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Cerebroprotective Effect of Polybion against Radiation and Cadmium Induced Changes in the Swiss Albino Mice

Arindam Basu
Associate Professor (Zoology)
R.N.Ruia Govt.College,Ramgarh Shekhawati,Sikar
Manisha Agarwal
Professor (Zoology)
Ekta Kumari, Neha Budania
Research Scholar
**Radiation Biology Laboratory, Govt. Dungar College, Bikaner (334001)*
Email-abasu101020@gmail.com, Mobile-9983357962

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Abstract

The brain is highly vulnerable to environmental toxicants such as ionizing radiation and cadmium, both of which can induce severe neurodegenerative alterations through oxidative stress, inflammation, and neuronal cell death. Radiation exposure damages neural stem cells and disrupts neurogenesis, while cadmium accumulates in brain tissues and promotes oxidative injury and mitochondrial dysfunction. Since antioxidant therapy has shown promise in reducing neurotoxicity, the present study was designed to evaluate the neuroprotective efficacy of Polybion, a B-complex multivitamin formulation, against radiation- and cadmium-induced brain damage in Swiss albino mice.

Male Swiss albino mice were divided into different experimental groups including sham control, cadmium-treated, irradiated, combined radiation and cadmium-treated, and Polybion-pretreated groups. Animals were exposed to gamma radiation doses of 2.0 Gy and 4.0 Gy, with cadmium chloride administered orally at 20 ppm. Polybion syrup was given orally at a dose of 0.01 ml/animal/day for seven days prior to treatment and continued until the completion of the experiment. Animals were autopsied at 1, 2, 4, 7, 14, and 28 days post-treatment, and brain tissues were subjected to histopathological evaluation.

Histological observations revealed significant neurotoxic alterations in radiation- and cadmium-exposed groups, including pycnotic nuclei, cytoplasmic vacuolation, necrosis, hemorrhage, hydrocephaly, malformed corpus callosum, venous congestion, and disruption of normal cytoarchitecture. Combined exposure to radiation and cadmium produced more severe and synergistic damage compared to individual treatments. Higher radiation doses showed greater tissue injury and delayed recovery. However, Polybion-treated groups demonstrated reduced histopathological damage, decreased neuronal degeneration, and earlier recovery at all observation intervals. The protective effect of Polybion may be attributed to its antioxidant and neuroprotective properties, which help reduce oxidative stress and support cellular repair mechanisms.

The findings of the present study suggest that Polybion possesses significant neuroprotective potential against radiation- and cadmium-induced brain injury and may serve as a beneficial therapeutic supplement for minimizing neurotoxicity caused by environmental and radiation-related hazards.

Keywords*: Road, Infrastructure, Development, India, Rural, Urban, Economy etc.*

Introduction

The brain is highly sensitive to environmental toxins and oxidative damage, making it vulnerable to agents such as ionizing radiation and heavy metals like cadmium. Exposure to these toxicants has become a major health concern because of their ability to induce neurological dysfunction,

cognitive impairment, and behavioural abnormalities. Radiation exposure may occur during cancer radiotherapy, industrial applications, or accidental exposure, whereas cadmium contamination is commonly associated with industrial waste, cigarette smoke, polluted food, and water. Despite their different routes of exposure, both radiation and cadmium produce severe neurotoxic effects mainly through oxidative stress, inflammation, and neuronal cell death.

Ionizing radiation affects the central nervous system by damaging neural stem cells and disrupting neurogenesis, particularly in the hippocampus and subventricular zone, which are important regions for memory and learning. Radiation exposure enhances the production of reactive oxygen species (ROS), activates inflammatory cytokines, and reduces the levels of important neuroprotective factors. These alterations lead to apoptosis, impaired neuronal signalling, and long-term cognitive deficits. In addition, radiation-induced mitochondrial dysfunction and metabolic disturbances further contribute to neuronal injury.

Cadmium is another potent neurotoxic agent known for its long biological half-life and ability to accumulate in body tissues, including the brain. It can cross the blood–brain barrier and induce oxidative stress by increasing ROS generation and lipid peroxidation. Cadmium exposure also alters intracellular signalling pathways such as the mTOR pathway, leading to neuronal degeneration, mitochondrial dysfunction, and both apoptotic and necrotic cell death. Continuous accumulation of cadmium may therefore result in progressive neurodegenerative changes and impaired brain function.

Since oxidative stress and inflammation are the major mechanisms involved in radiation- and cadmium-induced neurotoxicity, antioxidant-based therapeutic approaches have gained considerable attention. B-complex vitamins are known to play important roles in cellular metabolism, DNA repair, neuronal function, and antioxidant defence. Polybion, a multivitamin formulation containing essential B-complex vitamins, may therefore provide neuroprotection by reducing oxidative damage, improving cellular repair mechanisms, and maintaining neuronal integrity.

Considering the limited studies on the combined neuroprotective role of Polybion against radiation- and cadmium-induced brain damage, the present study was designed to evaluate its protective efficacy in mice. The study aims to investigate whether Polybion supplementation can reduce oxidative stress, neuronal injury, and biochemical alterations induced by these toxic insults, thereby helping to preserve normal neurological function.

Procurement of Animals

For the study, a male Swiss albino mice was taken, about six to eight weeks old—from the animal house at CCS University in Hissar. Settled them into an air-cooled room so that we could keep a close eye on the temperature and lighting to keep them comfortable. Their main diet was standard mouse feed from Brook Bond Lipton India, but also treated them to germinated gram occasionally. They had fresh tap water ad libitum and as a safety measure to keep them healthy added a bit of tetracycline to their water every two weeks to prevent any infections.

Cadmium Chloride Treatment

To study the effects of cadmium, we added cadmium chloride ($CdCl_2$)—which we sourced from S.D. Fine Chemicals in Boiser—directly into the animals' drinking water.

Source of Irradiation

The animals used in the experiment were irradiated at the Radiotherapy Department of Prince Bijay Singh Memorial Hospital, Bikaner (Rajasthan) by Theratron, a Cobalt-60 beam therapy unit which was a source, procured from Atomic Energy Agency Ltd., Canada.

Mode of Irradiation

All the mice were exposed to Co^{60} y-radiation simultaneously in a well-ventilated wooden box of size 30 cm x 30 cm x 5cm having a glass lid. The box was placed at a distance of 75cms from the radiation source.

During experimentation, the dose rate varied from 0.97 Gy/min to 1.97 Gy/min. The dose was calculated at the midpoint by multiplying dose rate and tissue air ratio. The tissues of Swiss albino mice were assumed to be equivalent to human soft tissues.

Polybion

Polybion syrup was procured from Merck Company, Gujrat, India. Polybion was administered orally at a dose rate of 0.01 ml/animal/day. The drug was given from seven days prior to the commencement of cadmium chloride treatment or irradiation.

Materials and Methods

Herbal plants and products represent important source of natural antioxidant and offer an alternative to synthetic protectors. Therefore, for the purpose of studying the modification by Polybion against radiation and cadmium, male Swiss albino mice were divided into seven groups. The mice were exposed to gamma radiation (2.0 Gy

and 4.0 Gy) and also provided cadmium 20ppm both separately and combined. The Polybion was given to experimental groups after irradiation and cadmium treatment. Polybion syrup was administered orally at a dose rate of 0.01ml/animal/day. Polybion was given seven days prior to radiation or cadmium chloride or combined treatment. A minimum of five animals from each group were sacrificed by cervical dislocation and autopsied at each post treatment intervals of 1,2,4,7,14,28 days. Brain is taken out and was kept at -20^{0}c. After sacrificing the animals, pieces of the cerebral cortex will be taken out and some of them will be immediately immersed in Bouin's fixative for 24 hours. The tissues would be washed in water to remove excessive of fixative, dehydrated in graded series of alcohol, cleared in xylene and embedded in paraffin wax. Section will be cut at 5 µ and stained in Harris haematoxylin and alcoholic eosin.

Experimental Design

To study the modulatory effect of Polybion in the brain of Swiss albino mice against the deleterious effect of cadmium and irradiation, the mice were divided into following groups:

GROUP-I (Sham Irradiated Animals-Normal)

Animals of this group were sham-irradiated and served as normal group.

GROUP-II (Cadmium chloride treated animals)

The animals of this group were orally fed with cadmium chloride solution at the dose of 20 ppm ad libitum in drinking water continuously till the last autopsy day.

GROUP-III (Only irradiated animals)

Animals of this group were exposed to sub-lethal doses of gamma radiation from Cobalt 60 source. This group was divided into two sub-groups, each of which was exposed to a different dose of radiation: -

Sub group IIIa: 2.0 Gy

Sub group IIIb: 4.0 Gy

GROUP IV (Animals treated with radiation and cadmium chloride)

Mice of this group were administered cadmium chloride orally at a dose of 20 ppm and were also exposed to different doses of radiation. This group was further divided into two sub groups on the basis of radiation dose received:

Sub group IVa: 2.0 Gy + $CdCl_2$

Sub group IVb: 4.0 Gy + $CdCl_2$

GROUP V (Cadmium chloride and Polybion treated animals)

The mice of this group were orally fed with cadmium chloride at a dose of 20 ppm and were administered Polybion orally at a dose of 0.01 ml/animal/day, from seven days prior to cadmium chloride treatment and this was continued up to last day of autopsy.

GROUP VI (Radiation and Polybion treated animals)

The animals of this group were irradiated with a sub lethal dose of gamma rays from a cobalt-60 source. Polybion was provided orally, from seven days prior to the irradiation and continued till the 28th day.

This group was further divided into two sub-groups on the basis of radiation dose administered:

Sub group VIa: 2.0 Gy+ Polybion

Sub group VIb: 4.0 Gy + Polybion

GROUP VII (Radiation, Cadmium chloride and drug treated animals)

Mice of this group were given CdCl, orally at the dose rate of 20 ppm and were also administered Polybion (0.01 ml/animal/day) from seven days prior to cadmium chloride ($CdCl_2$) treatment and irradiation and this was continued till the last day of autopsy interval (i.e.28th day). This group was further divided into two sub-groups, each of which was irradiated with a different dose of radiation:

Sub group VIIa: 2.0 Gy + $CdCl_2$ + Polybion

Sub group VIIb: 4.0 Gy + $CdCl_2$ + Polybion

AUTOPSY: Five animals of each group (groups II to VII) were autopsied after cervical dislocation at each posttreatment intervals of **1,2,4, 7, 14** and **28 days**. In addition, five sham-irradiated (normal) mice were also autopsied in a similar manner. Immediately after the autopsy, the brain was taken out and weighed. Later on, the width and length of brain were also recorded. Afterwards, part of brain was kept at **-20° C** for biochemical investigation and the rest of brain was fixed in Bouin's Fluid for histological studies.

Histological Studies

- The histopathological changes observed were pycnotic nuclei and crenated cells with condensation of nuclear material resulting into hyperchromatic cells.
- Hydrocephaly with enlarged lateral ventricles was also noted. Corpus callosum was seen malformed.
- Thickened meninges and venous congestion were also noticed.
- In the irradiated brains cytoarchitectonic layers were reduced in depth and showed

some degree of intermixing of cells of various laminae.

- Hematoma was present between the cortex and medulla with numerous pycnotic and necrotic nuclei.
- After exposure to a higher dose (6.0 Gy) similar changes were noticed but they were more pronounced and there was late manifestation of recovery.
- In the combined treatment of radiation and cadmium chloride synergistic effects were observed.
- The Polybion treated animals exhibited less severe damage as compared to non-drug treated animals at all the corresponding intervals.
- An early and fast recovery was also noticed in Polybion pretreated animals.

Result

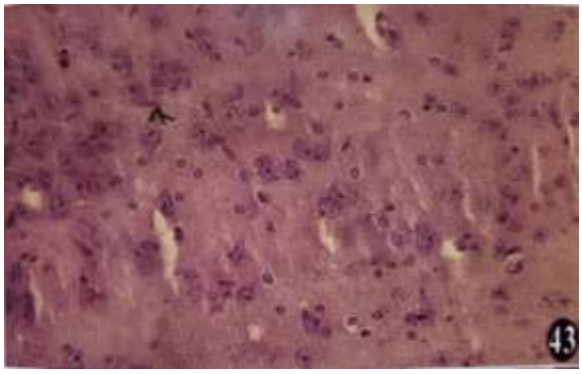

Fig.1. Photomicrograph of brain of mice after 7-days of gamma ray exposure (2.0 Gy) with prior administration of Polybion exhibiting cytoplasmic degranulation and vacuolation. Crenated cells and pycnotic nuclei are also seen.

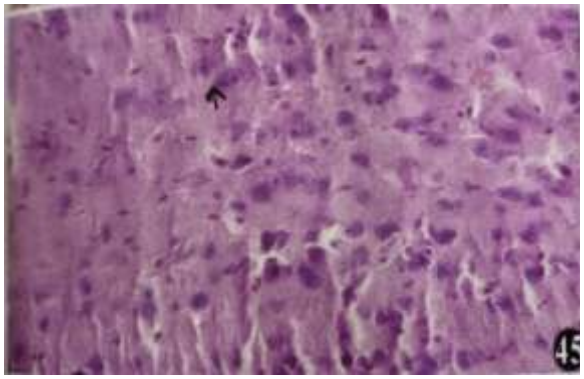

Fig.2. Photomicrograph of brain of mice after 28-days of gamma ray exposure (2.0 Gy) with prior administration of Polybion illustrating almost normal architecture.

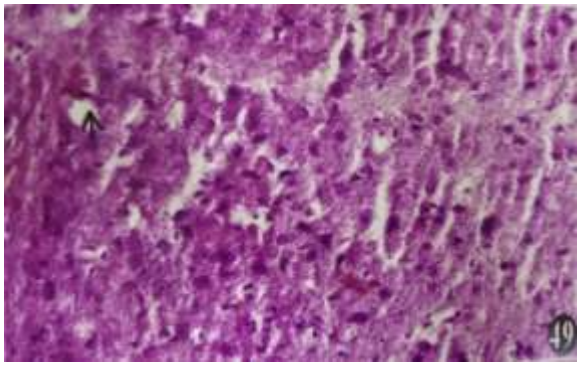

Fig. 3. Photomicrograph of brain of mice after 7-days of gamma ray exposure (4.0 Gy) with prior administration of Polybion illustrating distorted cerebral cortex, cytoplasmic degranulation and vacuolation. Karyolysis and karyorrhexis are also visible.

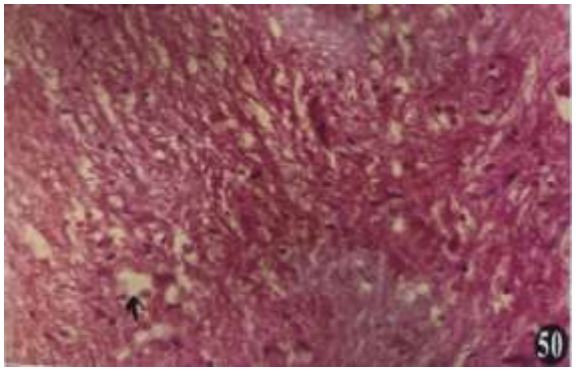

Fig.4. Photomicrograph of brain of mice after 14-days of gamma ray exposure (4.0 Gy) with prior administration of Polybion representing oedematous cells. Many fusiform cells and pyramidal cells are clearly visible. Fluid infiltration is also seen.

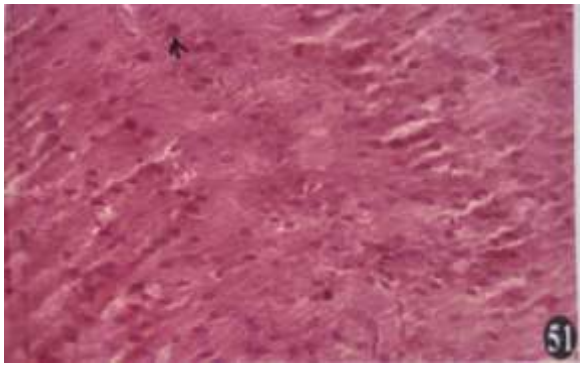

Fig.5. Photomicrograph of brain of mice after 28-days of gamma ray exposure (4.0 Gy) with prior administration of Polybion exhibiting disturbed laminar pattern and irregular arrangement of neurons

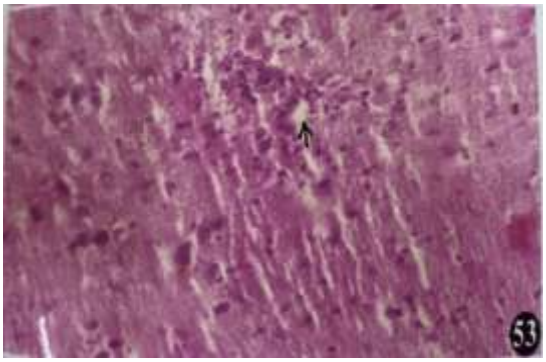

Fig.6. Photomicrograph of brain of Swiss albino mice after 2-days of combined treatment of gamma rays (2.0 Gy) and Cadmium chloride in the presence of Polybion depicting distortion in cerebral cortex tissue, pycnosis, karyolysis and enucleation.

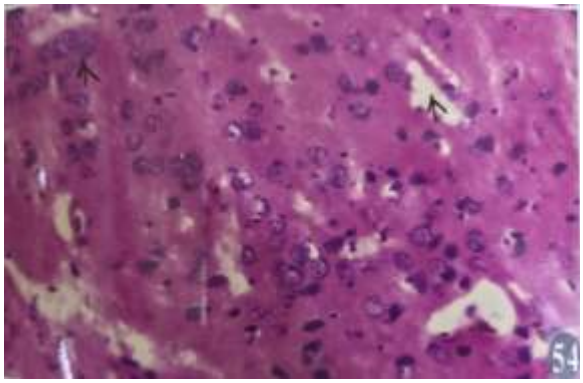

Fig.7. Photomicrograph of brain of Swiss albino mice after 4-days of combined treatment of gamma rays (2.0 Gy) and Cadmium chloride in the presence of Polybion displaying nuclear distortion and displacement. A few abnormal giant cells and clustering of granular cells are also evident.

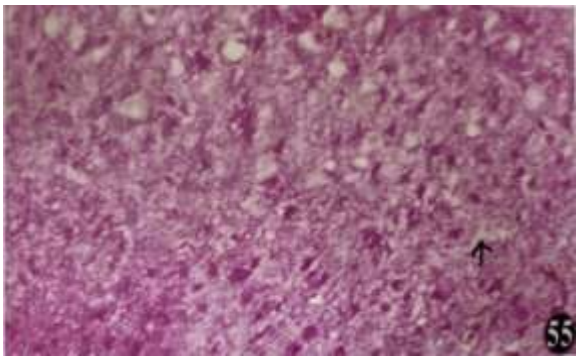

Fig.8. Photomicrograph of brain of Swiss albino mice after 7-days of combined treatment of gamma rays (2.0Gy) and Cadmium chloride in the presence of Polybion illustrating distorted cerebral cortex and cytoplasmic vacuolation. Loss of neuropil is also seen.

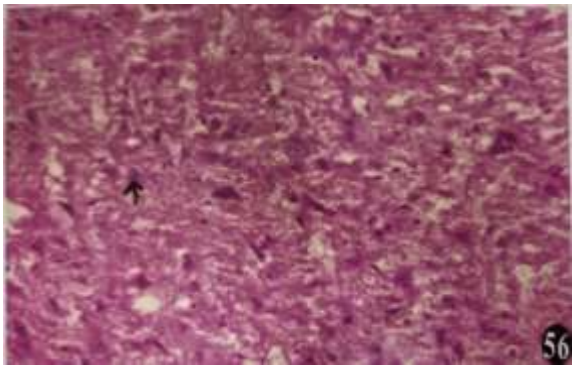

Fig.9. Photomicrograph of brain of Swiss albino mice after 14-days of combined treatment of gamma rays (2.0 Gy) and Cadmium chloride in the presence of Polybion exhibiting nuclear pycnosis. Scattered granular cells are also seen.

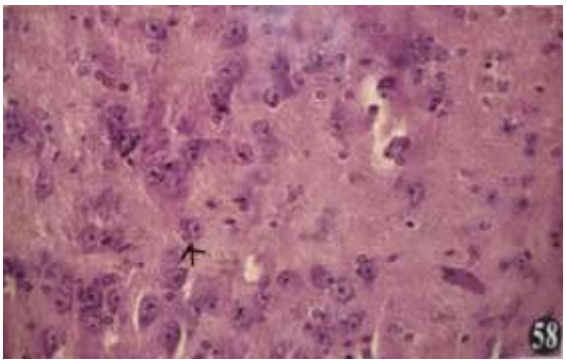

Fig.10. Photomicrograph of brain of Swiss albino mice after 1-day of combined treatment of gamma rays (4.0 Gy) and Cadmium chloride with prior administration of Polybion showing karyolysis and karyorrhexis.

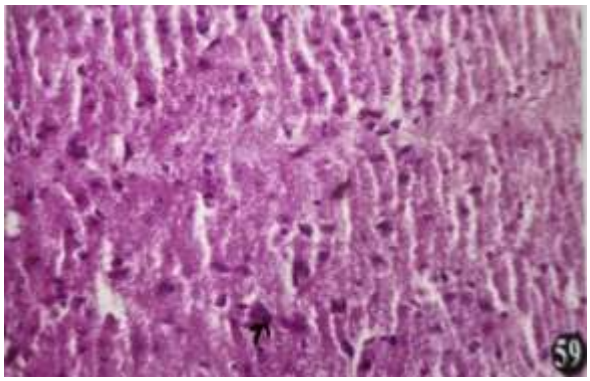

Fig.11. Photomicrograph of brain of Swiss albino mice after 2-days of combined treatment of gamma rays (4.0 Gy) and Cadmium chloride with prior administration of Polybion depicting completely disorganised cerebral architecture. Crenated cells, pycnotic nuclei and cytoplasmic vacuolation are clearly evident. Spongy degeneration of neuropil is also visible.

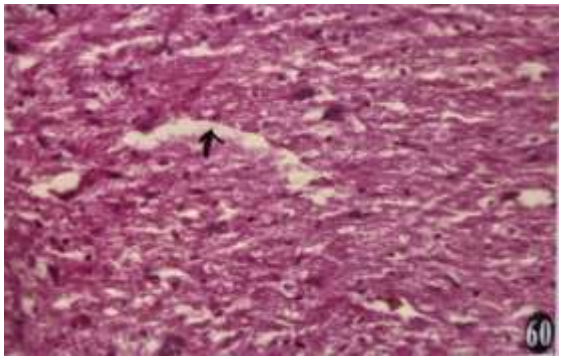

Fig.12. Photomicrograph of brain of Swiss albino mice after 4-days of combined treatment of gamma rays (4.0 Gy) and Cadmium chloride with prior administration of Polybion displaying spongy degeneration of the neuropil. Karyolysis and karyorrhexis are clearly evident. A damaged blood vessel is also seen.

Discussion

The present investigation was carried out to evaluate the Cerebroprotective efficacy of Polybion against radiation- and cadmium-induced histopathological alterations in the brain of Swiss albino mice. The findings of the present study clearly demonstrate that exposure to gamma radiation and cadmium chloride, either individually or in combination, produced severe neuronal and vascular damage in brain tissues. Histological observations revealed pycnotic nuclei, cytoplasmic vacuolation, karyolysis, karyorrhexis, venous congestion, hemorrhage, spongy degeneration of neuropil, hydrocephaly, malformed corpus callosum, and distortion of normal cerebral architecture. However, pretreatment with Polybion significantly reduced the severity of these lesions and promoted earlier tissue recovery, suggesting its considerable neuroprotective potential.

The brain is highly sensitive to oxidative injury because of its high oxygen consumption, abundant polyunsaturated fatty acids, and relatively limited antioxidant defence system. Ionizing radiation induces radiolysis of water molecules, resulting in the generation of reactive oxygen species (ROS) such as hydroxyl radicals, hydrogen peroxide, and superoxide anions. These free radicals initiate oxidative damage to lipids, proteins, nucleic acids, and cellular membranes, ultimately leading to neuronal degeneration and apoptosis. Radiation exposure also disrupts mitochondrial function and activates inflammatory signalling pathways, thereby aggravating tissue injury (Karmaker *et al.*, 2021).

Several earlier investigations support the present findings regarding radiation-induced neurodegeneration. Tada *et al.* (2000) reported that X-irradiation produced a prolonged reduction in cell proliferation in the dentate gyrus of adult rats, indicating that neural precursor cells are extremely sensitive to radiation-induced injury. They further observed that apoptosis increased rapidly following irradiation and that neural stem cell populations failed to repopulate effectively even after prolonged intervals. Similarly, Mizumatsu *et al.* (2003) demonstrated that low-dose irradiation markedly reduced hippocampal neurogenesis and increased apoptosis in the sub granular zone, which may contribute to cognitive impairment following cranial irradiation. These studies strongly support the histopathological observations of neuronal degeneration, pyknosis, and cortical disorganization observed in the present investigation.

Likewise, Achanta *et al.* (2012) demonstrated that localized irradiation of the subventricular zone severely impaired the generation of proliferating neural precursor cells and disrupted migration of neuroblasts in mice. Lazarini *et al.* (2009) further reported that cranial irradiation reduced olfactory bulb neurogenesis for prolonged periods and affected long-term neuronal functioning. These reports collectively indicate that radiation severely affects neurogenesis, neuronal organization, and brain tissue integrity, which correlates well with the distorted cortical layers, malformed corpus callosum, and disrupted cytoarchitecture observed in the present study.

The present investigation also revealed marked histopathological alterations following cadmium chloride exposure. Cadmium is a highly toxic environmental pollutant with a long biological half-life and a strong affinity for sulfhydryl-containing proteins. It crosses the blood–brain barrier and induces oxidative stress by increasing ROS production and suppressing endogenous antioxidant systems. Cadmium-induced oxidative injury damages mitochondrial membranes, alters ATP production, disrupts calcium homeostasis, and activates apoptotic signalling pathways, thereby leading to neuronal degeneration.

Agnihotri *et al.* (2015) demonstrated that the brain is one of the most susceptible organs to cadmium-induced oxidative stress because of increased lipid peroxidation and altered antioxidant defence mechanisms. Their study reported enhanced ROS generation, DNA damage, and increased expression of apoptotic markers in brain tissues following cadmium exposure. Similar observations were recorded in the present study where cadmium-treated animals exhibited pycnotic nuclei, cytoplasmic vacuolation, necrosis, and vascular congestion.

Further support for the present findings comes from López *et al.* (2006), who demonstrated that cadmium exposure induced ROS generation and lipid peroxidation in cortical neurons, leading to

both apoptotic and necrotic cell death. They also reported mitochondrial membrane dysfunction and ATP depletion in neuronal cells exposed to cadmium. Likewise, Chen *et al.* (2011) reported that cadmium activates the mTOR signalling pathway through ROS-mediated mechanisms, resulting in neuronal apoptosis. Their findings indicated that oxidative stress plays a central role in cadmium-induced neurodegeneration and that antioxidants may significantly reduce neuronal injury. Wang and Du (2013) also reviewed that cadmium-induced neurotoxicity involves oxidative damage, blood–brain barrier disruption, altered neurotransmission, inflammation, and epigenetic modifications. These reports strongly correlate with the histological abnormalities observed in the present study.

The combined exposure of gamma radiation and cadmium chloride produced more severe histopathological alterations than either treatment alone, indicating a synergistic interaction between the two toxic agents. Combined treatment groups exhibited extensive pyknosis, karyolysis, spongy degeneration of neuropil, distorted cortical layers, damaged blood vessels, and severe disorganization of cerebral architecture. The severity of lesions was particularly higher in animals exposed to 4.0 Gy radiation along with cadmium chloride, where delayed recovery and persistent neuronal damage were evident even at later autopsy intervals.

The synergistic effect observed in the combined treatment groups may be attributed to cumulative oxidative stress and enhanced free radical generation. Radiation produces immediate ROS generation through radiolysis, whereas cadmium simultaneously impairs antioxidant defence systems and mitochondrial functions. The combined action therefore amplifies lipid peroxidation, inflammatory cytokine production, DNA fragmentation, and apoptotic signalling pathways, leading to severe neuronal injury and delayed recovery.

One of the most significant findings of the present investigation was the marked reduction in tissue injury in Polybion-treated animals. Polybion pretreatment resulted in comparatively preserved neuronal organization, reduced pyknosis, decreased vacuolation, lesser vascular congestion, and earlier restoration of normal cerebral architecture. Recovery was significantly faster in Polybion-pretreated groups compared to untreated groups at corresponding intervals.

The protective effect of Polybion may be attributed to its B-complex vitamins, including vitamin B1 (thiamine), vitamin B2 (riboflavin), vitamin B3 (niacin), vitamin B6, vitamin B12, and pantothenic acid, which are known to play important roles in cellular metabolism, neuronal repair, antioxidant defence, and neurotransmitter synthesis. Vitamin B12 has been shown to possess antioxidant and anti-inflammatory properties by scavenging ROS and maintaining intracellular glutathione levels. Fakhrabad *et al.* (2022) demonstrated that vitamin B12 significantly reduced oxidative stress, inflammation, and apoptosis in paraquat-induced neurotoxicity in mice. Their study reported improvement in motor coordination and reduction in inflammatory cytokines following vitamin B12 administration.

Niacin (vitamin B3), another important constituent of Polybion, has also been reported to possess neuroprotective effects. Gasperi *et al.* (2019) reviewed the role of niacin in neuronal survival, DNA repair, oxidative metabolism, and neuroprotection in various neurological disorders. Recently, Tunç *et al.* (2025) demonstrated that niacin administration significantly reduced oxidative stress, neuroinflammation, and neuronal apoptosis following whole-brain irradiation. Their study further showed improved hippocampal neuronal density and cognitive function in irradiated animals treated with niacin.

Pantothenic acid has similarly been shown to improve mitochondrial function and reduce oxidative stress in irradiated brain tissues. Sm *et al.* (2018) demonstrated that pantothenic acid treatment reduced lipid peroxidation and restored antioxidant balance and neurotransmitter metabolism in gamma-irradiated rats. These findings strongly support the present observations regarding the faster recovery and reduced neuronal degeneration observed in Polybion-treated groups.

The antioxidant and membrane-stabilizing properties of Polybion may therefore reduce lipid peroxidation, preserve mitochondrial integrity, enhance DNA repair mechanisms, and maintain neuronal metabolism following radiation and cadmium exposure. Reduced vascular congestion and edema observed in Polybion-treated animals further suggest its possible role in maintaining vascular integrity and minimizing inflammatory responses.

The dose-dependent increase in tissue injury observed in the present investigation is also consistent with earlier reports demonstrating that higher radiation doses produce greater oxidative stress and neuronal degeneration. Animals exposed to 4.0 Gy exhibited more pronounced histological abnormalities than those exposed to 2.0 Gy, indicating a direct relationship between radiation dose and severity of neurotoxicity. Similarly, combined treatment groups demonstrated greater tissue injury than single-treatment groups, highlighting the importance of evaluating combined environmental and radiation-induced toxicities.

The present histopathological findings also correlate with previously reported biochemical alterations induced by radiation and cadmium exposure, including changes in proteins, glycogen, phospholipids, cholesterol, DNA, RNA, and antioxidant enzyme activities. Structural degeneration observed histologically may therefore be associated with underlying oxidative imbalance and metabolic disturbances within neuronal tissues.

Recent studies have also highlighted the importance of antioxidants and natural neuroprotective agents against radiation-induced brain injury. Adnan *et al.* (2022) reviewed the radioprotective role of natural polyphenols and reported that antioxidant compounds reduce radiation-induced oxidative stress, inflammation, and DNA damage through free radical scavenging and enhancement of endogenous defence systems. Akhlada *et al.* (2024) similarly emphasized the role of natural neuroprotective compounds in minimizing radiation-induced neurological damage through antioxidant and anti-inflammatory mechanisms. These findings support the present observations that antioxidant supplementation can significantly attenuate radiation- and cadmium-induced neurotoxicity.

Thus, the present study provides strong evidence that Polybion possesses significant Cerebroprotective efficacy against radiation- and cadmium-induced neuronal injury. Since oxidative stress and inflammation are central mechanisms underlying radiation-induced neurodegeneration and heavy metal toxicity, antioxidant-based supplementation using Polybion may prove beneficial in reducing neuronal damage and accelerating tissue recovery.

From a clinical perspective, these findings may have important implications for reducing neurotoxicity associated with radiotherapy, occupational radiation exposure, environmental pollution, and heavy metal toxicity. Polybion, being an economical and easily available multivitamin preparation, may serve as a supportive therapeutic supplement for minimizing oxidative neuronal injury. However, further investigations involving molecular markers, antioxidant enzyme profiling, neurotransmitter analysis, behavioural studies, and ultrastructural evaluation are required to better understand the precise mechanisms responsible for its neuroprotective action.

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Conclusion

The present study demonstrates that exposure to gamma radiation and cadmium chloride induces significant neurotoxic alterations in the brain of Swiss albino mice. Histopathological observations revealed severe neuronal degeneration, pyknosis, cytoplasmic vacuolation, vascular congestion, edema, hemorrhage, disruption of cortical architecture, and degeneration of neuropil, indicating extensive oxidative and cellular damage. These findings are consistent with earlier reports showing that ionizing radiation and cadmium generate excessive reactive oxygen species (ROS), impair antioxidant defense systems, damage mitochondrial function, and activate apoptotic pathways leading to neuronal injury (Tada et al., 2000; Mizumatsu et al., 2003; López et al., 2006; Wang & Du, 2013; Chen et al., 2011).

The severity of damage was markedly greater in animals receiving combined radiation and cadmium treatment, suggesting a synergistic interaction between the two toxic insults. Radiation-induced ROS generation together with cadmium-mediated suppression of endogenous antioxidant mechanisms appears to intensify oxidative stress, neuronal degeneration, and delayed tissue recovery. Similar synergistic neurotoxic mechanisms have been reported in studies evaluating radiation-associated oxidative injury and cadmium-induced neuronal apoptosis (Agnihotri et al., 2015; Chen et al., 2011).

Pretreatment with Polybion significantly reduced the extent of histopathological damage and promoted earlier recovery of brain architecture. Polybion-treated animals showed reduced pyknosis, lesser vacuolation, improved neuronal organization, and decreased vascular abnormalities compared with untreated groups. The protective efficacy of Polybion may be attributed to the antioxidant and neuro-supportive roles of B-complex vitamins, which participate in DNA repair, mitochondrial energy metabolism, neurotransmitter synthesis, maintenance of myelin integrity, and reduction of oxidative stress (Fakhrabad et al., 2022; Gasperi et al., 2019; Tunç et al., 2025; Sm et al., 2018).

Overall, the findings suggest that Polybion possesses considerable cerebroprotective potential against radiation- and cadmium-induced neurotoxicity. Being an economical and clinically available multivitamin preparation, Polybion may serve as a supportive therapeutic agent for minimizing neuronal damage associated with radiation exposure, environmental pollutants, and oxidative stress-related neurological disorders. However, further investigations involving molecular biomarkers, antioxidant enzyme profiling, neurotransmitter analysis, behavioral studies, and clinical evaluation are required to elucidate its precise mechanisms of neuroprotection and therapeutic applicability.