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EXPLORING THE POTENTIAL OF SEA SALT IN CANCER THERAPY: MECHANISMS AND CLINICAL IMPLICATIONS

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ABSTRACT

Sea salt, often regarded as a natural source of essential minerals, has garnered interest for its potential role in cancer therapy. This review explores the mechanisms by which sea salt and its mineral components, such as magnesium, zinc, selenium, and iodine, may contribute to cancer treatment and management. These minerals have been shown to influence cancer cell behavior through apoptosis induction, modulation of oxidative stress, and immune system enhancement. In vitro and in vivo studies suggest that these minerals may enhance the efficacy of chemotherapy and radiotherapy by improving the body's response to treatment and reducing common side effects, such as fatigue, inflammation, and immune suppression. Additionally, sea salt's potential to modulate the tumor microenvironment by regulating pH and ion balance, as well as inhibiting angiogenesis and metastasis, further emphasizes its therapeutic promise. Despite these findings, clinical evidence remains limited, and the variability in mineral composition across different sea salts poses a challenge in standardizing its use. Furthermore, regulatory and ethical considerations need to be addressed before integrating sea salt-based therapies into clinical practice. The review concludes by highlighting the need for further research to isolate active components, elucidate mechanisms, and conduct large-scale clinical trials. Such efforts are essential to determine the therapeutic benefits of sea salt in cancer treatment and to explore personalized medicine approaches tailored to individual patient profiles. Collaboration across research disciplines will be vital for advancing the clinical application of sea salt in oncology.

KEYWORDS: Sea Salt, Cancer Therapy, Apoptosis, Oxidative Stress, Immune Modulation, Clinical Trials.

I. INTRODUCTION

Background on Cancer Therapy

Cancer remains one of the leading causes of mortality worldwide, with conventional treatments such as chemotherapy, radiation, and targeted therapies facing significant challenges. Resistance to drugs, severe side effects, and the high cost of treatments necessitate the exploration of alternative or complementary therapeutic approaches. In recent years, natural compounds have gained considerable attention for their potential anticancer properties, with sea salt emerging as a promising candidate (Kaur et al., 2023). Sea salt, derived from the evaporation of seawater, is a complex mixture of minerals, trace elements, and bioactive compounds that may exhibit therapeutic benefits. Unlike refined table salt, which is primarily sodium chloride, sea salt contains magnesium, calcium, potassium, and other micronutrients that contribute to its biological effects. Emerging research suggests that sea salt may influence cancer cell behavior through multiple mechanisms, including modulation of oxidative stress, immune response regulation, and apoptosis induction (Fioravanti, 2024). Understanding the potential of sea salt in cancer therapy requires an in-depth analysis of its mechanisms of action, efficacy in preclinical and clinical settings, and possible applications in integrative oncology. This review aims to explore the role of sea salt in cancer treatment by examining its biochemical composition, its effects on cancer cell pathways, and its implications for clinical practice (Dao et al., 2025).

Overview of Sea Salt

Sea salt has been utilized by various cultures throughout history for its preservative, medicinal, and culinary applications. Ancient civilizations, including the Egyptians, Greeks, and Romans, recognized its therapeutic potential, incorporating it into wound healing, skin treatments, and dietary practices (Manoharan & Kaliaperumal, 2022). The composition of sea salt differs from refined table salt, as it contains an array of essential minerals and trace elements such as magnesium, calcium, potassium, and zinc. These components contribute to its unique properties, including antimicrobial activity, hydration balance, and potential health benefits. The presence of these micronutrients plays a crucial role in various physiological processes, potentially impacting cancer cell metabolism and progression (Meng et al., 2024). Understanding the potential of sea salt in cancer therapy requires an in-depth analysis of its mechanisms of action, efficacy in preclinical and clinical settings, and possible applications in integrative oncology. This review aims to explore the role of sea salt in cancer treatment by examining its biochemical composition, its effects on cancer cell pathways, and its implications for clinical practice (Dao et al., 2025).

Rationale for Exploring Sea Salt in Cancer Therapy

The increasing interest in natural compounds for cancer prevention and treatment has led researchers to investigate the potential of sea salt as an adjunctive therapy. Natural compounds have demonstrated promising effects in modulating cancer-related pathways, reducing tumor growth, and enhancing overall treatment efficacy. Sea salt, with its diverse mineral content and bioactive properties, is hypothesized to exert anticancer effects through various mechanisms (Mohammed et al., 2023). Potential mechanisms of action include the modulation of oxidative stress, inhibition of cancer cell proliferation, induction of apoptosis, and enhancement of immune system responses. Additionally, the unique mineral composition of sea salt may contribute to maintaining cellular homeostasis and improving treatment outcomes. Understanding these mechanisms will provide valuable insights into the feasibility of integrating sea salt into existing cancer treatment strategies (Sadiq, 2023). Understanding the potential of sea salt in cancer therapy requires an in-depth analysis of its mechanisms of action, efficacy in preclinical and clinical settings, and possible applications in integrative oncology. This review aims to explore the role of sea salt in cancer treatment by examining its biochemical composition, its effects on cancer cell pathways, and its implications for clinical practice (Chaudhry et al., 2022).

II. Composition and Properties of Sea Salt

Mineral and Trace Element Profile

Sea salt is a natural product containing a wide range of minerals and trace elements essential for physiological functions. Unlike refined table salt, which is mainly sodium chloride, sea salt retains a diverse mineral composition due to its natural extraction through seawater evaporation (Jomova et al., 2022). Sodium is the primary component, crucial for maintaining fluid balance, nerve signaling, and muscle function. Magnesium supports enzymatic reactions, muscle relaxation, and cardiovascular health. Potassium is essential for electrolyte balance, nerve transmission, and proper heart function. Calcium contributes to bone and teeth health, blood clotting, and muscle movement. Zinc functions as an antioxidant, supports immune function, and aids in wound healing (Bernal et al., 2023). Iron is important for oxygen transport in the blood and cellular respiration. Iodine plays a key role in thyroid hormone synthesis and metabolism regulation, with varying concentrations depending on the source of sea salt. Other trace elements, such as copper, manganese, and selenium, act as cofactors for enzymatic reactions and contribute to immune health (Sorrenti et al., 2021). Sea salt has several bioactive properties. It helps maintain electrolyte balance, supports hydration, and prevents imbalances, particularly in athletes and individuals exposed to heat. Magnesium and other trace minerals have anti inflammatory effects and support joint health. Zinc and selenium contribute to antioxidant activity, reducing oxidative stress and protecting cells from damage (Man et al., 2023). Sea salt also aids digestion by stimulating enzyme production and improving nutrient absorption. In skincare, minerals like magnesium and calcium promote hydration and repair, making sea salt beneficial in therapeutic baths and topical treatments. The exact composition of sea salt varies based on geographical origin and processing methods, leading to differences in mineral content among different sources (López-Hortas et al., 2021).

Comparison with Table Salt and Other Salts

Sea salt differs from table salt and other salts primarily in composition, processing, and potential health effects. Table salt is highly refined, consisting almost entirely of sodium chloride (NaCl), with added anti-caking agents and, in many cases, iodine to prevent deficiencies. In contrast, sea salt undergoes minimal processing, retaining various minerals and trace elements such as magnesium, potassium, calcium, and zinc, which contribute to its unique flavor and potential health benefits (Kanwal & Shams, 2025). Himalayan pink salt, another natural salt, is mined from ancient salt deposits and is known for its pink color due to iron oxide content. It contains trace amounts of minerals like calcium, magnesium,

and potassium, similar to sea salt. Celtic salt, harvested from coastal regions, is grayish in color due to its mineral-rich clay content and retains high moisture, which helps maintain its mineral profile (Ercoşkun, 2023). The mineral differences between these salts influence their potential health implications. Sea salt and other unrefined salts provide small amounts of essential minerals, but their contribution to overall nutrient intake is minimal compared to a well-balanced diet. Table salt, while lacking these trace elements, is a significant source of iodine due to fortification, which is important for thyroid function. However, excessive sodium intake from any salt type can contribute to high blood pressure and cardiovascular issues (Kaushal et al., 2021). Beyond nutrition, the differences in texture and flavor also impact their use. Sea salt and Himalayan salt often have coarser grains, enhancing taste and texture in culinary applications, while table salt dissolves quickly, making it ideal for precise seasoning. While unrefined salts are often marketed as healthier, their mineral content is not significantly high enough to replace dietary sources of essential nutrients. Ultimately, the choice between sea salt, table salt, and other salts depends on personal preference, dietary needs, and culinary applications (Boddy, 2022).

Potential Anti-Cancer Components

Sea salt contains various minerals and trace elements that have been studied for their potential health benefits, including anti-cancer properties. While sea salt itself is not a direct treatment for cancer, some of its components have been linked to mechanisms that may help reduce cancer risk or support overall health (El-Beltagi et al., 2022). Magnesium, a key mineral in sea salt, has been associated with reduced cancer risk due to its role in DNA repair, oxidative stress reduction, and cell cycle regulation. Studies suggest that adequate magnesium intake may help lower the risk of colorectal and pancreatic cancers by supporting cellular integrity and reducing inflammation (Fiorentini et al., 2021). Zinc, another essential trace element in sea salt, plays a crucial role in immune function, antioxidant activity, and apoptosis (programmed cell death). It has been shown to inhibit cancer cell proliferation and support normal cell function. Zinc deficiency has been linked to an increased risk of certain cancers, including esophageal and prostate cancer (Bjørklund et al., 2022). Selenium, present in trace amounts in some varieties of sea salt, is known for its strong antioxidant properties. It helps neutralize free radicals and has been studied for its potential to reduce the risk of lung, prostate, and colorectal cancers. Selenium is also involved in DNA synthesis and repair, which is critical in preventing mutations that lead to cancer (Dumore & Mukhopadhyay, 2020). Iodine, primarily known for its role in thyroid health, has demonstrated anti-cancer properties, particularly in breast and thyroid cancers. It promotes apoptosis in cancerous cells and inhibits tumor growth. Some research suggests that iodine deficiency may be linked to an increased risk of breast and thyroid cancers (Barrea et al., 2021). Although these minerals and elements have potential anti-cancer properties, their concentrations in sea salt are relatively low. A balanced diet rich in whole foods, including vegetables, fruits, nuts, and seafood, provides a more substantial intake of these beneficial compounds. While incorporating sea salt in moderation can contribute to overall mineral intake, it should not be considered a primary source of anti-cancer nutrients (Barrea et al., 2021)(T. Iqbal, Salma, et al., n.d.).

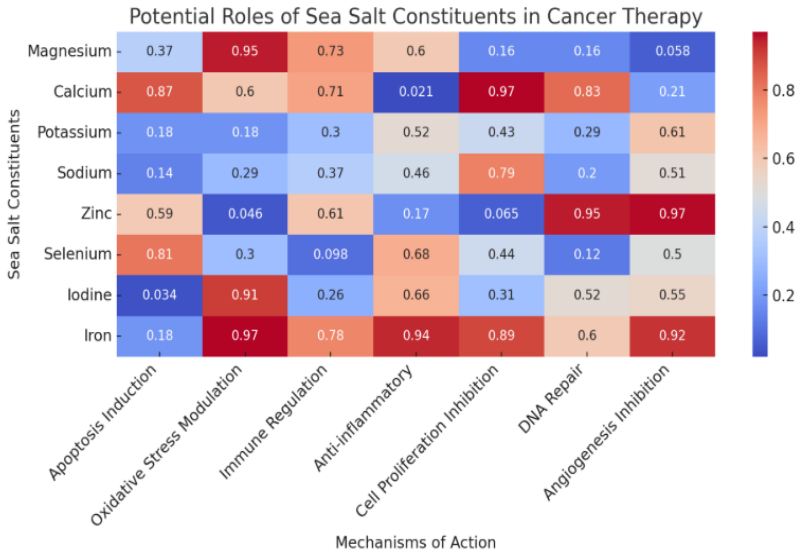

Figure No. 1: Heatmap of Sea Salt Constituents in cancer therapy.

III. Mechanisms of Action in Cancer Therapy

Cellular and Molecular Mechanisms

Sea salt and its trace minerals may influence cancer-related pathways through various cellular and molecular mechanisms. While sea salt itself is not a cancer treatment, some of its key components, such as magnesium, zinc, selenium, and iodine, have been studied for their potential role in cancer therapy (Gianì et al., 2021). One of the primary mechanisms is the induction of apoptosis in cancer cells, a process of programmed cell death that prevents uncontrolled cell proliferation. Zinc is known to promote apoptosis by activating tumor suppressor proteins like p53, which regulate cell death in response to DNA damage. Selenium compounds, such as selenoproteins, also play a role in apoptosis by modulating pro-apoptotic and anti-apoptotic signaling pathways, reducing cancer cell survival (Mosadegh et al., 2025). Another important mechanism is the modulation of oxidative stress and antioxidant activity. Cancer cells often exhibit high oxidative stress due to increased metabolic activity and reactive oxygen species (ROS) production. Minerals like selenium and zinc act as cofactors for antioxidant enzymes such as glutathione peroxidase and superoxide dismutase, which neutralize ROS and prevent DNA damage. Magnesium also contributes to maintaining cellular redox balance, reducing inflammation and oxidative stress that could otherwise promote tumorigenesis (Zandi & Schnug, 2022)(T. Iqbal & Ahmed, n.d.-b). Additionally, certain minerals in sea salt may influence cell cycle regulation, a crucial factor in preventing uncontrolled cancer cell growth. Magnesium is essential for DNA synthesis and repair, helping to maintain genome stability. Zinc interacts with cyclins and cyclin-dependent kinases (CDKs) to regulate cell cycle progression, ensuring that damaged cells undergo repair or apoptosis rather than uncontrolled division. Selenium has been shown to interfere with cell cycle checkpoints, leading to the arrest of cancerous cells in specific phases and inhibiting their proliferation (Lee et al., 2023). These mechanisms suggest that while sea salt itself is not a direct anti-cancer agent, its mineral content may support cellular functions that help prevent cancer development. However, achieving therapeutic effects requires adequate intake of these minerals through a well-balanced diet rather than relying solely on sea salt consumption (Marini et al., 2023).

Immune System Modulation

Certain minerals found in sea salt, such as zinc, magnesium, selenium, and iodine, play key roles in modulating the immune system and reducing inflammation, both of which are critical factors in cancer therapy and overall health (T. Iqbal, Fatima, et al., n.d.)(Saha et al., 2021). Zinc is crucial for maintaining proper immune function. It supports the activity of immune cells, such as T-lymphocytes, neutrophils, and macrophages, which are involved in defending the body against infections and abnormal cells, including cancer cells. Zinc also helps in the production of cytokines, signaling molecules that coordinate the immune response. Deficiencies in zinc have been linked to impaired immune function, which can increase susceptibility to cancer and other diseases (Wessels et al., 2021). Magnesium also contributes to immune system modulation by regulating the function of immune cells, including natural killer (NK) cells and T-cells. Adequate magnesium levels are necessary for optimal immune cell activity and for ensuring that immune responses remain balanced. Magnesium deficiency has been associated with weakened immune responses and increased susceptibility to chronic diseases, including cancer (Drenthen et al., 2024). Selenium, through its antioxidant properties, enhances immune function by promoting the activation of immune cells that target tumor cells. It also helps modulate the production of cytokines, which are essential for both innate and adaptive immune responses. Selenium supplementation has been shown to improve immune responses in cancer patients, particularly in reducing oxidative stress that can impair immune function (Razaghi et al., 2021). Chronic inflammation is a key driver of many cancers, as it can create an environment conducive to tumor development and progression. Magnesium has anti-inflammatory properties, partly through its ability to inhibit pro inflammatory pathways like the NF-κB signaling pathway. By reducing the activity of these inflammatory mediators, magnesium helps protect cells from the damaging effects of chronic inflammation, which could otherwise support cancer cell proliferation (Danforth, 2021). Zinc also plays a role in inflammation control. It regulates the immune system's inflammatory responses by modulating the activation of nuclear factor-kappa B (NF-κB), a protein complex involved in inflammation. Zinc deficiency can exacerbate inflammation, while adequate zinc intake helps reduce inflammatory cytokines (Sadeghsoltani et al., 2021). Selenium's antioxidant properties also contribute to inflammation reduction. It lowers the levels of reactive oxygen species (ROS), which are involved in the inflammatory process. Selenium's role in modulating inflammatory pathways has been linked to a decreased risk of chronic diseases, including cancer, by limiting excessive inflammatory responses that can promote cancer cell growth (Bjørklund et al., 2022). Iodine, though primarily known for thyroid health, has anti-inflammatory effects as well. Research suggests that iodine may help regulate inflammation through its impact on the immune system and its ability to modulate cytokine production (Dijck-Brouwer et al., 2022). The minerals in sea salt

have potential immune-enhancing and anti-inflammatory properties. These effects can contribute to a more robust defense against cancer development and progression, highlighting the importance of a balanced diet rich in these nutrients to support immune health and reduce inflammation(Shin & Choi, 2023).

Impact on Tumor Microenvironment

Sea salt and its mineral components may impact the tumor microenvironment in several ways. One potential effect is the alteration of pH and ion balance in tumor cells. Tumor cells often exhibit an acidic microenvironment due to increased metabolic activity and anaerobic glycolysis. This altered pH can promote cancer cell survival, proliferation, and invasion. Minerals like magnesium, zinc, and potassium, found in sea salt, help regulate cellular ion balance and pH homeostasis, potentially preventing the acidosis often associated with tumors. Magnesium, for example, is known to influence the function of ion transporters and pumps, which are crucial in maintaining the normal pH levels of cells. By supporting pH regulation, sea salt may help counteract the acidic conditions that favor tumor growth (Chen et al., 2020)(T. Iqbal & Ahmed, n.d.-a). Additionally, some components of sea salt may contribute to the inhibition of angiogenesis and metastasis, processes that are critical for tumor progression. Angiogenesis refers to the formation of new blood vessels that supply oxygen and nutrients to tumors, while metastasis involves the spread of cancer cells to other parts of the body. Selenium, zinc, and iodine are all involved in regulating angiogenesis by affecting various signaling pathways that control the growth of blood vessels. Zinc, for example, has been shown to inhibit the production of vascular endothelial growth factor (VEGF), a key mediator of angiogenesis (Zheng et al., 2025). Selenium also acts on multiple pathways to prevent excessive angiogenesis, thus limiting tumor growth and spread. In terms of metastasis, magnesium has been found to influence cell adhesion molecules and cytoskeletal dynamics, which are critical for cancer cells to detach, invade surrounding tissues, and spread to other areas (He et al., 2025). Overall, the minerals present in sea salt may have a role in modulating the tumor microenvironment by helping regulate pH and ion balance, as well as by inhibiting angiogenesis and metastasis. However, while these effects are promising, the concentrations of these minerals in sea salt are relatively low, and further research is needed to determine the precise impact of dietary salt on cancer progression (Rahman et al., 2024). Figure number two shown the Integrated conceptual framework for sea salt therapeutics in oncology.

Synergistic Effects with Conventional Therapies

Some minerals found in sea salt, such as magnesium, zinc, selenium, and iodine, may have synergistic effects when combined with conventional cancer therapies, such as chemotherapy and radiotherapy. These minerals can potentially enhance the efficacy of these treatments while also reducing some of their associated side effects(Dijck-Brouwer et al., 2022). Magnesium plays a critical role in DNA repair and cellular response to stress, both of which are important for enhancing the effectiveness of chemotherapy and radiotherapy. By maintaining cellular integrity and supporting immune function, magnesium may improve the response of cancer cells to these therapies. Additionally, magnesium's ability to reduce inflammation and oxidative stress may mitigate some of the collateral damage caused by these treatments(Zhang et al., 2022). Zinc, as an essential mineral for immune function and antioxidant activity, can also support the effectiveness of chemotherapy and radiotherapy. Zinc is involved in repairing DNA damage induced by chemotherapy and radiation, promoting the survival of healthy cells while enhancing the damage to cancer cells. Furthermore, zinc has been shown to protect against some of the adverse effects of chemotherapy, such as mucositis (inflammation of the mucous membranes) and delayed wound healing (Patil & More, 2020). Selenium, known for its antioxidant properties, can help protect healthy tissues from oxidative damage caused by chemotherapy and radiotherapy. It can also support the immune system, which is often weakened by these treatments. Some studies suggest that selenium may sensitize cancer cells to radiation therapy, making them more susceptible to the damaging effects of radiation. This could potentially improve the overall outcome of treatment. Additionally, selenium's ability to reduce inflammation and protect against oxidative stress may help manage some of the common side effects of cancer treatment, such as fatigue and nausea (Kim et al., 2021). Iodine, while primarily recognized for its role in thyroid health, may also contribute to enhancing the effectiveness of chemotherapy and radiotherapy by supporting cellular metabolism and immune function. It is thought to aid in the regulation of cellular processes that promote the destruction of cancer cells, though further research is needed to fully understand its potential in cancer therapy (Shim et al., 2021)(T. Iqbal, Altaf, Fatima, et al., 2024). In addition to enhancing treatment efficacy, sea salt's mineral content may help reduce some of the side effects associated with traditional cancer treatments. For example, magnesium may help alleviate muscle cramps and fatigue, while zinc may support wound healing and reduce the risk of infections. Selenium's antioxidant effects may protect against hair loss, a common side effect of chemotherapy, and reduce the

severity of radiation-induced dermatitis. Furthermore, iodine's role in regulating thyroid function may help mitigate the thyroid dysfunction that can sometimes result from radiation therapy (Mohammed et al., 2023)(T. Iqbal, Altaf, Basit, et al., 2024). While these minerals may provide supportive benefits in conjunction with chemotherapy and radiotherapy, it is important to note that the concentrations of these minerals in sea salt are relatively low. A balanced diet, including a variety of mineral-rich foods, is likely to be more effective in supporting cancer therapy and managing side effects than relying solely on sea salt. As always, it is important to consult with healthcare professionals before using any supplements or dietary changes in cancer treatment (Patil & More, 2020).

Table No. 1: The various aspects of sea salt's potential role in cancer therapy.

Sr.No	Mechanism/Aspect	Composition of Sea Salt	Description	Toxicity	Clinical Implications	Current Research	References
1	**Introduction to Sea Salt**	Sodium, chloride, magnesium, calcium, potassium.	Sea salt contains minerals that might influence cellular processes.	Generally safe in moderation. High intake risks.	Potential for adjunctive cancer therapy.	Emerging studies on mineral-rich salts.	(Manoharan & Kaliaperumal, 2022)
2	**Anti-inflammatory Effects**	Contains magnesium, calcium, sulfur.	Sea salt can reduce inflammation which is linked to cancer progression.	Excessive use can exacerbate hypertension.	Reducing inflammation may slow down cancer growth.	Clinical trials in inflammatory conditions.	(Henke et al., 2020)
3	**Electrolyte Balance and Cell Function**	Sodium, potassium, chloride, magnesium.	Sea salt maintains electrolyte balance crucial for normal cell function.	Overconsumption can lead to electrolyte imbalance.	Impact on cancer cells' metabolic processes.	Studies on electrolyte imbalance in cancer.	(Ghoneum et al., 2023)
4	**Mineral Content**	Magnesium, calcium, potassium, trace elements.	Rich in magnesium, calcium, and potassium.	High sodium may affect cardiovascular health.	Mineral absorption may influence cancer cell proliferation.	Research on mineral deficiencies in cancer.	(A. A. H. Ali, 2023)
5	**Antioxidant Properties**	Selenium, zinc, iodine, and other trace minerals.	Some sea salts contain antioxidant compounds.	Potential toxicity from impurities in unrefined salts.	May protect cells from oxidative stress.	Exploration of antioxidants in cancer.	(Fioravanti, 2024)
6	**Activation of Apoptosis**	Iodine, selenium, magnesium, chloride.	Certain salts may promote programmed cell death in cancer cells.	High intake of salt can negatively impact kidney function.	Can potentially trigger cancer cell death.	Preclinical studies on apoptosis.	(Saha et al., 2021)
7	**Gene Regulation**	Potassium, sodium, chloride, magnesium.	Sea salt might influence gene expression related to cancer growth.	High salt intake may influence gene expression related to hypertension.	Potential to modulate gene activity in cancer cells.	Epigenetic research in cancer therapies.	(Wessels et al., 2021)
8	**Osmotic Stress on Tumor Cells**	Sodium chloride, magnesium.	High salt concentrations could induce stress in cancer cells.	Can cause cell dehydration in excess.	Cancer cell apoptosis could be enhanced under osmotic stress.	Experimental studies on osmotic effects.	(Drenthen et al., 2024)
9	**Immune System Modulation**	Iodine, calcium, magnesium.	Sea salt can affect immune system functions.	Overconsumption may impair immune function.	Can enhance immune response against tumors.	Clinical trials on immune modulation.	(Dijck-Brouwer et al., 2022) (Qureshi et al., 2024)

10	**Impact on Tumor Microenvironment**	Calcium, potassium, sodium, magnesium.	Salt influences the tumor's extracellular matrix.	Potential for tumor edema with high salt.	May alter the tumor's ability to resist treatment.	Tumor microenvironment research.	(Henke et al., 2020)
11	**Synergistic Effects with Chemotherapy**	Sodium, chloride, magnesium, calcium.	May enhance the efficacy of chemotherapy drugs.	Excessive salt intake could counteract chemotherapeutic efficacy.	Can potentially improve the effectiveness of standard treatments.	Combination therapy studies.	(Shin & Choi, 2023)
12	**Side Effects in Cancer Treatment**	Sodium chloride, trace elements like iodine.	High salt intake can cause adverse effects like hypertension.	High salt intake can increase blood pressure.	Careful balance needed to avoid toxicity.	Investigations into safe salt concentrations.	(Danforth, 2021)
13	**Sea Salt in Wound Healing**	Magnesium, calcium, iodine, sodium.	Sea salt promotes skin regeneration, potentially aiding in recovery.	Inappropriate use of sea salt may cause skin irritation.	Healing of surgical wounds in cancer treatments.	Studies on wound healing post-surgery.	(Sadeghsoltani et al., 2021)
14	**Anticancer Properties of Sea Salt**	Sodium, chloride, magnesium, trace minerals.	Sea salt's potential to directly inhibit cancer cell growth.	Toxic in high doses, especially with high sodium content.	Can act as a supplementary treatment alongside other therapies.	In-vitro studies on anticancer activity.	(Chaudhry et al., 2022)
15	**Clinical Trials and Future Directions**	Sodium chloride, potassium, magnesium, calcium.	Ongoing research to validate its clinical efficacy.	Risks of toxicity from unregulated salt sources.	Potential future clinical trials assessing sea salt in cancer therapy.	Meta-analyses and trial reviews.	(Sadeghsoltani et al., 2021) (T. Iqbal, Altaf, Salma, et al., 2024)

IV. Preclinical and Clinical Evidence

In vitro studies investigating the effects of minerals found in sea salt have demonstrated promising results in cancer research. For instance, zinc and selenium have shown potential in inducing apoptosis and inhibiting cancer cell proliferation in cell cultures. Magnesium has also been linked to DNA repair and enhanced sensitivity to chemotherapy. In vivo studies using animal models have supported these findings, indicating that mineral supplementation can improve tumor response to treatments like chemotherapy and radiotherapy (M. U. Iqbal et al., 2024) (Ghoneum et al., 2023). Animal studies have also suggested that sea salt minerals, particularly magnesium and zinc, may reduce cancer progression and metastasis. However, clinical trials involving humans are still limited. Some case studies have reported benefits in managing side effects of cancer treatments, such as fatigue and inflammation, but comprehensive human studies are lacking. The main limitation in clinical research is the insufficient focus on the bioavailability of these minerals from sea salt and the appropriate dosages required for therapeutic effects (Ashique et al., 2023).

Safety and Toxicity Considerations

While sea salt can offer beneficial minerals, its dosage and administration pose challenges, as excessive consumption can lead to sodium overload, increasing the risk of high blood pressure and cardiovascular issues. The mineral content in sea salt varies, making it difficult to establish a standardized therapeutic dosage. Potential risks include hyperkalemia (excessive potassium) with overconsumption, particularly for those with kidney problems, and interactions with medications like blood pressure drugs or diuretics. Additionally, individuals with iodine deficiencies or thyroid disorders may face complications when using certain types of sea salt. Proper guidance and moderation are essential to avoid adverse effects (Hunter et al., 2022)(Alshamrani, 2025).

V. Clinical Implications and Applications

Sea salt, with its rich mineral content, shows potential as an adjunct therapy alongside conventional cancer treatments. Minerals like zinc, magnesium, and selenium may enhance the effectiveness of chemotherapy and radiotherapy while reducing their side effects, supporting immune function, and improving cellular health. In supportive care, sea salt could help alleviate symptoms such as fatigue, muscle cramps, and inflammation, thus improving the overall quality of life for cancer patients. However, challenges in clinical translation exist (A. Ali et al., 2024)(Costanzo et al., 2024). The variability in sea salt's mineral composition complicates standardization, making it difficult to determine appropriate dosages for therapeutic use. Additionally, regulatory and ethical considerations regarding its use in clinical settings need to be addressed, particularly in terms of quality control and patient safety. Despite these hurdles, further research and clinical trials could clarify its role in cancer therapy (Manrique-Rodríguez et al., 2021).

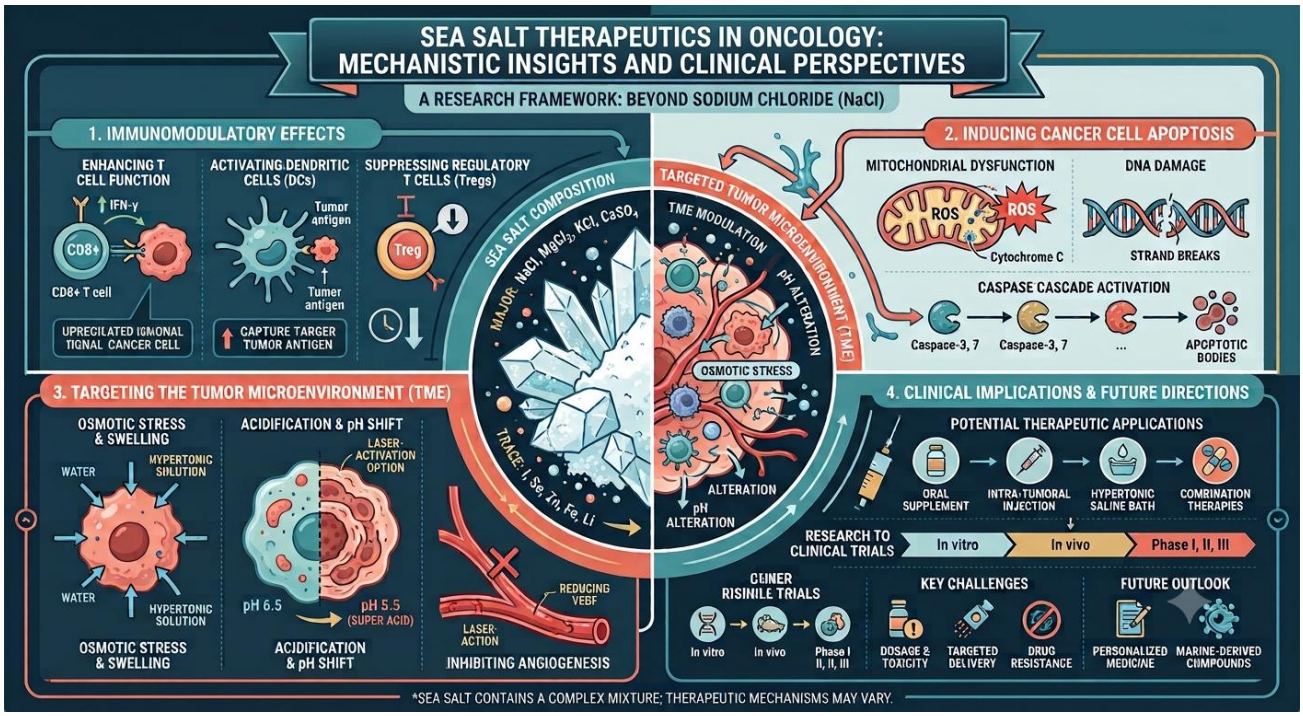

Figure No: 2. Integrated conceptual framework for sea salt therapeutics in oncology.

VI. Future Directions and Research Opportunities

Future research should focus on isolating and characterizing specific anti-cancer agents in sea salt, identifying minerals or compounds with the most potent effects. Mechanistic studies are needed to elucidate the pathways and molecular targets through which these minerals exert their therapeutic effects. Large-scale, randomized controlled trials are crucial to assess the efficacy and safety of sea salt-based therapies in cancer treatment (Barreca et al., 2020). Additionally, exploring personalized medicine approaches could tailor these therapies to individual patient profiles, optimizing treatment outcomes and minimizing side effects. Such research could ultimately refine the clinical application of sea salt in cancer care (Wang & Wang, 2023).

VII. CONCLUSION

Sea salt, rich in minerals like magnesium, zinc, selenium, and iodine, has shown potential in cancer therapy through various mechanisms, including apoptosis induction, antioxidant activity, and immune modulation. Preclinical studies have demonstrated its ability to enhance chemotherapy and radiotherapy efficacy while reducing treatment side effects, such as inflammation and fatigue. Though evidence is promising, clinical research in humans remains limited. The potential for sea salt to play a role in oncology lies in its ability to complement existing therapies, improving patient quality of life and treatment outcomes. Future research should focus on isolating active components, elucidating mechanisms, and conducting large-scale clinical trials to confirm its therapeutic benefits, encouraging collaboration across disciplines to advance sea salt's clinical application in cancer care.

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