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Dissolved Organic Carbon Originating from Riparian Buffers Imparting Self Purification Properties to River a Review

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Abstract:- National forests and water strategy has brought focus to the establishment of riparian buffers to protect the river environment. The riparian area is that area of land located immediately adjacent to rivers, streams and lakes. Riparianbuffers plays a significant role for the protection of rivers as well as diversity along the banks of rivers. A review was prepared to assess the efficacy of riparian buffers of a particular site or landscape for determining its actual contribution to rivers. Riparian buffers also acts as a bio filter and important secondary compounds of valuable importance are leached from the vegetation in the form of allochthonous carbon (carbon derived from leaf and leaf litter) from these sites which may likely be responsible for playing a vital role in maintaining and purifying water quality. Present review paper mainly focuses on riparian vegetation (buffers) and itsvarious carbon content with its associated impact on the water bodies and vegetation itself. Hence riparian buffers needs to be restored to reduce water contaminants, hence maintaining purity.

***Keywords*:-** *Riparian Buffer, Water Quality, Vegetation, Leaf Litter, Secondary Metabolites, Allochthonous Carbon.*

I. BACKGROUND

A. *Riparian Vegetation (Buffers) and its Carbon Content*

Riparian habitats serve as transitional ecotones that regulate the exchange of biotic and abiotic materials between the upland watersheds and streams.Healthy riparian ecosystem provides good quality water, sediments filtration, and nutrition enrichment(Thilina*et al.* 2015).

- It buffer out pollutants, provides organic matter for terrestrial and aquatic organisms and also functions as a passage for association of animals which includes some important roles played by riparian vegetation(Bhaskar *et al.2015*).

- Riparian vegetation along water courses had been used as well as distinguished forincorporating nutrients like Carbon (C), Nitrogen (N) and Phosphorus (P)(Zhang *et al*. 2013).

- Healthyriparianhabitats provides numerous ecosystem servicesand functions, such as they function as filters through the retention of nutrients and sediment within agricultural runoff(Bradburn *et al.* 2010).

- The retention of pollutants in the buffer zone depends on the buffer width and sorption properties (Christof *et al*. 2014).

- Vegetated riparian buffers alongside streams are thought to be effective at intercepting and controlling chemicalloads from diffuse agricultural sources entering water bodies such as rivers exposed to pesticide input. Riparian buffers are most efficient at improving water quality when they include herbaceous plants in this filter strip along with deep rooted trees which are dominant in that landscape and shrubs along the rivers(Fortier *et al*.2016).

- Riparian vegetation is a major source of energy and nutrients for stream communities.Riparian forest and vegetation can be functioned as a buffer region in urbanizing watershed to protect and to improve water quality (Vyas *et al.* 2012).

- Riparian buffers control in-stream temperatures by shading the river water. In healthy streams light controls primary productivity (Ryan *et al*. 2016).

- In nutrient rich streams shade can influence the impact of nutrient enrichment and prevent the development of algal blooms or excessive algal growth which will lead to eutrophication preventing the growth of aquatic organisms(Sweeney and Newbold.2014).

- Riparian vegetation influences river principal production directly through blocking of daylight and inputs of organic matter from the vegetation, and indirectly through filtering of terrestrial runoff and temperature (Smiley *et al*.2011).

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B. Presence of Dissolved Organic Carbon in the Riparian Vegetation

Cycling of carbon (C) and nutrients plays vital role for functioning of every ecosystem.Biogeochemical cycles of Carbon (C) and Nitrogen (N) are balanced by a network of inter-actions between plants, litter, soil chemistry, microbial communities, enzyme machinery and climate conditions (Horwath 2015).

- Organic carbon in lotic systems comes from two main sources: (a) Allochthonous carbon is of terrestrial nature originating from the surrounding forest and buffers and (b) Autochthonous carbon is from photosynthetic production within the stream. (Michael *et al*. 2012).

- Autochthonous sources of organic matter are considered to make only a minor contribution to the total energy pool of forest streams. Dissolved organic carbon (DOC) in the flowing water column of small streams derives mainly from allochthonous sources, i.e. leaching of adjacent soil, input of leaf litter, and dead wood (Adam *et al*. 2014) Leaves of gymnosperms contribute more organic matter to river which is collectively called as allochthonous carbon (Robert*et al*. 2012).

- Both allochthonous and autochthonous-derived carbon sources are important to support bacterial production in the dynamic food web in streams (Fukuda *et al*. 2006).

- Plant and wood debris from riparian vegetation is a major source of organic matter to stream and river channels(Attermeyer*et al*. 2013).

- There exists some carbon in the catchment soils and plants of riparian vegetation (Berhongaray *et al*.2013).Riparianforests contribute nearly 93% of the total organic matter load exported annually to stream water from a huge watershed(Goncalves &Callisto2013).

- Large tree and wood debris have a significant relation with stream chemistry mainly through its affect on erosion and deposition of sediments, organic matter, and related chemicals inside river channels(Dosskey*et al*. 2010].

- Despatching of woody debris, leaves, stems, barks and partially decomposed plant parts contributing coarse and fine particulate organic matter from riparian vegetation to streams have been hypothesized to form biogeochemical hot spots that regulate the export of Dissolved organic carbon (Wilkinson *etal*.2013).

- Stream water dissolved organic carbon (DOC) concentrations arises from the fact that dissolved organic carbon plays an integral role in the biogeochemistry and ecology of surface waters across forested regions of the world. DOC directly affects the food web structure in lakes which exerts control on the acid-base chemistry of surface waters (Buffam *et al*. 2008).

- Present review paper is mainly focused on the leaching of dissolved organic carbonoriginating from different sources and its effects on streams. The paper includes the sources, causes and effects of different types of organic carbon and their description.

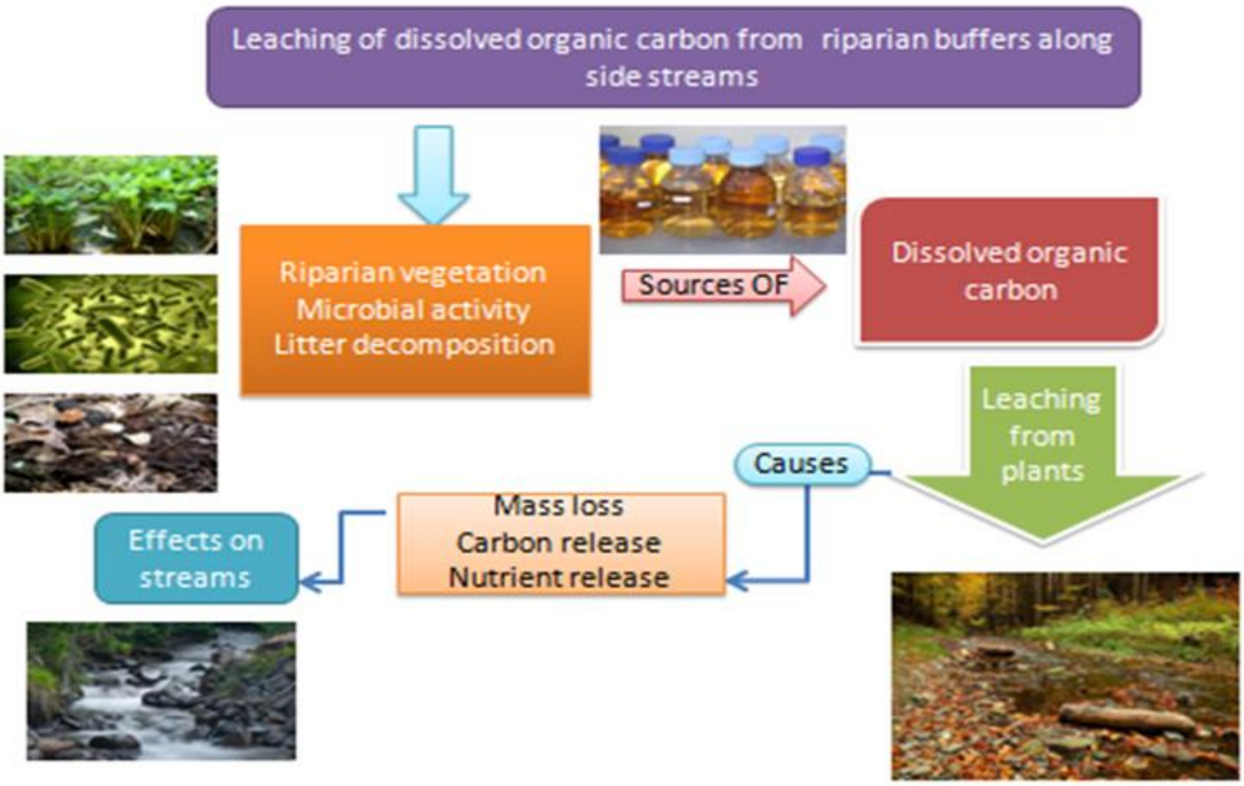

Fig 1 Sources, Effects and Causes of Dissolved Organic Carbon Leaching from Riparian Buffers Into Streams.

Table 1 Depicts the Types, Source, Fraction and Degradation Rates of Carbon

Types of Carbon	Source of Carbon	Fraction of Carbon	Degradation Rate
Labile carbon	Flora (Riparian buffers)	40%	Medium
Semi labile carbon	Humus (Litterdecomposition)	50%	High
Refractory carbon	Carbonates and bicarbonates (microbial activity)	30%	Slow

II. SOURCES OF LEACHING OF DISSOLVED ORGANIC CARBON

A. *Leaching of Dissolved Organic Carbon from Riparian Buffers*

The mobilization of Carbon from the terrestrial into aquatic ecosystem is of prime importance on a global scale andis referred as Dissolved Organic Carbon because of its moveable nature.This dissolved organic carbon which originate form riparian buffers plays some role in imparting purification to river water (Batjes 1996).

- The amount of secondary metabolites of organic nature that enters the wetland ecosystem from terrestrial riparian forests is estimated to be considerableand the compounds which are derived from the breakdown of leaf litter such as phenols are thought to have a significant impact on river water quality (Kitamura H.2009).

- Increased leaching of terrestrial carbon into surface waters has been observed in many regions of the temperate and boreal climate (Erlandssonet al. 2008).

- For the mobilization of Dissolved organic carbon from terrestrial to aquatic ecosystems the role of headwaters is especially relevant (Laudon et al. 2011).

- The continuous leakage of dissolved organic matter (DOM) from terrestrial ecosystems in the water bodies results in the high concentrations of organic substrates in rivers and is responsible for the brown colour as well as the turbidity of the water (Moore et al2011).
- Overall, the Dissolved organic carbon export from terrestrial to aquatic ecosystems after logging is dependent on two major mechanisms (Kreutzweiseret al. 2008).

- First, change of factors whichcontrols soil solution concentrations of Dissolved organic carbon which, if increased, will also increase the export of carbon from these soils. Second increased water fluxes may also increase the nutrient export simply by increasing the transport(Schelkeret al.2012).

- Wood is also considered to be an important component of the organic matter in stream ecosystems (Loreaet al. 2011).

- Rapid leaching of low molecular weight compounds within 24 hr has been observed from a variety of dried hardwood leaves (Mengxue et al.2015).

- Wood breakdown began with a moderately rapid mass loss which can be attributed to the leaching of soluble substances or secondary metabolites. Leaching from wood has been regarded as a minor process because of the low content of soluble material as well as the low surface: volume ratio of coarse wood. Pine branches had the slowest breakdown rate. Gymnosperm wood is known to breakdown slowly because of its low percentage of living tissue and due to its low nutrient and high lignin contents (Mohammed et al.2013).

- In contrast, angiosperm wood decomposes faster, a trait further enhanced by the larger diameter and the connection of its tracheids, which facilitates the penetration of fungal hyphae. Leaf litter chemical quality (Carbon to Nitrogen ratio C: N) and polyphenolics content are used as an indicator of leaf litter mass loss and presence of dissolved organic carbon released into river water through leaching (Michael.2012).

- As literature reviewed inputs of leaves are 2.5 times higher than those of small wood because leaves are flushed away far more easily than wood (Elosegiet al 1999).For significant leaching to occur, leaves must reside at a site for a sufficient period of time. The presence ofthe secondary compounds that leached from river also depends upon the resident time of these compounds, the period for their degradation. The nature of the leached secondary metabolites and the rates at which they occurs vary among plant species and the parts of the plant as well as depends on the stage of plant decomposition(Kitamura. 2009).

- Leaching is purely an abiotic process which occurs within the first 24 hours after plant immersion in water. It has been reviewed that 25% of the initial dry mass of leaves is lost due to leaching. Dissolved Organic Matter is primarily comprised of secondary metabolites which are basically soluble carbohydrates or polyphenols(Benner et al.2011). The amount of litter that enters the streams contributes large amounts of organic carbon. Litter fall from this gymnosperms and angiosperms may consist of leaves and leaf fragments, needles, floral parts, bark, wood (branches and twigs), cones and nuts, fruits, and other plant parts (Adam.2015).

B. *Leaching and Litter Decomposition*

Litterfall from riparian vegetation provides streams with allochthonous organic matter, which can be used as an energy source for the aquatic food web. The amount of litter produced in forests and entering the streams varies considerably and depends on factors such as climate,

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vegetation, type of soil, age of the trees and morphologic characteristics of the streams(Congyan2012).

- Copious investigationshave recommended that leaf breakdown in streams iscontrolled by environmental factors, such as watertemperature, the activity of macroinvertebrates andthe concentration of dissolved nutrients in the streamwater(Veronica et al. 2012).

- Perhaps the most expansively studied aspect of leafbreakdown in stream ecosystems is the variabilityamong different species of leaves (Shuiwang2014).

- The process of decomposition of leaves can be divided into three phases which are referred as leaching, conditioning, and fragmentation (Veronicaet al2012). At early stage of decomposition, the large amounts of dissolved materials in fresh litter could be leached (Schreeget al. 2013).

- This labile leachate could trigger the carbon use efficiency of microorganisms and thereby further promote decomposition (Cotrufoet al. 2015).

- Decomposition of plant litter is one of the most fundamental processes for global carbon budgets, as approximately half of the ecosystem productivity is returned to the soil via litter decay in terrestrial ecosystems. In natural autumnal leaf-fall; total dissolved organic carbon levels generated were 10 times higher. Free amino acids were also leached from deciduous leaves(Liping et al.2016).

- Leaf litter decomposition is a natural process and is very useful in ecosystem study because of its role in ecosystem such as carbon budgets, soil organic matter formation, and nutrientcycling(Yang et al. 2014). Litter shed by trees functions as a key energy source for low order streams running through forests. Decomposition rates increase with nitrogen content of leaves (Moore et al.2011).

- Nitrogen which is derived from amino acids breaks down faster since amino acids are highly sensitive to temperatures and degrades faster due to the loose bonding between them (Cortes et al.1994). When litter inputs from a riparian forest are excluded from an upland area, food web structure has been observed to be altered (Naimanet al. 2005).

- In general, high concentrations of dissolved nutrients, primarily carbon (C), nitrogen (N) and phosphorus (P), hasten the processing of leaves (Moore et al.2011).

C. Leaching of Dissolved Organic Carbon from Microbial Activity

It is observed that the senescent leaves contained a large amount of liable organic carbon and these compounds could be easily extracted with water. In a watercourse, leaves undergo conditioning and fragmentation due to microbial and invertebrate activity after leaching of its secondary metabolites (Allan1995).

- The speedy collapse of plants may be due to intrinsic nature of the leaves (e.g., chemical composition and texture), or the hydrological and chemical features of the stream such as high-water flow and nutrients such as Carbon, Phosphorus and Nitrogen in water. After initial leaching of soluble compounds, leaf breakdown is affected by abiotic fragmentation, microbial decomposition and invertebrate feeding (Silvia et al. 2016).

- Factors which affect the rates at which leaves breakdown in river include water temperature, leaf "toughness" and aspects of stream water chemistry can be understood by the following parameters including pH, Total organic carbon and Ultraviolet spectroscopy(Peterson &Cummins 1974). Most of the initial rapid loss in leaf weight could be attributed to rapid leaching of secondary metabolites(Kaushik & Hynes 1971).

- The role of polyphenols in stream ecosystem is known to justify that polyphenols play various roles in plant biology and in terrestrial nutrient cycling including defence against herbivores and contribution to plant colours (Haslam 1981).

- The main conclusions which are derived after an enormous literature survey are that fungi dominate early and advance stages of leaf decomposition and later on bacteria balance fungi and play a vital role in decomposition rather than replacing them. The chemical changes of leaves begin as soon as they fall into the stream, with the leaching of soluble secondary compounds. Riparian tree richness which are present alongside streams, are likely to increase the number of fungal species that degrades leaves in streams (Laitung& Chauvet 2005) which in turn increases the amount of litter consumption by invertebrates (Lecerf et al. 2005).

- Similarly, a diet of mixed-species litter which contains plants parts of gymnosperms as well as angiosperms may increase invertebrate growth rate (Swan & Palmer 2006). Similarly, detritivore secondary production, is enhanced in streams lined by diverse riparianvegetation which in turn leads to a positive feedback on litter decomposition in our near future (i.e., at time scales of months and years)(Bray et al.2012).

- Low flow conditions observed at many rivers could also reduce leaf breakdown rates through the accumulation of soluble polyphenols that can also inhibit microbial activity (Neil et al.2012). Increased microbial activity in soil enhances the production of dissolved organic carbon (Kalbitz et al.2007).

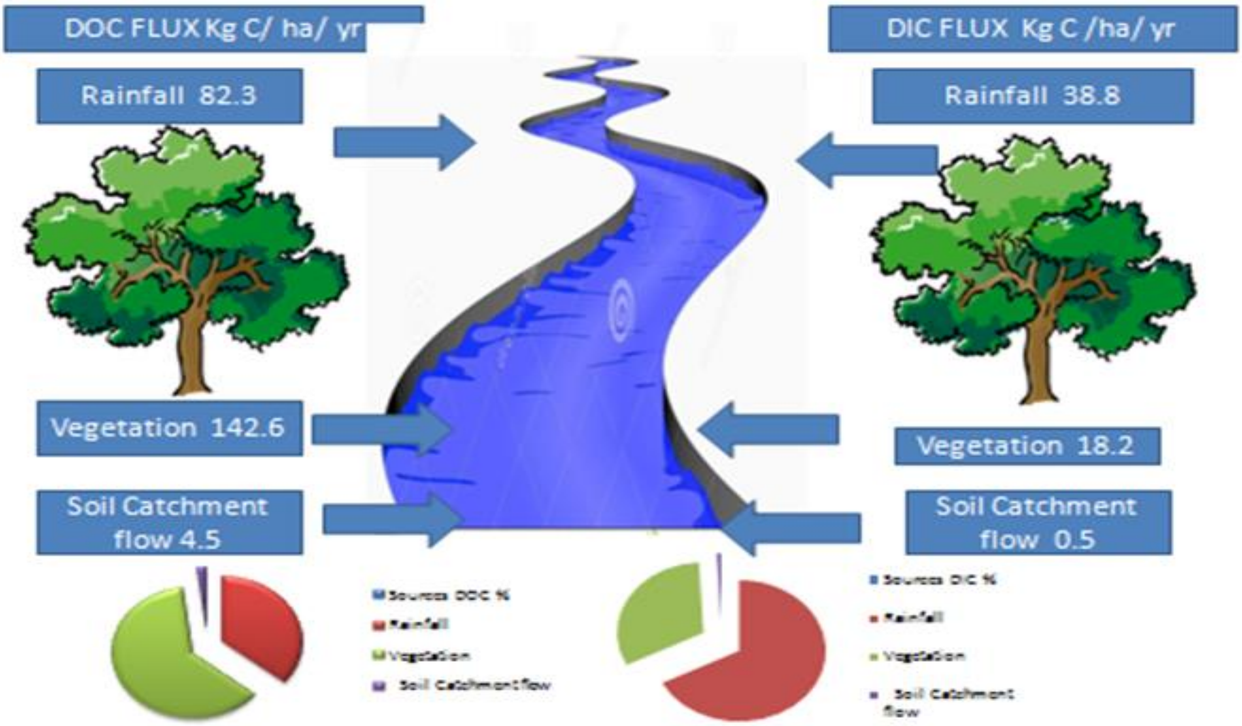


Fig 2 Depicting Percentage Wise(%) Contribution of Sources of Dissolved Organic and Inorganic Carbon in Rivers

III. EFFECTS OF LEACHING OF DISSOLVED ORGANIC CARBON

A. Effects of Leaching on Mass Loss

Leaching is considered important for leaf litter decomposing in aquatic environments, and its contribution to mass loss is considered as an initial stage (Xia 2012).

- The leaching of litter has concluded that the total amount of water soluble organic and inorganic substances leached from ground litter after one day ranged from 8-25% of the dry mass among litter types. The amount of water-soluble substances was greater when leaching took place under anaerobic conditions than under aerobic. Aliphatic acids are formed during decomposition and large amounts were leached from needle litter of pine and spruce at high temperatures (Zhu et al, 2012).

- Thus leaching was not only modulated by abiotic factors such as pH value and temperature, but also affected by the functional traits of plant litter, which have been proved to be a predominant factor controlling on litter decomposition within a given ecosystem worldwide (Makkonen et al.2012).

- Generally, leaching is largely completed within the first 24-48 h after immersed in water and the loss up to 30% of the original mass, depending on litter species. However, it is noteworthy that although, the mass loss in the first day may account for a large amount of the whole losing mass, the period of leaching is a prolonged process developing over weeks (Ghani et al.2013).

- Leaves lose up to 40% of their dry mass by leaching in water for a few hours (Cummins 1972) and it has been seen that a portion of the material leached from leaves precipitated out. After reaching river or stream, these leaves suffer various physical and chemical processes including an initial rapid leaching phase when organic compounds are lost, bacterial and fungal colonisation happens (Datry et al. 2011)and mechanical breakdown of leaf structure occurs due to heavy churning and velocity of water and due to shredder invertebrates(Grace 2001).

- The leaching of soluble compounds may account for considerable loss of leaf initial mass and can be responsible for greater reduction of secondary metabolite or compounds concentration from leaves finally emerging into river (Goncalves et al. 2012).

- Initial losses for different leaf species and streams include nitrogen, carbon, phosphorus, calcium, magnesium, potassium and various organic compounds such as polyphenols (George et al. 1991).Secondary metabolites (i.e,total polyphenols and tannins) were swiftly leached and was four times greater for temperate leaves and tropical leaves (Odiwe 2016). Both temperate and tropical species lost more than 50% of their secondary metabolites during the first week of incubation in the river.
- In water, the decomposition of allochthonous organic matter that comes from decomposition of leaf litter starts immediately and usually occurs in three overlapping phases:

- Leaching of secondary metabolites, which can lead to loss of approximately 42% of the initial mass of the detritus leaves forming leaf litter(Abelho 2001)
- Decomposition by microorganisms, which may be responsible for the loss of Ca. 27% of the mass of leaves mass(Hieber&Gessner 2002)
- Biological and physical fragmentations. It is justified that an increase in the velocity of water flow causes increased physical fragmentation and breakdown of the debris adduced from adjacent terrestrial vegetation.

B. Effects of Leaching on Carbon Release

Dissolved organic carbon (DOC) leached from decomposing litter is the most important carrier for the flux of nutrients and transport of hydrophobic pollutants (Maria et al. 2011).

- ➢ Natural dissolved organic carbon is composed of components that have widely differences in physicochemical properties and also consisted of mixtures of labile and refractory carbon (Kumar et al. 2014). The fraction of carbon leached as Dissolved organic carbon decreased with time for all litter types except for the fresh needle litter in a broadleaf forest (Hagedorn &Machwitz 2007).

- ➢ Elevated CO2 decreased lignin degradation but accelerated both carbon mineralization and DOC leaching from the litter and Dissolved organic carbon was less biodegradable when its parent litter was incubated under elevated CO2(Susan et al. 2009).

- ➢ However, most of the literature available on litter fall shows that litter mainly arises from forests area(Gaurav Mishra & Rajesh Kumar 2016). Presence of wood has shown that the stream can preserve more coarse particulate organic matter from wood as compared to leaves(Patricia et al. 2016). On the other hand, the removal of wood from streams has been shown to decrease the capacity of the streams to retain coarse particulate organic matter (Eggert et al. 2012).

- ➢ Different species contribute different amounts of carbon that leached from litter as observed in a short-term leaching experiment, with the two evergreen coniferous species Cedrusdeodara and Pinus wallichinia(self-observed). Various ions such as carbonate, sodium, nitrate, magnesium, potassium, bromine and calcium are excreted and are also responsible for the production of some allelopathic substances such as phenols and esters(Brock et al. 1994).

- ➢ The effect of leaf litter on the chemical quality of streams reported that the decay of leaves in rivers generally induced greater water colour and low dissolved oxygen concentration since oxygen are required by the microorganism for the decomposition process which reduces the dissolved oxygen level(Ferreria et al. 2015).

C. Effects of Leaching on Nutrient Release

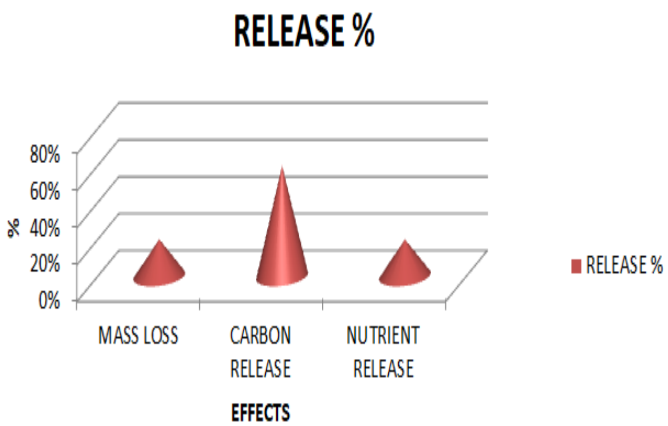
Plant litter from vegetation is a primary energy and nutrient source for wetland ecosystems(Neil et al. 2012).

- ➢ Nutrient leaching from freshly senesced litter could provide essential materials available for plant and microbial uptake, such as orthophosphate, inorganic and organic nitrogen.Terrestrial litter from riparian and upland vegetation also serves as a nutrient source for downstream water via direct litter fall, transport of litter, or litter-derived nutrients via wind or runoff and by seepage(Barry et al. 2014).

- ➢ Dissolved organic matter originating from woodlands or as breakdown products in adjacent rivers would contain secondary metabolites or other edible compounds of low molecular weight suitable as substrates for bacteria in the river(Congyan et al. 2012).

- ➢ Substrate enhancement from this source could result in accelerated organic matter restoration within the river (Wetzel 1971).

- ➢ Temperature was proven to be an important factor affecting Dissolved organic carbon leaching (Andersson & Nilsson 2001), indicating that temperature must be taken into consideration while assessing the effect of leaching on litter decomposition.



Graph 1 Depicting Effects of Dissolved Organic Carbon on Reduced Fraction

IV. EFFECTS OF LEACHING ON STREAMS

- ➢ Although, the Dissolved organic matter leaching from the leaves of riparian trees might be an important pathway through which organic matter or secondary metabolite is supplied to stream ecosystems (Mary et al. 2016).

- ➢ Dissolved Organic Carbon or Dissolved Organic Matter affects river and stream pH and protects organisms by reducing the toxicity and bioavailabilty of contaminats by exposure to ultraviolet radiation(William et al. 2015). In addition to Dissolved organic carbon, the concentration of total sugar and polyphenol in the leachate increased as these are among the most major

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forms of dissolved organic matter leached from leaf litter (Suberkroopet al. 1976). However, the rapid leaching of these leaf compounds may have condensed the inhibitory effect on invertebrates(Adamczyk2016).

- Leaching depends on various conditions such as river water temperature, velocity, temperature, sunlight, leaf species, and drying of litter. Pine needles contribute more secondary compounds than other plants (Hansson et al. 2010). Polyphenols have shown to leach from leaves and stems for a longer period of time(Canhoto and Grace1996).
- The release of total phosphorus and dissolved organic carbon from coniferous and deciduous leaves dipped in water concluded that the period of leaching is a prolonged process developing over weeks(France et al.1997).
- Water temperature is influenced by ultraviolet radiation andvarious parameters such as pH, electrical conductivity, turbidity, dissolved organic carbon and nutrient concentration, and leaf chemistry is determined by the presence of secondary compounds such as tannins and structural characteristics of leaves are considered important factors controlling microbial colonization as well as decomposition of leaf litter in streams (Pascoal et al .2004).
- Riparian forests contributing dissolved organic carbon have the supreme potential to improve water quality along rivers(Peter et al. 2011).

V. CONCLUSIONS

It is now well established that allochthonous organic matter is important in the productivity of streams. From papers reviewed it develops a clear scenario that the leaves that fall in rivers or streams,releases some compounds with considerable loss of mass. Organic matter which are coming into streams also influence organic Carbon and Nitrogen which is released in stream waters (Wetzel *et al*. 1972). In some streams or rivers, it can be analysed that the availability of reactive dissolved organic carbon may limit microbial transformations.

The relative importance of the riparian zone in stream ecosystems varies as you move from small, narrow upland streams where the riparian vegetation has a significant influence on river water quality to larger, wider lowland rivers, where many of the aquatic ecological processes occur independently of the immediate riparian vegetation, but instead rely heavily on inputs from upland vegetation. It is therefore vitally important to view our streams as continuums and recognise that upland vegetation communities play a critical role in the functioning of the entire river system to maintain in a good health.

The restoration techniques of riparian vegetation can also be used to remove or reduce nutrients or sediments that have detrimental effects on human health and aquatic life such as pesticides, insecticides and herbicides. For example, nitrogen which is present in all insecticides and is a component of all insecticide and herbicides, which is required in small amounts for growth of living organisms as well as for the inhibition for some pests and weeds but can, pose health risks if the concentrationsexceeds the permissible limit. Excess nitrogen enters streams from fertilizer runoff, animal wastes, sewer lines, and there is atmospheric deposition of nitrous oxides from fossil fuel combustion (e.g., automobile exhaust) which might pose a serious impact on water quality if not checked.

Ecological restoration of riparian vegetation is used to enhance the ability of a stream to naturally remove nitrogen through denitrification in which nitrates which are harmful are converted to gaseous nitrogen, a process performed naturally by microorganisms in the water and subsurface area of water. Environmental protection agency scientists are examining the effects of stream restoration on water quality in Baltimore, Maryland, where a degraded urban stream vegetation has been restored to stabilize stream banks. Hence riparian buffers (vegetation) needs to be restored and conserved which is highly necessary and indispensable for maintaining a healthy river environment. Hence restoration and maintenance of riparian vegetation is recognized as being animportant aspect of combating dry land salinity, improving water quality, organic matter inputs, providing shades to river, hence maintaining the temperature of the stream, reducing soil erosion andloss of riparian habitats. Maintaining a healthy riparian vegetation is utmost necessary to maintain a continuous river flow with a constant supply of energy. Riparian habitats have significant effects on material fluxesbetween terrestrial and riverine ecosystems. It is also a powerful indicator of catchmenthealth which helps in determining how alive a river or stream is, which is necessary for its conservation (Doskey*et al*. 2010).

With the accurate technique, stream channels and corridors (riparian zones) can be restored and reconstructed to improve habitat for fish and to stabilize banks against erosion and incision (gouging). Such efforts can serve to benefit water quality; however, the effectiveness of restoration of riparian vegetation for improving surface or groundwater quality has not been thoroughly assessed but requires a attention for the future. Introduction of *Pinus Patula* and other angiosperms and gymnosperms species such as *CedrusDeodara* and *Pinus Wallichinia* decrease harmful substance which run off in river and stream water(Van Lill*et al*.1980).

The purpose to present this review literature is to clarify the leaching characterstics of secondary metabolites from leaves, stems, leaf litters of the gymnosperm species that are dominant in the riparian zone of a river or stream and how they impact on riverwater quality. This organics in turn acts as a inhibitor substance for the inhibiton of microorganisms. If the harmful microbial load is reduced, then the original property of the river water can be maintained.

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