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Health Risk Associated with Cassava and it's Cyanogenic Properties: A Review of the Literature

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Abstract: Cassava an edible tuber crop consumed in different forms by people in different parts of the world contains a very poisonous component cyanogenic glycosides, which can result in fatal cyanide poisoning if not properly detoxified by appropriate means (soaking, drying, boiling, frying etc.). Water pollution is one of the major global challenges that society must address in the 21st century aiming to improve water quality and reduce human and ecosystem health impacts. Industrialization, climate change, and expansion of urban areas produce a variety of water pollutants. This study aims to review researches by different authors on cyanide poisoning, mode of poisoning, mode of detection and ways of prevention as described by various authors. The authors used secondary sources by reviewing archival literature of past studies such as journal and conferences proceedings, magazines, books, internet sources and so on. In this study the authors discussed some of the relevant findings related to the release of cyanide in water as a means of detoxification, the possible risks for human health, detection and treatments of its poisoning by different authors. Anthropogenic activities are identified as the main source of the increasing amounts of pollutants found in water. The authors reported on some of the methods in which this contamination occurs and ways to prevent future contamination as discussed by various authors. Cyanide poisoning is very fatal but is rarely discussed by people so there is need for constant sensitization on the harms associated with cassava and ways to prevent poisoning. In this study, the authors found that cyanide poisoning is a source of major concern and more sensitization should be carried out as well as regular checks and supervision should be carried out in high risk areas in terms of cyanide poisoning by appropriate bodies in charge.

Keywords: Cyanide: Water: Contamination: Pollution: Human Health: Poisoning: Cassava.

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1.0 Introduction of the Study

Cassava an edible tuber crop consumed in different forms by people in different parts of the world contains a very poisonous component cyanogenic glycosides, which can result in fatal cyanide poisoning if not properly detoxified by appropriate means (soaking, drying, boiling, frying etc.) (Alitubeera *et al., 2019*). Cyanogenic glycosides are a group of chemical compounds which occur naturally in over 2 000 plant species with at least 25 cyanogenic glycosides known to be found in the edible parts of plants. Cyanogenic glycosides alone are relatively non-toxic. However, as a result of enzymatic hydrolysis by beta-glucosidase following maceration of plant tissues as they are eaten, or by the gut microflora, cyanogenic glycosides are broken down to release hydrogen cyanide which is toxic to both animals and humans. The potential toxicity of a cyanogenic plant depends primarily on its capacity to produce hydrogen cyanide (Food safety Focus, 2018). Cyanogenic glycosides are present in most plants because they act as a defense mechanism, which is evident as they occur at a significant rate only after plant tissues have been disrupted by herbivores, fungal attack, or mechanical means (Njoku *et al., 2018*).

Cassava (*Manihotesculenta*), is an edible tuberous root that is resistant to drought, diseases, and pests, it is a major source of carbohydrates in tropical areas, the second most widely grown and consumed food in Nigeria in many different processed form. Cassava comes in two types (Sweet and Bitter Cassava). Sweet cassava roots contain less than 50 mg per kilogram of hydrogen cyanide on fresh weight basis, whereas that of the bitter variety may contain up to 400 mg per kilogram as a reason, sweet cassava roots can generally be made safe to eat by peeling and thorough cooking. However, bitter cassava roots require more extensive and complicated processing for detoxification (Ukonu et al., 2022; Ubreye Benjamin et al., 2022). One of the traditional ways to prepare bitter cassava roots is by first peeling and grating the roots, and then prolonged soaking of the gratings in water to allow leaching and fermentation to take place, followed by thorough cooking to release the volatile hydrogen cyanide gas. Cutting the roots into small pieces, followed by soaking and boiling in water is particularly effective in reducing the cyanide content in cassava. Whilst fresh cassava requires traditional methods to reduce its toxicity, adequately processed cassava flour and cassava-based products have very low cyanide contents and are considered safe to use (Food safety Focus, 2018). Cyanide, a toxic contaminant, occurs naturally in most plants but has high concentration in cassava and bamboo shoot. It is released into the environment through volcanoes and natural biogenic processes from higher plants, bacteria, algae and fungi, biomass burning, discharges from, smoke industries, waste water treatment, tobacco smoke, wood smoke, from burning plastics, vehicular emission, inadequately processed cassava products etc (Agency for Toxic Substances and Disease Registry, 1997).

Cyanide exist in water as hydrogen cyanide (HCN) at PH less than 8 which is more harmful to aquatic life than the free cyanide ion. The cyanide toxic effect is due to its reaction with the trivalent ion in the cytochrome oxidase to inhibit electron transport and hence prevent the cells from consuming oxygen which leads to rapid impairment of the vital functions (Cacace *et al., 2007*). Hyper baric oxygen (HPO), hydroxocobalimine, dicobalt-EDTA, IV dimethylaminophenol have been reported to be cyanide antidote which are effective in experimental and human cyanide poisoning (Lam & Lau, 2000; Ukonu et al., 2022; Owolabi et al., 2022). Exposure to small amounts of cyanide can be deadly regardless of the route of exposure. Cyanide is very poisonous; it stops cellular respiration by inhibiting an enzyme in mitochondria called cytochrome c. oxidase in the body. Water is a transparent and nearly colorless chemical substance that is the main constituent of Earth's streams, lakes, and oceans, and the fluids of most living organisms. The importance of water for human survival as well as many other sectors of the economy cannot be overemphasized. So, the contamination of sources of water should be of high priority due to the health risk associated with its contamination even as some anions are found in water are useful to human body, many others are harmful (Tayfur *et al.*, 2011). Water is an essential part of daily human activities as it is used in almost all activities carried out by humans. Water is an essential source for detoxification of cassava to render it safe for consumption but with the detoxification of cassava, the water used becomes polluted and there is need for careful disposal to avoid contamination of major source of water which can lead to health risk for people in the area.

Roots of cassava which are mainly starch are extremely rich in carbohydrates. According to Food and Agriculture Organization, cassava is the third most important source of calories in the tropics, after rice and corn (Ukonu et al., 2022; Owolabi et al., 2022). Cassava is consumed in various types of ways, which includes being eaten as whole root, grated root or root chips. In addition, it is prepared into flour which in turn can be used for cooking or production of cassava-based products such as breads, crackers, and puddings or beverages made with tapioca pearls, they can also be fermented and then cooked for consumption. Cassava leaves are also eaten in some countries following extensive boiling. Apart from being used as human food, cassava products are also used as animal feed (Food safety Focus, 2018). Detailed studies of the fate and contents of cyanide in cassava, cassava bi-product and human beings as well has become a major task in research and there is continuous challenge to develop new methodology and optimize the already existing methodologies. Health education about cyanide poisoning from cassava and the need to adequately process cassava to reduce cyanogenic content must be conducted regularly by public health officials (Alitubeera *et al., 2019*). Therefore, this study aims to review researches by different authors on cyanide poisoning, mode of poisoning, mode of detection and ways of prevention as described by various authors.

2.0 Review of Relevant Literature

2.1 Cassava Plant

Cassava Plant (Manihotesculentacrantz) belong to the family of Euphorbiaceae (Spurge family), native of Brazil and Paraguay (Stephen,1995) which is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, is a major source of carbohydrates. The cassava root is long and tapered with a firm homogenous flesh encased in a detectable rind about 1mm thick, rough and brown on the outside. Commercial varieties can be 5 to 10 cm in diameter at the top and 50 to 80 cm long. A woody cordon runs along the root's axis. The flesh tuber can be chalk-white or yellowish. Cassava roots are highly rich in starch and contain significant amount of calcium (50 mg/100g), phosphorus (40 mg/100g) and vitamin C (25 mg/100g) (Cassava Wikipedia, 2017), however they are poor in protein and other nutrients. In contrast, cassava leaves are a good source of protein, it is supplemented with the amino acid methionine despite containing cyanide (Cassava Wikipedia, 2017). Cassava root size and shape depends on their varieties as well as environmental factors. Cassava is a tropical root crop requiring at least 8 months of warm weather to produce a crop. It is traditionally grown in a savanna climate, it does not tolerate flooding, in droughty areas, it loses its leaves to conserve moisture, producing new leaves when rain resume. It takes 18 or more months to produce a crop under adverse condition such as cool or dry weather. Cassava does not tolerate freezing conditions. It tolerates a wide range of soil from pH 4.0 to 8.0 and is most productive in full sun (Cassava Wikipedia, 2017).

2.1.1 History of the Cassava Plant

The oldest direct evidence of cassava cultivation came from a 1,400 years old Maya site in El Salvador (University of Colorado at Boulder, 2007), although the specie Manihotesculenta originated further in South Brazil and Paraguay. Wild population of Manihotesculenta sub specie, Flebellifolia, are shown to be the progenitor of domesticated cassava found in west central Brazil where it was likely first domesticated not more than 10,000 years A.D. By 6,600 B.C, manioc pollen appeared in the Gulf of Mexico lowlands at the San Andres archaeological site. With its high food potential, it became a staple food of the native population of North and South America, South Mesoamerica and the Caribbean. By the time of the Spanish conquest, its cultivation was continued by the Colonial Portuguese. Forms of the modern domesticated specie can be found growing in the South of Brazil and there are several wild Manihot species, all varieties of Manihotesculenta are cultigens (Pope *et al.*, 2001).

2.1.2 Production / Economic Impact of Cassava

Cassava is one of the most staple food crops of more than 500 million people and is a typical crop in developing countries (Hahn *et al.,* 1985). Cassava is considered an important source of energy in diets. Cassava is known to produce 250,000 calories/hectare/day compared to 200,000 for maize, 176,600 for rice, 114,000 for sorghum and 110,000 for wheat. Cassava is the third largest source of human food in the world, with Africa as its largest center of production (Philip, 1983; Ukonu et al., 2022; Owolabi et al., 2022).

Cassava plays a major role in efforts to alleviate the African food crisis because of its efficient production of food energy, year-round availability, tolerance to extreme stress conditions and suitability to present farming and food systems in Africa (Hahn *et al.*, 1985). World production of cassava root was estimated to be 184 million tons in 2002 (Cassava Wikipedia, 2017). The majority of production is in Africa where 99.1 million tons were grown, 51.5 million tons were grown in Asia and 33.2 million tons in Latin America and the Caribbean (Cassava Wikipedia, 2017). Nigeria is the world's largest producer of cassava (Cassava Wikipedia, 2017). However, based on the statistics from the Food and Agricultural Organization (FAO) of the United Nations, Thailand is the largest world exporter of cassava in 2005. The second largest exporting country is Vietnam with 13.6%, and then increased to 55.8% and Costa Rica 2.1% (Cassava Wikipedia, 2017). World-wide cassava production increased by 15.5% between 1988 and 1990 (Cassava Wikipedia, 2017). Cassava plays a role in developing countries farming especially in sub-saharan Africa because it thrives well on poor soil and low rainfall and is a perennial crop that can be harvested as required. Its wide harvesting window allows it to act as a famine reserve crop and is invaluable in managing labor schedules. Cassava is regarded as subsistence or cash crop of low-income families or resource poor farmers (Stone *et al., 2002)*. A 1992 *study* revealed that about 42% of harvested cassava roots in West and East Africa are processed into dried chips and flour (Cassava Wikipedia, 2017). In Ghana, cassava and yam occupy important positions in the agricultural economy and contribute about 46% of agricultural gross domestic product (GDP) (Cassava Wikipedia, 2017). Cassava accounts for a daily calorie intake of 3% in Ghana and it is grown by every farming family. The importance of cassava to many Africans is epitomized in the Ewe (a language spoken in Ghana, Togo and Benin) name for the plant, meaning "there is life".

2.1.3 Importance of Cassava Processing

Raw cassava roots must be used immediately, processed or preserved in order to prevent decomposition since they cannot be stored for long because they begin to rot within 3 - 4 days of harvest. Thus processing helps to remove or reduce the level of toxic cyanogenic glucosides and other toxic contaminants present in the cassava root as well as altering the available energy of the cassava, increasing the shelf life, improving the palatability and conversion into stable product (Wyllie *et al.,* 1984). Cassava processing varies according to the form in which the cassava is to be consumed from simple sun-drying to complex methods involving fermentation to complicated procedures like processing into garri (Wyllie *et al.*, 1984). Some of these processes reduce cyanide more effectively than others. The specific effects of various processing techniques on the cyanide content of cassava are discussed below.

2.1.3.1 Peeling: Many methods of cassava processing starts with the peeling of the tubers. Generally, the cassava peel contains higher cyanide content than the pulp. Removal of the peels reduces the cyanogenic glucoside content considerably to at least 50% in cassava tubers. In studies carried out by Tewe, the peel of the "bitter" cassava variety was shown to contain an average of 650 ppm and the pulp to contain 310 ppm total cyanide (Tewe, 1983; Eshiett et al., 2022).

2.1.3.2 Grating: This process takes place after peeling and is sometimes applied to whole tubers. Grating of the whole tuber ensures the even distribution of the cyanide in the product and will also make the nutrients contained in the peel available for use. In the grated product, the concentration of cyanide depends on the time during which the glucoside and the glucosidase interact in an aqueous medium. Grating also, obviously, provides a greater surface area for fermentation to take place (Tewe ,1983).

2.1.3.3 Soaking: It provides a suitably larger medium for fermentation and allows for greater extraction of the soluble cyanide into the soaking water. The process removes about 20% of the free cyanide in fresh root chips after four hours, although bound cyanide is only negligibly reduced. Bound cyanide begins to decrease only after the onset of fermentation (Cooke *et al.*, 1985). A very significant reduction in total cyanide is achieved if the soaking water is routinely changed over a period of 3-5 days. A stimulation of the technique, followed by sun drying showed a reduction of cyanide of about 98.6% of the initial content in the roots (Cooke *et al.*, 1985).

2.1.3.4 Fermentation: Microbial fermentation have traditionally played important roles in food processing for thousands of years. Most marketed cassava products like "garri", "fufu", "lafu", etc. in Africa and they're are obtained through fermentation. The importance of fermentation in cassava processing is based on its ability to reduce the cyanogenic glucosides to relatively insignificant level (Chala et al., 2022; Enyi et al., 2022). Some cyanidrophilic/cyanide tolerant microorganisms effect breakdown of the cyanogenic glucoside. Also, the longer the fermentation process, the lower the residual cyanide content and generally, fermented cassava products store better and are often low in residual cyanide content. Onabowale developed a combined acid hydrolysis and fermentation process at FIIRO (Federal Institute for Industrial Research, Oshodi, Nigeria) and achieved 98% reduction in total cyanide after dehydration of the cassava flour for use in the feeding of chickens (Onabowale, 1988).

For "lafu" (cassava flour) production in Nigeria, peeled or unpeeled cassava tubers are traditionally immersed either in a running stream, or in stationary water (near a stream) or in an earthen ware vessel and fermented until the roots become soft. The peel and central fibres of the fermented roots are manually removed and the recovered pulp is hand mashed or pounded. The microorganisms involved in "lafu" (cassava flour) production include four yeasts: Pichia onychis, Candida tropicalis, Geotrichum candida and Rhodotorulasp.; two molds: Aspergillus niger and penicillium sp. and two bacteria: leuconostoc sp. and corynebacterium sp. Moisture, pH and temperature conditions are critical for the growth of these microorganisms in roots and thus for fermentation (Nwachukwu *et al.*, 1985).

2.1.3.5 Drying: Drying is the simplest method of processing cassava: Drying reduces moisture, volume and cyanide content of roots, thereby prolonging product shelf life and facilitates the continuation of the fermentation process. Total cyanide content of cassava chips could be decreased by only 10 - 30% through fast air drying. Slow sun-drying, however, produces greater loss of cyanide. Drying may be in sun or over a fire. The former is more common because it is simple and does not require fuel wood (Tewe ,1983). Gomez et al indicated that more than 86% of cyanide present in cassava was lost during sun drying (Gomez *et al.*, 1984).

2.1.3.6 Boiling/Cooking: As with soaking, the free cyanide of cassava chips is rapidly lost in boiling water. About 90% of free cyanide is removed within 15 minutes of boiling fresh cassava chips, compared to a 55% reduction in bound cyanide after 25 minutes. Cooking destroys the enzyme linamarase at about 72 ^{0}C thus leaving a considerable portion of the glucoside intact (Philip, 1983).

2.1.3.7 Milling: The dried root pieces and fermented / dried pulp are milled into flour by pounding in mortar or using hammer mills. Milling with hammer mills done at village level may also reduce cyanide. The dried cassava roots (both fermented and unfermented) are often mixed in a ratio of 2 to 3 parts cassava with one part of sorghum, millet and or maize and milled into a composite flour. Mixing cassava with cereals increases food protein and enhances palatability by improving consistency (Nwachukwu *et al.*, 1985**).**

2.1.4 Cassava Toxicity

Cassava roots and leaves cannot be consumed raw because they contain two cyanogenic glucosides, linamarin and lotaustralin. These are decomposed by linamarase, a naturally occurring enzyme in cassava, liberating hydrogen cyanide (HCN) (Casereda *et al.*, 1996). Cassava varieties are often categorized as either "sweet" or "bitter", signifying the absence or presence of toxic levels of cyanogenic glucosides. The so called "sweet" (actually not bitter) cultivars can produce as little as 20 mg/kg of cyanide of fresh roots, whereas "bitter" ones may produce more than 50 times as much (1 g/kg) of cyanide. Cassava grown during drought is high in these toxins, cyanide (Aregheor *et al., 1991*). A dose 40 mg of pure cassava cyanogenic glycoside is sufficient to kill a cow. In case of human malnutrition, where the diet lacks protein and iodine processed roots of high hydrogen cyanide cultivars may result in serious health problems. Apart from cyanide which is part of cassava plant and a contaminant that causes cassava poisoning when not properly processed.

2.2 Cyanide

2.2.1 Cyanide

Cyanide is a chemical compound that contains the cyano group -C≡N, which consists of a carbon atom triple bonded to a nitrogen atom. Cyanide could be a gas; hydrogen cyanide or a solid; potassium cyanide or sodium cyanide and they are fast-acting poisons that can be lethal. It's one of the fastest acting poisons known, and if a significant amount is ingested, it can lead rapidly to death of the person that ingested it. Upon ingestion, it binds to hemoglobin, which is a molecule in red blood cells responsible for carrying oxygen to the cells in our body. Hemoglobin then carries cyanide to the body's tissues, where it can bind to an enzyme called cytochrome oxidase. This enzyme is a vital tool cells require to make use of oxygen, and with cyanide bound to it, they are unable to do so (Chemistry of poisons, 2015).

2.2.2 History of Cyanide

The word "cyanide" was extracted from "ferrocyanide", a cyanide derivative of iron. The name "ferrocyanide" was invented as meaning "blue substance with iron" as ferrocyanides were first discovered as components of the intensely coloured dye prussian blue. Kyanos is Greek for (dark) blue (Shumi et al., 2021; Chala et al., 2022; Enyi et al., 2022). Cyanide was widely known or used as poison until the 18th century, beginning with some experiments by a German painter, Heinrich Diesbach who in 1704 was only trying to improve the colours on his palette. He spent hours at the laboratory of a Berlin Alchemist, trying to create a low shade of red paint, in search for a low shade of red he continuously mixed together strange mixtures, eventually mixing dried blood, green vitriol (iron sulfate) and potash (potassium carbonate) before heating the whole concoction over an open flame. Instead of the bloody crimson he expected, the concoctions he had mixed yielded a different brilliance, the deep violet-blue glow of a fading twilight. Diesbach called the vivid pigment berlin blue, English chemist would later rename it prussian blue. In the history of poisons, the story of cyanide is always colored blue.

2.2.3 Coordination Chemistry

The cyanide anion is a potent ligand for many transition metals (Sharpe, 1976). The very high affinities of metals for this anion can be attributed to its negative charge, compactness and ability to engage in π-bonding. Well known complexes include:

- Hexacyanides $\{M(CN)_6\}^{3-}$ {M is Ti, V, Cr, Mn, Fe, Co} which are octahedral in shape.
- Tetracyanides $\{M(CN)_4\}^{2-}$ {M is Ni, Pd, Pt} which are square planar in their geometry.
- Dicyanides $\{M(CN)_2\}^{-}$ {M is Cu, Ag, Au} which are linear in geometry.

Certain enzymes, the hydrogenase contain cyanide ligands attached to iron in their active sites. The biosynthesis of cyanide in the (NIFE)-hydrogenases proceeds from carbamoyl phosphate which converts to cysteinylthiocyanate, the CN-donor (Reissman, *et al* 2003).

Organic derivatives: Because of the cyanide anion‟s high nucleophilicity, cyano groups are readily introduced into organic molecules by displacement of a halide group (e.g. the chloride on methyl chloride). Organic cyanides are generally called nitriles. Thus, CH_3CN can be called methyl cyanide but more commonly referred to as acetonitrile. In organic synthesis, cyanide can be used to lengthen a carbon chain by one, while retaining the ability to be functionalized.

$RX + CN^- \longrightarrow RCN + X^-$ (nucleophilic substitution) followed by

1) $RCN + 2H_20 \longrightarrow RCOOH + NH_3$ (hydrolysis under reflux with mineral acid catalyst) or
2) $2RCN + Li\ AlH_4 + (2^{nd}\ step)\ 4H_20 \longrightarrow 2RCH_2NH_2 + Li\ Al\ (OH)_4$ (under reflux in dry ether, followed by addition of H_20).

2.2.4 Chemical Tests for Cyanide

2.2.4.1 Prussian Blue: Iron (II) sulphate is added to a solution suspected of containing cyanide such as the filtrate from the sodium fusion test. The resulting mixture is acidified with mineral acid (Ganjeloo *et al.*, 1980). The formation of Prussian blue is an indication on the presence of cyanide.

2.2.4.2 Para-Benzoquinone in DMSO: A solution of para-benzoquinone in DMSO react with inorganic cyanide to form a cyanophenol which is fluorescent. Illumination with a UV light gives a green/blue glow if the test is positive.

2.2.4.3 Copper and an Aromatic Amine: This is used by fumigators to detect hydrogen cyanide, copper (II) salt and an aromatic amine such as benzidine is added to the sample. A positive test gives a blue colour. Copper (I) cyanide is poorly soluble. By sequestering the copper (I), the copper (II) is rendered a stronger oxidant. The copper in a cyanide facilitated oxidation, converts the amine into a colored compound.

2.2.4.4 Pyridine-Barbituric Acid Colorimetry: A sample containing inorganic cyanide is removed with air from a boiling acid solution into a basic absorber solution. The cyanide salt absorbed in the basic solution is buffered atan of pH 4.5 and then it is reacted with chlorine to form cyanogens chloride. The cyanogen chloride formed, binds pyridine with barbituric acid to form a strongly colored red dye that is proportional to the cyanide concentration. This colorimetric method is used to analyze cyanide in water, waste water and contaminated soils.

2.2.4.5 Gas Diffusion Flow Injection Analysis (amperometry): Instead of distilling, the sample is injected into an acidic stream where the HCN formed is passed under a hydrophobic gas diffusion membrane that selectively allows only HCN to pass through. The HCN that passes through membrane is absorbed into a basic carrier solution that transports the cyanide to an amperometric detector that accurately measures cyanide concentration with high sensitivity.

2.2.5 Sources of Cyanide

Cyanides are produced by certain bacteria, fungi and algae and are found in nearly 1,500 plants generally in form of sugars or lipids. Cyanides occur naturally in peach seeds, cherry pits, tapioca apple seeds, green beans, bitter almonds, peas, apricots, cassava roots, sweet potatoes, flax seeds, lima beans and bamboo shoots which contain the highest amount of cyanide sugar. Some millipede insects like burnet release hydrogen cyanide as a defense mechanism. The combustion of any material containing carbon and nitrogen, fumes from exhaust of vehicles, tobacco smoke, wood smoke and smoke from burning nitrogen containing plastics (particularly acrylonitriles) naturally releases a clinically significant amount of cyanide when burnt. Cyanide may be found in water and soil near discharges from organic chemical industries, iron and steel works, waste water treatment facilities etc (Anon *et al.,* 2004).

2.2.6 Cyanide Poisoning

Cyanide is especially poisonous because it stops cellular respiration by inhibiting an enzyme in mitochondria called cytochrome c oxidase in the fourth complex of the election transport chain (found in the membrane of the mitochondria of the eukaryotic cells), it attaches itself to the iron within this protein. The binding of cyanide to this cytochrome prevents transport of electrons from cytochrome c oxidase to oxygen. As a result, the electron transport chain is disrupted, meaning that the cell can no longer aerobically produce ATP for energy (Eshiett et al., 2022; Osho & Haruna, 2022). Tissues that mainly depend on aerobic respiration such as the central nervous system and the heart are particularly affected whereby it stops its action in respiration. Following absorption, cyanide is quickly and widely distributed to all organs and tissues of the body. Ingestion leads to particularly high levels in the liver when compared with inhalation exposure, but both routes lead to high concentrations in plasma and erythrocytes and in the heart, lung and brain

2.2.7 Effect of Cyanide Poisoning

Exposure to small amounts of cyanide can be deadly regardless of the route of exposure. Inhalation of high concentrations of cyanide within a short time harms the brain and heart which can cause a coma with seizures, apnea and cardiac arrest leading to death in a matter of minutes (Shumi et al., 2021; Chala et al., 2022; Enyi et al.,2022). These effects can occur rapidly depending on the amount eaten or inhaled. At lower dose, loss of consciousness may be preceded by general weakness, giddiness, headache, vertigo, confusion and perceived difficulty in breathing, nausea, vomiting, sweating, burning sensation in the mouth and throat etc. Chronic exposure to lower levels of cyanide over a long period result in increased blood cyanide levels which can result in weakness, permanent paralysis, nervous lesions, hypothyroidism and abortions, mild liver and kidney damages, pulmonary edema and hypertension (Soto-Blanco *et al* 2002). Also children have been born with thyroid disease because of the mother's exposure to cyanide and thiocyanate during pregnancy. Other effects of cyanide include cyanide disease like irreversible paralysis of the legs in children and women of child bearing age, tropical ataxic neuropathy (TAN), goiter, cretinism and stunting of growth in children (Soto-Blanco *et al.,* 2002).

2.2.8 Cyanide Poisoning Detection

After cyanide poisoning, increased levels of cyanide and thiocyanate are detectable in blood and urine. Harmful effects can occur when blood levels of cyanides are higher than 0.05 ppm, but some effects can occur at lower levels. Tissue levels of cyanide can be measured if cyanide poisoning is suspected. However, cyanide and thiocyanate cleared rapidly from the body in urine or exhaled breath, for that reason, blood measurements are only useful for detecting recent exposure. In general, if cyanide exposure is suspected, treatment should be started immediately without waiting for the results of blood cyanide measurement. Blood cyanide concentrations may be measured as a means of confirming the diagnosis in hospitalized patients or to assist in the forensic investigation of a criminal poisoning (Toxicity cyanide, 2017).

2.2.9 Cyanide Poisoning Treatment

Symptomatic patients especially those with severe manifestations, may benefit from specific antidotal therapy or agent which are found in the standard cyanide antidote kit used by the militaries of some countries which include amylnitrite, sodium nitrite and sodium thiosulphate with high dose oxygen should be given as soon as possible (George, 2020). Other new antidotal agent recommended by health agencies like International Programme on chemical safety U.S.A, UK Health and Safety Executive (HSE), Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), Food and Drug Administration (FDA) are hydroxocobalamin which is available in a cyanokit antidote kits, 4-dimethylaminophenol, dicobaltedetate, and glucose and oxygen therapy. As cyanide is such a fast-acting poison, it can be hard to administer any antidote in time if a lethal dose has been ingested. There's no universally agreed method for treating cyanide poisonings, and different treatments are favored in different countries. Nitrite compounds are commonly used; this transform hemoglobin into methemoglobin, which cyanide will bind to preferentially instead of the cytochrome oxidase enzyme. However, as methemoglobin does not carry oxygen, it must in turn be treated with methylene blue (Chemistry of Poisons, 2015).Also one can reduce the exposure to cyanide by not breathing in tobacco smoke, in the event of a building fire, one should evacuate the building immediately, smoke from burning plastics contain cyanide (and carbon monoxide), smoke can lead to unconsciousness or death. People should avoid eating seeds to prevent accidental cyanide poisoning. Thiosulfates are commonly administered in combination with nitrites, as they help convert the cyanide to thiocyanate, which can then be eliminated from the body in the urine. Other compounds that can also be used include cobalt-containing compounds, as cobalt forms a complex with cyanide ions. However, these cobalt compounds also have the disadvantage of being highly toxic themselves. Vitamin B12a has also been used, which can bind the cyanide to form another harmless form of vitamin B12, Diets containing adequate amounts of protein improve recovery from cyanide exposure incidents. Also vitamin B12 reduces the negative effects of chronic exposure (Toxicity Cyanide, 2017).

As mentioned, cyanide is fast-acting, and some cases, too fast for administration of an antidote. After death, cyanide poisoning can be detected in a number of ways; today, instrumental methods can be used, but there is also a simple, lab-based test. A tissue sample is added to 5% sodium hydroxide solution, which is in turn added to a solution containing 5% iron (II) sulfate and 1% iron (III) chloride. This is heated to 60˚C for 10 minutes, then transferred to a solution of hydrochloric acid. The appearance of a blue coloration, caused by the formation of the iron-cyanide complex known as Prussian blue, indicates the presence of cyanide ions in the original sample (Chemistry of Poisons, 2015). Despite the ease of detection of cyanide poisoning, occasionally, murders often happen through cyanide poisoning as was seen in the case of Lottery winner Urooj Khan in Chicago in the year 2012, who diedshortly after collecting winnings of almost half a million dollars, and though his death was originally thought to be from natural causes, later autopsy revealed he had ingested a lethal dose of cyanide, though again the perpetrator remains unidentified (BBC News).

3. Methodology of the Study

Cassava and Cyanide poisoning has been discussed extensively by a lot of authors. The methods through which cyanide poisoning occurs, detection as well as treatment has been extensively discussed but not much awareness is known on the dangers of cyanide to the environment and to the human body in general. The risk attached with Cassava and its poisoning effect was determined by the authors with the help of standard literature procedures in their research work. Thus the aim of this study is to review the research work done by respective authors on cassava and cyanide poisoning and detection, poisoning, damages to human health and treatments all of which were noted in this work.

4. Conclusion of the Study

The aim of this study was to review researches by different authors on cyanide poisoning, mode of poisoning, mode of detection and ways of prevention as described by various authors. The authors used secondary sources by reviewing archival literature of past studies such as journal and conferences proceedings, magazines, books, internet sources and so on. From the literature review of existing studies, the mode at which hydrogen cyanide is generated in cassava and why it is present is extensively discussed. The risk attached to consumption of cassava is mentioned as well as ways to detect, treat, and prevent cyanide poisoning is extensively discussed. Much work need to be done on sensitization of cyanide poisoning as there is little to no awareness on its dangers and modes of poisoning. Sources of water as well as other sources used for detoxification of cassava should be monitored regularly to ensure proper measures are taken for safety as well to help minimize health risk associated with consumption of cassava in un-detoxified form. In this study the authors found some of the relevant findings related to the release of cyanide in water as a means of detoxification, the possible risks for human health, detection and treatments of its poisoning by different authors. Anthropogenic activities are identified as the main source of the increasing amounts of pollutants found in water. The authors presented the methods in which this contamination occurs and ways to prevent future contamination as discussed by various authors. Cyanide poisoning is very fatal but is rarely discussed by people so there is need for constant sensitization on the harms associated with cassava and ways to prevent poisoning. Therefore, this study found that cyanide poisoning is a source of major concern and more sensitization should be carried out as well as regular checks and supervision should be carried out in high risk areas in terms of cyanide poisoning by appropriate bodies in charge.

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8.0 Reference of the Study

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