner M, Erikson KM, Herrero Hernandez E, Tjalkens R. Manganese and its role in Parkinson's disease: from transport to neuropathology. Neuromolecular Med. 2009; 11:252-266. [PubMed19657747]
57. https://orcid.org/my-orcid?orcid=0000-0002-9764-6048
58. https://scholar.google.com/citations?user=99wmG2IAAAAJ&hl=en
59. Aschner M, Guilarte TR, Schneider JS, Zheng W. Manganese: recent advances in understanding its transport and neurotoxicity. Toxicol Appl Pharmacol. 2007; 221:131-
60. 147. [PubMed: 17466353]
61. Atianjoh FE, Ladenheim B, Krasnova IN, Cadet JL. Amphetamine causes dopamine depletion and cell death in the mouse olfactory bulb. Eur J Pharmacol. 2008: 589:94-
62. 97. [PubMed: 18544452]
63. Avila-Costa MR, Colin-Barenque L, Zepeda-Rodriguez A, Antuna SB, Saldivar OL, Espejel-Maya G, Mussali-Galante P, del Carmen Avila-Casado M. Reyes-Olivera A, Anaya-Martinez V, Fortoul TI. Ependymal epithelium disruption after vanadium pentoxide inhalation. A mice experimental model. Neurosci Lett. 2005; 381:21-25. [PubMed: 15882783]
64. Avila-Costa MR, Montiel Flores E, Colin-Barenque L, Ordonez JL, Gutierrez AL, Nino-Cabrera HG, Mussali-Galante P. Fortoul TI. Nigrostriatal modifications after vanadium inhalation: an immunocytochemical and cytological approach. Neurochem Res. 2004; 29:1365-1369. [PubMed:15202766]
65. Baker H, Kawano T, Margolis FL, Joh TH. Transneuronal regulation of tyrosine hydroxylase expression in olfactory bulb of mouse and rat. J Neurosci. 1983; 3:69-78. [PubMed: 6130133]
66. Bengtsson, S.; Tyler, G. Vanadium in the environment. London. University of London Monitoring and Assessment Research Centre; 1976. vol. (MARC Report No. 2) Bertine KK, Goldberg ED. Fossil fuel combustion and the major sedimentary cycle. Science. 1971;173:233-235. [PubMed: 17741418]
67. Braak H, Braak E. Pathoanatomy of Parkinson's disease. J Neurol. 2000; 247(Suppl 2):113-110. [PubMed: 10991663]