SCIENTIFIC ARTICLE

Prodigious action of microbes on poisonous ravage waste degradation

Angayarkanni Jayaraman*[1], Thandeeswaran Murugesan[1], Nisshanthini Durairaj[2], Karunya Jairaman[1] and Muthusamy Palaniswamy[3]

1Department of Microbial Biotechnology, Biotechnology, Bharathiar University, Coimbatore – 641 046 . 2 Molecular Diagnostics Lab, Bhat Bio- Tech India Pvt Ltd, Bengaluru -561229. 3Department of Microbiology, Karpagam Academy of Higher Education, Coimbatore – 641 021

E-mail :angaibiotech@buc.edu.in

*For correspondence

Abstract

Cyanide is highly toxic for most living organisms because it forms very stable complexes with transition metals (ie. Iron), that is essential for protein function, as in cytochrome oxidase, haemoproteins as well as other metal–containing oxidases or oxygenases. The removals of cyanide by the physical and chemical methods are more expensive and thus alternative process like biodegradation technologies are under focus. The microorganisms utilize potassium and sodium cyanide as a sole source of carbon and nitrogen for the degradation process. Cyanide degrading bacteria are noted to produce pteridines, a cofactor for the activation of cyanide monooxygenase which is needed for cyanide degradation. Peridines being a potential therapeutic agent, the production of pteridines by these organisms are needed to be explored in future.

Keywords: Biodegradation, Cyanide degradation, Cyanide Monooxygenase, Pteridine

Introduction

In the wake of Technology development and Industrial revolution, rapid industrialization has resulted in amassment of waste in the form of both solid and liquid. While addressing the global challenge in sustainable development, the waste degradation must be given priority over the production process. The product would fulfill certain needs of human kind but the waste accumulation deprives the whole community of healthy environment by piling up the pollutants. If improperly managed, this waste can pose dangerous health and environmental consequences. In this context, biodegradation is found to be the best approach to retract the adverse impact and reduce the pollution effect. Biodegradation is the nature's way of cleaning up the environment by breaking down the complex toxic matter to simple nontoxic matter for the utilization of the biota.

Cyanide waste

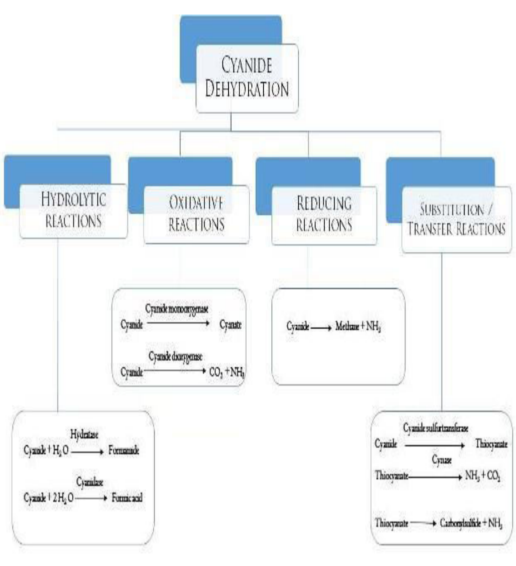
Cyanide is an ancient molecule that might be involved in the prebiotic synthesis of different nitrogenous compounds, including amino acids and nitrogenous bases. Cyanides include a type of chemicals that present the cyano (−C≡N) group and they can be found in nature in many different forms owing to the chemical properties of this group. Cyanide is generated as a natural compound by some bacteria, algae, fungi, higher plants and even by insects, either as a biomolecule for guarding mechanism or as repulsive molecule. Plants are the main source of cyanide in the biosphere because they cogenerate cyanide with ethylene (Peiser *et al.*, 1984) in addition to generating cyanoglycosides and cyanolipids. Moreover, cyanide has also been shown to be produced as part of active iron-cyanide complexes of catalytic proteins (Reissmann *et al.*, 2003). Even though natural processes generate cyanide, the human activity is the major contributors which tip the balance in nature creating environmental havoc.

Toxicity of cyanide waste

Cyanide can enter the human system either by inhalation or ingestion or adsorption. The fatal doses for human adults have been prescribed as 1-3 mg/kg body weight if ingested, 100-300 mg/L if inhaled, and 100 mg/kg body weight if adsorbed (Huiatt, 1984). Cyanide released from industries worldwide has been estimated to exceed 14 million kg per year which is an alarming quantity (Naveen *et al.*, 2011). A short-term exposure of cyanide, causes rapid breathing, tremors and other neurological effects, and long-term exposure to cyanide causes weight loss, thyroid effects, nerve damage, and even death. Skin contact with cyanide-containing liquids may produce irritation and sores (Dash *et al.*, 2009). Cyanide is also known as a major inhibitor of the enzyme cytochrome oxidase as well as haemoproteins and other metal–containing oxidases or oxygenases (Knowles, 1976). As cyanide is a metabolic inhibitor of terminal cytochromes of electron transport chains (Dumestre *et al.*, 1997; Yanase *et al.*, 2000), cyanide pollution causes great damage to ecosystems.

Microbial degradation of cyanide waste

In India, Central Pollution Control Board has set a minimal national standard limit for cyanide in wastewater as 0.2 mg/L. In the current scenario wastewater treatments for cyanide removal physical and chemical methods are employed which are often expensive and involve the use of additional hazardous reagents (chlorine and sodium hypochlorite) for alkaline chlorination, ozonization, wet-air oxidation and sulfur-based technologies (Watanabe *et al.*, 1998**,** Patil and Paknikar, 2000). Further each of these technologies has its own cost and disposal considerations (Saarela and Kuokkanen, 2004). Thus cyanide treatment hollered out for an alternative treatment process capable of achieving high degradation efficiency at low costs. Biodegradation technologies are scrupulously appealing for cyanide wastes with added organic supplements for microbial growth which results in production of eco-friendly products like CO_2, formate, formamide and methane (Dubey and Holmes, 1995; Raybuck, 1992). It was earlier contemplated that cyanide was the pioneer organic compound on earth, from which the chemical building blocks of life evolved (Oparin, 1957; Rawls, 1997). Many microorganisms can use potassium or sodium cyanide as a sole source of carbon and nitrogen. Despite the toxicity of cyanide towards living organisms, biodegradation of cyanide bank upon the easy adaptation and enrichment of indigenous microorganisms which can utilize cyanide as substrate (Dash *et al.*, 2009).



Propitious omen of cyanide degradation by oxidation

The oxidative pathway of cyanide conversion involves oxygenolytic conversion to carbon dioxide and ammonia. There are two types of oxidative pathway involving three different enzymes. The first oxidative pathway involves cyanide monooxygenase and cyanase. The second oxidative pathway utilizes cyanide dioxygenase to form ammonia and carbon dioxide directly (Ebbs, 2004). Between the two pathways the first pathway involves a positive product named pteridine which has several biological implications both in prokaryotes and eukaryotes.

Cyanide monooxygenase in the first oxidative pathway (Raybuck, 1992; Ebbs, 2004) converts cyanide to cyanate. The cyanate is then catalyzed by cyanase resulting in the conversion of cyanate to ammonia and carbon dioxide. Cyanases have been identified in numerous bacteria, fungi, plants and animals. Cyanide monooxygenase (CNO) is located in the cytosolic fraction of cells induced with cyanide and requires both reduced pyridine nucleotide (NADH) and a source of reduced pterin as a cofactor (Kunz *et al.*, 1992; Fernandez *et al.*, 2004). Cyanide monooxygenase is a pterin-dependent hydroxylase which means this enzyme requires pterin as a cofactor (Cabuk *et al.*, 2006). It is usually observed that cyanide-grown cells contain elevated levels of both cyanide mono- oxygenase and formate dehydrogenase (Kunz *et al.*, 1992). It was hypothesised that the cofactors production also increase with increased production of metabolic enzymes and it was proposed that cyanide degrading bacteria produces pteridines in large amounts (Nisshanthini *et al.*, 2015).

Owing to the therapeutical importance of pteridines, the production of pteridines by cyanide degrading bacteria using cyanide waste as substrate is a typical process of wealth from waste which needs to be explored in detail.

References

Cabuk, A., Arzu, T.U. and Nazif, K. (2006). Biodegradation of cyanide by a white rot fungus, *Trametes versicolor. Biotechnol .Lett.,* **28**: 1313 - 1317.

Dash, R.R., Gaur, A. and Balomajumder, C. (2009). Cyanide in industrial wastewaters and its removal: a review on biotreatment. *J. Hazard. Mater.*, **163**: 1-11

Dubey, S.K., Holmes, D.S. (1995). Biological cyanide destruction mediated by microorganisms. *World J. Microbiol. Biotechnol.*, **11**: 257-265

Dumestre, A., Therese, C., Jean, M.P., Mylene, G. and Jacques, B. (1997). Cyanide Degradation under Alkaline conditions by a strain of *Fusarium solani* isolated from contaminated soils. *Appli. Environ. Microbiol.* **63** (7): 2729-2734.

Ebbs, S. (2004). Biological degradation of cyanide compounds. *Curr. Opin. Biotechnol* .,**15**: 231-236.

Fernandez, R.F., Elena, D. and Daniel, A.K. (2004). Enzymatic Assimilation of cyanide via pterin – Dependent Oxygenolytic cleavage to ammonia and formate in *Pseudomonas fluorescens* NCIMB 11764. *Appli. Environ. Microbiol.*, **70**(1): 121-128.

Huiatt, J.L. (1984). Cyanide from mineral processing: problems and research needs. In proceedings of cinference on cyanide and the Environment , *Tuscon.,* 331-339.

Knowles, C.J. (1976). Microorganisms and cyanide. *Bacteriolo. Revi.*, **40** (3) 652-680.

Kunz, D.A., Olagappan, N., Silva-Avalos, J. and Elong, T.G. (1992). Utilization of cyanide as a nitrogenous substrate by *Pseudomonas fluorescens* NCIMB 11764: Evidence for multiple pathways of metabolic conversion, *Appli. Environ. Microbiol.*, **58**: 2022-2029.

Naveen, D., Majumder, C.B., Mondal. P. and Shubha, D. (2011). Biological treatment of cyanide containing waste water. *Res. J. Chemi. Sci*., **1**(7): 15-21.

Nisshanthini, S.D., Teresa infanta. S.A.K., Raja, D.S., Natarajan, K., Palaniswamy, M. and Angayarkanni, J. (2015). Spectral characterization of a pteridine derivative from cyanide – utilizing bacterium *Bacillus subtilis* – JN989651. *J. Microbiol* . **53**(4): 262-71.

Oparin, A.I. (1957). The origin of life of earth, Oliver and Boyd, London.

Patil, Y.B., Paknikar, K.M. (2000). Biodetoxification of silver-cyanide from electroplating industry wastewater. *Lett. Appl. Microbiol* ., **30**: 33-37.

Peiser, G.D., Wang, T.T., Hoffman, N.E., Yang, S.F., Liu, H.W. and Walsh, C.T. (1984). Formation of cyanide from carbon 1 of 1 – aminocyclopropane – 1 carboxylic acid during its conversion to ethylene . *Proed. Natl. Acad. Sci. USA*., **81**: 3059-3063.

Rawls, R. (1997). Earth is first organics, Chemical Engineering News, *American Chemi. Soci.*, 20-22.

Raybuck, S.A. (1992). Microbes and microbial enzymes for cyanide degradation. *Biodegradation*., **3**: 3-18.

Reissmann, S., Hochleitner, E., Wang, H., Paschos, A., Lottspeich, F., Glass, R.S. and Bock, A. (2003). Taming of a poison: Biosynthesis of the NiFe-hydrogenase cyanide ligands. *Science*., **299**: 1067-1070.

Saarela, K. and Kuokkanen, T. (2004). Alternative disposable methods for wastewater containing cyanide: Analytical studies on new electrolysis technology developed for total treatment of wastewater containing gold or silver cyanide, Pongr'acz E (ed.) Proceeding of the waste minimization and resources use optimization conference, University of Oulu, Finland, 107-121.

Watanabe, A., Kazuyoshi, Y., Kazunori, I. and Isao, K. (1998). Cyanide hydrolysis in a cyanide degrading bacterium , *Pseudomonas stutzeri* AK61, by cyanidase. *Microbiology.,* **144**: 1677-1682.

Yanase, H., Sakamoto, A., Okamoto, K., Kita, K. and Sato, Y. (2000). Degradation of the metal-cyano complex tetracyanonickelate (II) by *Fusarium oxysporium* N-10. Appl. Microbial. Biotechnol ., **53**: 328-334

RESEARCH REPORTS

CRISPR-like 'immune' system discovered in giant virus

Gigantic mimiviruses fend off invaders using defences similar to the Clustered regularly-interspaced short palindromic repeats (CRISPR) system deployed by bacteria and other microorganisms, French researchers reported. They say that the discovery of a working immune system in a mimivirus bolsters their claim that the giant virus represents a new branch in the tree of life.

Mimiviruses are so large that they are visible under a light microscope. Around half a micrometre across, and first found infecting amoebae living in a water tower, they boast genomes that are larger than those of some bacteria. They are distantly related to viruses that include smallpox, but unlike most viruses, they have genes to make amino acids, DNA letters and complex proteins.

This means that they blur the line between non-living viruses and living microbes, says Didier Raoult, a Microbiologist at Aix-Marseille University in France, who co-led the study with his Microbiologist colleague Bernard La Scola. Raoult says that he doesn't consider the mimivirus to be a typical virus; instead, it is more like a prokaryote microbes, including bacteria, that lack nuclei.

Like prokaryotes, mimiviruses are plagued by viruses known as virophages, Raoult, La Scola and their colleagues reported in 2008. Six years later, in 2014, they found a virophage named Zamilon that infects some kinds of