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Actinomycetes: A General Review

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Abstract*: Actinomycetes are the most prolific group of microorganisms. They are wide in distribution and known to occur in various environments. They produce various metabolites that are of industrial importance and therapeutic importance. These metabolites are known to control many human and plant pathogens. A huge number of currently used antibiotics including erythromycin, streptomycin, rifamycin and gentamycin, are isolated from soil and marine actinomycetes. This review summarizes about the actinomycetes from soil and marine environments including structure, taxonomy, pigmentation, advantages and disadvantages.

***Keywords*: Actinomycetes, harmful, beneficial, pigment, antibiotics**

I. INTRODUCTION

The word 'Actinomycetes" stands for "atkis" (a ray) and "mykes" (fungus) in Greek [1]. Actinomycetes are the group of microorganisms that exhibit the characteristics of both bacteria and fungi. They were considered as an intermediate group in between bacteria and fungi but latter on they were separated as a different group [2]. They are known to form thread-like filaments in soil, grow like fungal hyphae and are gram positive bacteria with high G+C content. They are present in terrestrial and aquatic systems [1]-[4]. Various metabolites that are economically valuable, such as antibiotics, anti-tumor agents immunosuppressive agents and enzymes are known to be produced by these organisms [3], [4]. They are also responsible for the characteristic 'earth' smell which is being attributed to Geosmin, a metabolite [5], [6]. Taxonomically, actinomycetes belongs class Actinobacteria of phylum Firmicutes. They are further divided into eight families such as Actinoplanaceae, Actinomycetaceae, Dermatophilaceae, Frankiaceae, Micromonosporaceae, Mycobacteriaceae, Nocardiaceae and Streptomyceteceae and has more than sixty genera [7]. Some of the representative genera of actinomycetes are Streptomyces, Actinomyces, Arthrobacter, Corynebacterium, Frankia, Micrococcus, Micromonospora and several others.

Cell wall of actinomycetes is known to be very rigid and maintains its structure. Sometimes in high osmotic pressure conditions the cell burst is prevented [8], [9]. Their cell wall consists of peptidoglycan, teichoic and teichuronic acid and polysaccharides [8] [10]. The cell wall composition is similar to gram positive bacteria due to its well-developed morphological and cultural charactersitics [1], [11] (Das et al., 2008; Cummins and Harris, 1954)[1, 11]. They exhibit mycelial growth and produce spores. Based on their cell wall constituents the actinomycetes were classified into four different groups [12].

TABLE 1. CELL WALL TYPES IN ACTINOMYCETES

S.no	Cell wall type	Sugar Pattern	Genera examples
1	I	No characteristic sugar pattern	Streptomyces, Streptoverticillicum
2	II	Araginose, Xylose (monosaccharide)	Actinoplanes, Micromonospora
3	III	No Sugar	Dermatophilus, Planomonospora
4	IV	Galactose, Arabinose	Mycobacterium, Nocardia

(Adapted from Lechevalier and Lechevalier, 1970[12].

Diverse physiological and metabolic properties are exhibited by actinomycetes [13], [14]. Various secondary metabolites from actinomycetes has been reviewed by [15]. The secondary metabolites that are produced by this group are known to have various biological activities especially those that are antagonistic in function [16]-[21]. Streptomyces genera members are known to produce more than 10,000 metabolites including volatile organic compounds [22]-[24]. Not only metabolites of clinical significance but also of industrial importance are being produced by these organisms such as colour pigments. Natural colours are produced by plants, animals and various groups of microorganisms including actinomycetes. These natural colour pigments are being used for different purposes (for eg. colouring agents, antioxidants and etc) in food and pharmaceutical industries [25].

TABLE 2. PIGMENTS PRODUCED BY ACTINOMYCETES MEMBERS

S.no	Pigment	Organism	Study
1	Anthracyclin glycoside	Streptomyces galilaeus, Streptomyces melanogenes, Streptomyces peucetius	Cassinelli et al 1982 [26]
2	Carotenoids	Streptomyces griseus, Streptomyces setonii, Streptomyces coelicolor	Takano et al 2006 [27]
3	Melanin	Streptomyces	Conn and Conn 1943 [28]
4	Naphthoquinone	Streptomyces coelicolor	Gerber and Wieclawek 1966 [29]
5	Prodigiosin	Serratia, S treptoverticillium rubrireticuli, Streptomyces longisporus	Venil and Lakshmanaperumalsamy 2009 [30]
6	Phenoxazinone	Streptomyces parvullus	Smith et al 2004 [31]
7	Violacein	Chromobacterium violaceum	Justo et al 2007 [32]

Studies have also shown that pigments isolated from actinomycetes members were shown antibacterial activities and industrial importance [33]-[35].

A. Actinomycetes From Soil Environment

Traditionally soil has been the source for the isolation of medicinally important actinomycetes. Nearly 80% of the commercially available secondary metabolites are from soil actinomycetes [36]. Of these, actinomycetales is an important group [17]. This order has nearly 80 genera that are mostly terrestrial in origin, some of them are aquatic and plant colonizers showing a diverse chemical and morphological characteristics, but also shows a distinct evolutionary line [37]. Primarily these are soil microorganisms that were found to have wide distribution ranging from deep sea soil sediments, low temperatures, soil from Antarctica and desert soil [38]-[44]. Many secondary metabolites are produced in different capacities that are known to have high commercial value, for which they are regularly screened for new metabolites [45], [46]. Antibiotics such as erythromycin, streptomycin, rifamycin, gentamycin and many others that are currently used are from soil actinomycetes [47]. Streptomyces and Micromonospora are the two major groups from which most of the antibiotics are isolated. Streptomyces accounts for nearly 80% of the antibiotics that are in use followed by Micromonospora with about one tenth of Streptomyces [48]. Streptomyces species is mostly being exploited by the industry for therapeutically important metabolites [22]. Streptomyces are known to be spore formers and shows filamentous nature [49], [50]. Members of this genera are shown to be devoid of any diagnostic sugar followed by a LL isomer of ‘2, 6- Diaminopimelic acid (LL-DAP)’ [51].

B. Actinomycetes from Marine Environment

Nearly ¾ th of the earth consists of sea water which hosts remarkable biodiversity [52]. Less than 10% of the sea surface is coastal area and the remaining is deep sea, more than 50% of it is more than 2000 m depth [52]. The deep sea environments are characterized by low light or completely lacks light, salinity, high pressures, low temperatures and less oxygen concentrations [53]. In spite of being geographically vast, information about the deep sea microbial diversity is scanty [52]. However, this environment was shown to be a source of novel organisms that are of therapeutic value and are less explored [53]. Due to the increasing number of aggressive pathogens, therapeutically important metabolites from actinomycetes especially from the marine environments may have an answer to combat these pathogens [54], [55]. Marine actinomycetes were shown to produce novel secondary metabolites [54], [55]. In 1984, it was a marine actinomycete Rhodococcus marinonascene that was first characterized [56]. After which, many studies were performed on the marine actinomycetes, some of them showed metabolic activites and some displayed adaptations to marine environment [57], [58]. The diversity of marine actinomycetes and their bioactive potential has been comprehensively reviewed by [59]. Most of the isolates belonged to Actinomadura, Aeromicrobium, Dietzia, Gordonia, Marinophilus, Micromonospora, Nonomuraea, Rhodococcus, Saccharomonospora, Saccharopolyspora, Salinispora, Streptomyces, Solwaraspora, Williamsia, Verrucosispora and several others genera. Streptomyces is also known to be present in marine systems and is known to be one of the largest number of species that shows diversity in physiology, morphology and their biochemical properties [59]. Salinispora genera was the first obligate marine actinomycete that was discovered [60]. Its members Salinispora arenicola and Salinispora tropica were also discovered to be obligate in nature [61].

Numerous pharmaceutically important metabolites have been isolated from marine actinomycetes, such as Abyssomicin C and Diazepinomicin [62] [63] (Riegdlinger et al 2004; Charan et al 2004) [62, 63]. Lam 2005 [54] has also reviewed actinomycetes metabolites from marine environments. Compounds such as Abyssomicins, Aureoverticillactam, Bonactin, Caprolactones, Chandrananimycins, Chinikomycins, Chlorodihydroquinones, Diazepinomicin, 3,6-disubstituted indoles, Frigocyclinone, Glaciapyrroles, Gutingimycin, Helquinoline, Himalomycins, Komodoquinone A, Lajollamycin, Marinomycins, Mechercharmycins, Salinosporamide A, Sporolides, Trioxacarcins and others that are known to have antimicrobial properties were majorly isolated from marine isolates of Streptomyces and Salinispora genera [54]. Many different classes of antibiotics such as pyridinium, chlorinated dihydroquinones and cyclomarazines were reported to be produced by Amycolatopsis alba var. nov. DVR D4, Streptomycetaceae strain CNQ-525 and Salinospora arenicola [64]-[66]. Cyclomarazines that were isolated from Salinospora arenicola showed inhibition against Vancomycin Resistant Enterococci (VRE) and Methicillin Resistant Staphylococcus aureus (MRSA) [64]. Nearly 70% of the Streptomyces members that were isolated from marine mollusks showed antagonistic properties but whereas only 20-25% of the same sediment isolates showed antagonism to the test organism [67]. Metabolites that have potential clinical benefits such as antitumor compounds such as anthracyclines (aclarubicin, daunomycin and doxorubicin), antimetabolites (pentostatin), aureolic acids (mithramycin), peptides (bleomycin and actinomycin D), enediynes (neocarzinostatin) and others [68], [69]. Marine actinomycetes developed exceptional physiological and metabolic properties that made them to survive in various habitats, and the potential to produce various compounds with therapeutic importance that are not much observed in their terrestrial members [70], [71]. Such properties could be attributed to their associations with various marine life [72]-[74]. Many type I polyketide compounds that show antitumor activity were isolated from actinomycetes of marine origin. Salinispora arenicola strain CNR-005 shown to produce arenicolides, a polyunsaturated macrolactone. The compound 'arenicolide A' showed cytotoxicity towards human colon adenocarcinoma cell line HCT-116 [75]. Two bicyclic polyketides, saliniketal A and B were isolated from the earlier strain. These compounds were shown to inhibit ornithine decarboxylase induction [76], [77]. Vibrio spp. isolate that was isolated from marine sediments was shown to produce antileukemic agent (L-asparginase) [67]. A marine actinomycete Micromonospora sp. L-25-ES25-008, isolated from sponge was reported to produce a macrolide 'IB-96212' [78]. This isolated compound showed high cytotoxicity against P-388 cell line in comparison with A-549, HT-29 and MEL28 cell lines [78].

C. Beneficial Effects

Actinomycetes are known to play a role in mineralization of nutrients and organic matter decomposition, they are known to be lignocellulose decomposers [79]. They also acts as biocontrol agents, especially on cellulose containing organisms such as Phytophthora [80]. In agroindustry, members of this group are being explored for its metabolites, as a plant growth promoters and as well as a biocontrol agents [81], [82]. Secondary metabolites from the actinomycetes have been shown to inhibit plant pathogens. Soil actinomycete was able to inhibit Erwina amylovora and Agrobacterium tumefaciens [102]. Members of Streptomyces species was shown to inhibit Oomycete members Pythium and Rhizoctonia [83]. Streptomyces was reported to be antagonistic to various plant pathogens such as Alternaria, Botrytis, Fusarium, Pythium, Phomopsis, Rhizoctonia and Sclerotinia [84]-[87]. Actinobacteria are known to play a role in humus formation and degradation of complex substances such as keratin, lignocelluloses, starch and chitin [13], [88], [89]. Xylanases were shown to be produced by Streptomyces spp., these enzymes are used to improve the rice straw pulp bleachability [90].Various enzymes that are known in organic matter degradation are produced by these organisms. Enzymes such as peptidases, pectinases, hemicellulases, keratinases, chitinases (e.g. Streptomyces viridificans), cellulases (e.g. Thermonospora spp.), proteases (Nocardia spp.), xylanases (Microbispora spp.), ligninases (Nocardia autotrophica), amylases (Thermomonospora curvata) and sugar isomerases (Actinoplanes missouriensis) are among the many enzymes that are produced by them [91]. Pectinases that are used widely in the clarification of fruit juices, degumming of fibres, wine making and retting of bast fibres are also reported in Streptomyces spp [92].

Not only for plants but also for human applications they produce enzymes. Members of actinomycetes group (Streptomyces griseus, S. karnatakensis, S. albidoflavus and Nocardia spp) were shown to be producers of L-Asparginase [93]-[95]. L-Asparginase is used in cancer therapy, especially in acute lymphoblastic leukemia [96], [97]. Many compounds that are having antitumor activity are also being produced from these organisms [68], [69].

They are shown to produce melanin or melanoid pigments, these pigments are also being used as a criterion in taxonomic studies [98]. Studies have shown that these pigments have radio protective and antioxidant properties [98] [99]. Melanin substances are being used in various preparations in medicine and cosmetic industry, it is being used as a bioplastic and biopolymer due to its ability to undergo polymerization [100].

D. Harmful Effects

Some of the members of actinomyces are known to be pathogenic in nature in both plants and humans. Scab disease of potato is known to be caused by Streptomyces scabies. It is known to attack various underground vegetables. It produces phytotoxin named as thaxtomin that causes necrotic lesions in potato [101]. Nearly half of the actinomyces species described so far are known to be pathogenic in nature to humans [102]. Many actinomycetes members have been isolated from less specific inflammatory conditions [103]-[109]. Some of the actinomycetes that are known to cause human diseases are A. naeslundii, A. odontolyticus, A. viscosus, A. meyeri, A. gerencseriae and A. israelii (facultatively anaerobic) [110]-[114]. Not only to humans but also to cattle these causes diseases. Actinomyces bovis was shown to cause granulomatous infections in cattle [112], [114], [115]. Over all, in less than 2% of the clinical cases reported they were also known to be pathogenic in nature, especially to humans [116].

II. CONCLUSION

Diseases are the key contributors of economic losses in plant production and human health. Some of the drugs that are in current use have become ineffective against various pathogens. It is pivotal for us to identify novel sources and drugs to counter these new threats that are arising probably due to the changing climatic conditions. Actinomycetes gave us significant amount of antibiotics. But studies focusing on this group are limited in spite of their wide occurrence and distribution in various environments. Studies indicated that there is an untapped potential in this group especially from the marine sources. For isolating of novel such compounds, use of high through put systems and advanced molecular studies might reveal better about the molecular basis of their production. Such studies should to be collaborative in between the academia and industry to optimise the benefits and also multi-disciplinary involving pharmacologists, microbiologists and pathologists.

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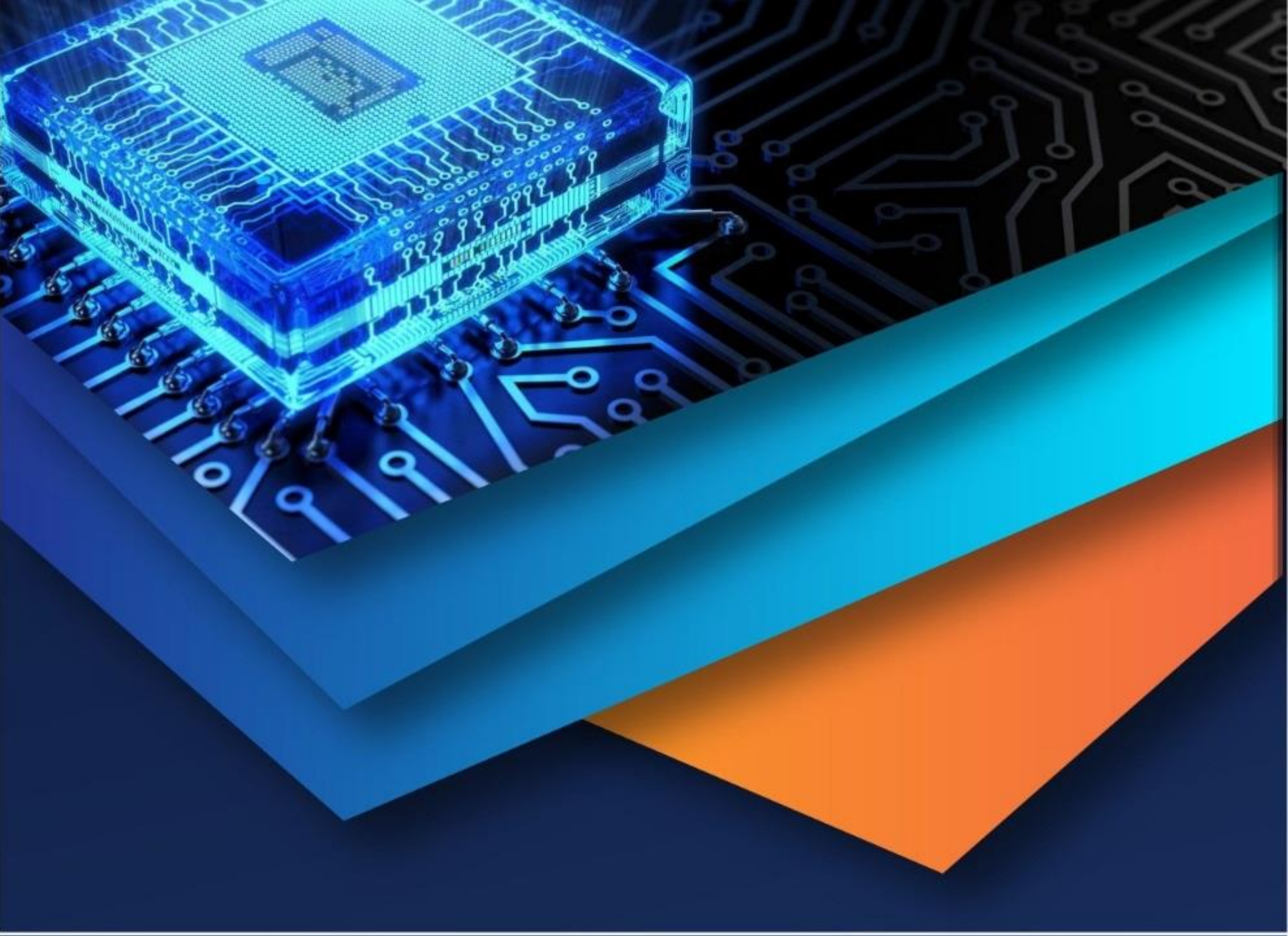

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