*International Journal For Technological Research In Engineering*
*Volume 4, Issue 10, June-2017* *ISSN (Online): 2347 - 4718*

# HIGH RUNOFFS POLLUTION LOAD: IMPLICATIONS AND CONTROLLING MEASURES

Er. Aijaz Ahmad Mir[1], Er. Kshipra Kapoor[2], Dr Javaid Ahmad Parray[3]
[1]M.Tech Scholar, [2]Assistant Prof. & Head, [3]Assistant Professor
[1,2]Department of Civil Engineering, Universal Institutions of Engineering and Technology, Lalru
[3]Environmental Science, Department of Higher Education, Jammu & Kashmir Govt.

***Abstract: The usual wear of automobiles and road surfaces deposits numerous environmental pollutants on roadways and parking lots including heavy metals such as copper, zinc, lead, nickel and cadmium. During rainfall and snow events, these metals are washed from the paved surface in stormwater runoff or plowed onto shoulders where they are trapped in snow and ice. The metal contaminants carried in the stormwater runoff and eventual snowmelt enters nearby surface waters and contributes to their degradation as well as threaten the survival of aquatic organisms at all levels of the food chain. This pathway of heavy metal contamination has become a significant concern due to increased urbanization and roadway construction. . The adverse impacts of the stormwater runoff can be minimized with structural and non-structural Best Management Practices (BMPs) or with a combination of them.***

***Keywords: Stormwater runoff, water pollution, Non-point Source Pollution ,water quality, highways, Best Management Practices (BMPs), environmental legislation***

## I. INTRODUCTION

The ever-increasing concerns for the environment pooled with a rising demand for transportation have forced a number of studies of the environmental costs of motor vehicle transportation in order to inform public policies (Delucchi 2000). However most of these studies focus on air pollution, the main environmental externality associated with road transportation, or noise. But there is a great lacuna regarding the impacts of motor vehicles on water quality. There is currently no good estimate of the aggregate impact of motor vehicle transportation on water pollution, and some data suggests that water externalities resulting from motor vehicle transportation are based on educated guesses (Litman (2002; Delucchi 2000). While the emphasis of recent regulations lead us to surmise that these impacts are substantial, it is still very difficult to quantify them reliably because motor vehicles are but one of many causes of non-point source pollution. Instead of trying to quantify the external costs caused by motor vehicle transportation on water quality, this research is concerned with the costs of controlling water pollution from motor vehicles focussing on various problems that have attracted considerable attention over the last few years particularly policy options for dealing with the non-point source pollution generated by the operation of motor vehicles. The negative environmental impacts of urban stormwater discharges are numerous and well documented (Driscoll et al. 1990; Bingham 1993; Mikkelsen et al. 1994; Pitt et al. 1995). In addition to carrying harmful substances into the environment, stormwater can cause flooding in urban areas during heavy rain events and other negative impacts resulting from the change in the natural hydrologic cycle. Such problems are expected to increase in severity in the future due to an increase in urban construction, its density and climate change (Semadeni-Davies et al. 2008; Rosenberg et al. 2010). The residues from the operation of motor vehicles contribute heavily to non-point source and groundwater pollution (Davis et al. 2001; Kayhanian et al. 2003). Pollutants from motor vehicles or from transportation infrastructure include sediments (from construction or erosion), oils and grease (from leaks or improperly discarded used oil), heavy metals (from car exhaust, worn tires and engine parts, brake pads, rust, or used antifreeze ,road salts, as well as fertilizers, pesticide, and herbicides (used alongside roads or on adjacent land Hill and Horner 2005). A range of toxic contaminants (heavy metals, and polycyclic aromatic hydrocarbons) are produced by vehicles, road wear and road maintenance (Opher et al. 2009). Each year, approximately 185 million gallons of improperly discharged used motor oil pollute streams, lakes, and coastal areas (EPA 1999b) and is of major concern since one gallon of used oil can contaminate 1 million gallons of water. Groundwater quality is also threatened with more than 450,000 confirmed fuel leaks from underground storage tanks (USTs) in the U.S., including 44,000 in California (EPA 2005). The current approach to dealing with motor vehicle externalities is typically reactive. Transaction costs are also frequently an issue because pollution often results from discharges of small amounts of pollutants in many different locations. Effective policies addressing water pollution from motor vehicles are likely to combine, in addition to best management practices (BMPs), public education campaigns, economic incentives, and enforcement. Better still, they should foster the integration of environmental considerations in the design of motor vehicles and the transportation infrastructure because addressing environmental problems after-the-fact is often much more costly than preventing them. The urban areas have been classified into main roads (including parking lots and airports), roofs, residential areas, commercial areas, industrial areas, parks and lawns, and open, undeveloped areas, all of which generate stormwater of different quality which transports different pollutants.

## II. LITERATURE REVIEW

Sources of Pollutants

Motor vehicles

Motor vehicle emissions, drips of crankcase oil, vehicle tyre wear and asphalt road surfaces, are all diffuse sources of chemical contaminants in urban environments. During rainfall, these contaminants are washed from roofs, roads and other surfaces into the stormwater system and then discharged into surface waterways and estuarine environments. Heavy metals (copper (Cu), lead (Pb) and zinc (Zn)) and polycyclic aromatic hydrocarbons (PAHs) are of particular concern in such runoff due to their prevalence, toxicity to aquatic organisms and persistence in the environment (Hoffman et al., 1984; Borchardt and Sperling, 1997; Walker et al., 1999). Other diffuse sources of PAHs and heavy metals include domestic fire emissions, the spillage or deliberate dumping of waste oil and the corrosion of roofing materials. Specific point sources, such as electroplating workshops, gasworks and commercial incinerators may also exist in urban catchments. Contaminant fingerprinting involving the use of concentration data or ratios of specific contaminants can allow the potential sources of these contaminants to be recognized (Walker et al., 1999; Gonzalez et al., 2000; McCready et al., 2000; Soclo et al., 2000). The sources of highway runoff pollutants can be classified into three different categories: (a) vehicle traffic, (b) snowmelt and ice-melt containing deicing chemicals, and (c) chemicals used to manage roadside vegetation (U.S Environmental Protection Agency [EPA], 2005). The major highway pollutant constituents and their sources are classified in different categories Table

Table Highway pollutant constituents and their source

| Constituent | Primary Source |
|---|---|
| Particulates snow/ice abrasives, sediment disturbance. | Pavement wear, vehicles, atmosphere, maintenance, |
| Nitrogen, Phosphorus | Atmosphere, roadside fertilizer use, sediments |
| Lead | Leaded gasoline, tire wear, lubricating oil and grease, bearing wear, atmospheric fallout. |
| Zinc | Tire wear, motor oil, grease. |
| Iron | Auto body rust, steel highway structures, engine parts |
| Copper | Metal plating, bearing wear, engine parts, brake lining wear, fungicides and insecticides use. |
| Cadmium | Tire wear, insecticide application |
| Chromium l | Metal plating, engine parts, brake lining wear. |
| Nicke | Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving. |
| Manganese | Engine parts |
| Bromide | Exhaust. |
| Cyanide | Anticake compound used to keep deicing salt granular |
| Sodium, Calcium. | Deicing salts, grease |
| Chloride | Deicing salts. |
| | Roadway beds, fuel, deicing salts. |
| Petroleum | Sulphate Spills, leaks, blow-by-motor lubricants, antifreeze, hydraulic fluids, asphalt surface leachate. |
| PCBs, pesticides | Spraying of highway right of way, atmospheric deposition, PCB catalyst in synthetic tires |
| Pathogenic bacteria | Soil litter, bird droppings, truck hauling livestock/stockyard waste. |
| Rubber | Tire wear |
| Asbestos* | Clutch and brake lining wear. |

(Kobriger, 1984)

*No mineral asbestos has been identified in runoff; however, some break-down products of asbestos have been measured

Commercial/Industrial areas:

Runoff from commercial and industrial areas typically can contain heavy metals, sediments, and a broad range of man-made organic pollutants including phthalates, PAHs, and other petroleum-based hydrocarbons (National Research Council 2009). Vehicles and pavement sealants are two common sources of pollutants from these areas.

Residential areas:

Runoff from residential areas can include the same road-based pollutants as well as herbicides, pesticides, surfactants, nutrients (from fertilizers), bacteria and viruses (from animal waste) well as sediment from dirt and gravel driveways. These contaminants can be entrained in stormwater runoff directly, or can reach downstream surface water bodies and marine environments via shallow groundwater flows. Zinc strips and other zinc based products are commonly used in residential areas to prevent and treat moss, and can add additional zinc to runoff from residential areas. Bleach and detergents are also commonly used for moss treatment. Most detergents contain phosphorus, which can contribute to eutrophication of surface water bodies.

Construction sites:

Runoff from construction sites can include sediments and other suspended material, which can increase turbidity or cloudiness in downstream receiving waters and can be deposited over the natural sediments of the receiving water and affect streams and wetlands (Barrett et al. 1998, Ecology 2014b, Horner et al. 2002a). Stormwater pollutants resulting from development can be dissolved in the water column or can be attached to particulates that settle in streambeds, lakes, wetlands, or marine estuaries. The toxic pollutants in the water column can have both immediate and long-term lethal impacts (Roy, Allison H., Wegner, Seth J., Fletcher, Tim D., Walsh, Christopher J., Ladson, Anthony R., Shuster, William D., Thurston, Hale W., Brown, Rebekah R. 2008). In addition, development can increase water temperatures by heating stormwater runoff as it passes over exposed surfaces, before being discharged to receiving waters (Wu, J. S., Allen, C. J., Saunders, W. L. and Evett, J. B. 1998 Stephenson et al., 1999,). A rise in water temperature can have direct lethal effects on aquatic organisms by reducing the available dissolved oxygen and potentially causing algae blooms that further reduce water clarity and the amount of dissolved oxygen in the water (Maestri, B. et al., 1988,).

## III. EFFECTS OF HIGHWAY RUNOFF ON RECEIVING WATERS

The type and size of the receiving body, the potential for dispersion, the size of the catchment area, and the biological diversity of the receiving water ecosystem are just some of the factors which determine the extent and importance of highway runoff effects. Hydrological effects of highways are highly site-specific. The extent of increased storm runoff volumes and peak discharges due to increased impervious cover depends on the relative sizes of highway right-of-way and total watershed area (Driscoll, E.D., Shelley, P.E., and Strecker, E.W., 1990a,). Highways also may cause hydrogeologic effects (Peterson, S.A., Miller, W.E., Greene, J.C., and Callahan, C.A., 1985 Parizek, 1971) including beheading of aquifers, the development of groundwater drains where cuts extend below the water table, changes in ground and surface water divides and basin areas, obstruction of groundwater flows by abutments, retaining walls, and sheet pilings, and changes in runoff and recharge characteristics. Heavy metals in highways runoff are usually not a toxicity problem, which actually depends, to a great extent, on the physical and chemical form of the heavy metals, their availability to aquatic organisms and the existing conditions of the receiving waters. In particular, water with high total metal concentration of a heavy metal may be, in fact, less toxic than one with lower concentration of this metal but in different form. For example, ionic copper is more harmful to aquatic organisms than organically bound copper (Yousef et al., 1985; Sartor et al., 1974; Thomson et al., 1997).

## IV. FACTORS AFFECTING THE QUALITY OF HIGHWAYS STORM RUNOFF

In urbanized areas, the greater the amount of impervious surfaces, such as roads, driveways, parking lots and buildings, and the amount of human activity will tend to accumulate greater contaminants or potential pollutants. However, these pollutants may be channeled directly into storm sewer systems. In less built-up areas, permeable surfaces act to filter out pollutants. Some pollutants may reach surface and ground waters through infiltration. The fate of and magnitude of pollutants found in highway runoff are site specific and are affected by the volume of traffic, design of the roadway, surrounding land use, climate and accidental spills. Traffic volume would seem to be an important factor for predicting runoff quality. Prior to storm events, roadways with average daily traffic (ADT) greater than 30,000 vehicles may produce runoff with two to five times the runoff pollutant levels found in that from rural highways. However, this highway runoff may not directly impact receiving streams.Numerous factors may affect the quality of highways storm runoff including:

- Traffic volume (roads with traffic volumes over 30.000 vehicles/day) (Wu, J. S., Allen, C. J.,Saunders, W. L. and Evett, J. B. (1998 Aldheimer and Bennerstedt, 2003),
- Rainfall characteristics (number of dry days preceding the rain event, rain intensity and volume of runoff),
- Highway pavement type the pollutants and

Apart from the above mentioned general factors, the range of the concentrations of pollutants and their load depend on the specific circumstances of the area or the seasonal changes which can take place. It is noticed that excess loads of solids usually referred to environmental sources and also, to highway maintenance works and not to the stormwater runoff in the highway network (Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. (1996). Many anthropogenic factors may affect highway runoff quality including: traffic density, surrounding land uses, driving activity, road maintenance practices, and construction and repair materials. However, rainfall and runoff studies that have attempted to identify a relationship between any of these variables and pollutant concentrations are generally inconclusive. For many pollutants, the mass of pollutant in the runoff is more important for estimating the impacts of runoff on receiving water quality than is the instantaneous concentration. The pollutant load is largely a function of the volume of runoff rather than the concentration and is generally predicted more accurately.

## V. CONTROL OF POLLUTANTS IN HIGHWAY RUNOFF

The control of pollution from highway runoff can be accomplished by both source management and control measures. Examples of source management are transportation and land-use planning, and highway design and operation. Structural controls include vegetative practices, ponds, infiltration methods, wetlands, and filters. Certain structures enhance the performance of these structural control methods. Each type of control method will be characterized and its strengths and weaknesses will be identified. The uses of herbicides and deicing salts are, however, the exception. There are also currently no realistic means of treating them within highway drainage systems. Use of de-icing salts and herbicides therefore needs to be restricted to the minimum necessary for the highway authority to comply with its responsibilities to maintain a safe highway.

Source Management

Transportation plans can be designed to reduce water pollution by lowering total vehicle miles traveled. Providing alternate modes of transportation (mass transit) or encouraging carpooling can reduce traffic congestion and fuel consumption. Successful programs reduce the total load of pollutants deposited on highways and rights-of-ways from vehicles (Burch et al., 1985a).Implementation of land-use plans provides indirect mitigation of highway runoff through effects on land use and associated traffic patterns. By controlling development location and density, traffic mix and density can also be controlled and runoff problems minimized. The goal of land-use planning for mitigation of highway runoff is to protect the environmental balance of an area in terms of runoff volume, rate, and water quality by restricting developments that generate high traffic volumes in sensitive areas (Burch et al., 1985b). Design and operation of highways affect traffic characteristics and pollutant deposition. Reduction of pollutant runoff can be accomplished by elimination of curbs and other barriers; traffic flow regulation; animal control, fertilizer and pesticide/herbicide application; and control of debris from mowing (Burch et al., 1985b). Eliminating barriers from highways prevents many sediments and other particulates from being trapped on the highway. Without curbs, wind and turbulence will remove much of the fine materials from the road. Materials that are not trapped on the roadway are generally immobilized on the roadside (Burch et al., 1985b). Fencing of highway rights-of-way to minimize animal access to the highway, improves safety conditions, reduces accidents, and thereby lessens pollutants from spills, debris, and litter. The use of fertilizers, particularly in areas with direct runoff to natural receiving waters, should be controlled to prevent unnecessary releases of nutrients. Pesticides and herbicides can cause significant acute and chronic toxic responses in terrestrial and aquatic ecosystems, but have not been found to be significant pollutants in highway runoff (Kobriger et al., 1984)

Land Use Controls

Local governments can exercise a variety of land use controls. Subdivision controls, for example, help to ensure that expected development will not compromise drinking water quality or ground water recharge. Requiring proper stormwater management in new developments and redevelopments can help prevent excessive runoff

Structural Best Management Practices

Structural best management practices are used to control runoff or temporarily store stormwater on site. In addition to reducing runoff volumes and rates, these structures can reduce pollutant loads in runoff, especially through settling of particles. Several types of BMPs rely on soils and vegetation to help with filtration, infiltration, and trapping of suspended particles. Vegetation-based structures, such as swales and bioretention cells, may be incorporated into LID designs.

## VI. CONCLUSIONS

The potential threat of highway runoff to receiving streams and groundwater resources may be mitigated by the application of highly effective active and passive means to “treat” it. Furthermore, utilizing proper sediment controls during highway construction will significantly reduce sediment loads on potentially impacted water resources. Roadway operation and maintenance practices can also have an impact on the composition of highway runoff. Best Management Practices (BMPs), either structural or non-structural will properly manage and effectively treat the on-going highway runoff pollutants. BMPs may include such control structures as grassy swales, filter strips, detention ponds, infiltration facilities, sand filter, street sweeping, wetland construction, grit separators, and sedimentation controls.

In order to effectively treat highway runoff, BMPs need to be incorporated early in the highway planning and design process. Such design factors, as the type of proposed highway facility, local watershed conditions, soil characteristics, surrounding land use, storm frequency, and receiving stream characteristics are all critically important design factors that need to be incorporated in the overall transportation planning process. Management practices to control runoff need to be practical, suitable for the site and cost effective. If proactive highway planning and design is initiated by the responsible transportation agency, the deleterious effects of highway runoff can be significantly reduced, if not totally eliminated. Therefore, water quality considerations should play a role in long range transportation planning and land use planning activities.

## REFERENCES

[1] Delucchi, M. A. (2000). Environmental externalities of motor-vehicle use in the US. Journal of Transport Economics and Policy 34

[2] Litman, T. (2002). Transportation Cost and Benefit Analysis: Techniques, Estimates, and Implications. Victoria Transportation Policy Institute, Victoria, Canada.

[3] Driscoll, E.D., Shelley, P.E., and Strecker, E.W., 1990a, Pollutant Loadings and Impacts from Highway Stormwater Runoff, Vol. 1: Design Procedure, Federal Highway Administration, Office of Research and Development Report No. FHW A-RD-88-006.

[4] Driscoll, E.D., Shelley, P.E., and Strecker, E.W., 1990a, Pollutant Loadings and Impacts from Highway Stormwater Runoff, Vol. 1: Design Procedure, Federal Highway Administration, Office of Research and Development Report No. FHW A-RD-88-006.

[5] Semadeni-Davies, A., Hernebring, C., Svensson, G., and Gustafsson, L-G. (2008). The impacts of climate change and urbanisation on drainage in Helsingborg, Sweden: Suburban stormwater. Journal of Hydrology, 350(1), 114-25.

[6] Rosenberg, N. J., Epstein, D. J., Wang, D., Vail, L.,Srinivasin,R.& Arond, J. G. 2010 Possibleimpacts of global warming on the hydrology of theOgallala Aquifer region. Climatic Change, 42,677–692.

[7] Davis, A. P., Shokouhian, M. and Ni, S. (2001). Loading estimates of lead, copper, cadmium, and zinc in urban runoff from specific sources

[8] Davis, A. P., 2007, Field performance of bioretention: water quality: Environmental Engineering Science, v. 24, no. 8, p. 1048-1064.

[9] Hill, K., Horner, R. (2005). Assessment of Alternatives in Roadside Vegetation Management

[10] Opher, T., Ostfeld, A.& Friedler, E. (2009). Modeling highway runoff pollutant levels using a data driven model. Water Science and Technology, 60(1), 19-28

[11] Hoffman, E.J., Mills, G.L., Latimer, J.S., an C

  

d Quinn, J.G., 1984, "Urban Runoff as a Source of Polycyclic Aromatic Hydrocarbons to Coastal Waters," Environmental Science and Technology, Vol. 18, No.8, pp. 580-587.

[12] Walker WJ, McNutt RP, Maslanka CA. The potential of urban runoff to surface sediments of the Passaic River: sources and chemical characteristics. Chemosphere 1999;38:363 – 77.

[13] Welker, Andrea L., Gilbert Jenkins, Jennifer K., McCarthy, Leslie, Nemirovsky, Evgeny. 2013. Examination of the material found in the pore spaces of two permeable pavements. Journal of irrigation and drainage engineering. 139(4): 278-284.

[14] Kobriger, N., and Gupta, M.K., 1984, Sources and Migration of Highway Runoff Pollutants, Vol. II: Methods, FHWA/RD-84/058 Federal Highway Administration, Washington, DC

[15] Barret, M. E., Irish, L. B., Malina Jr, J. F., & Charbeneau, R. J. (1998). Characterization of highway runoff in Austin, Texas, area. Journal of Environmental Engineering , 124 (2), 131-137.

[16] Barrett, Michael E. 2008. Effects of a permeable friction course on highway runoff. Journal of irrigation and drainage engineering. 134(5): 646-651.

[17] Roy, Allison H., Wegner, Seth J., Fletcher, Tim D., Walsh, Christopher J., Ladson, Anthony R., Shuster, William D., Thurston, Hale W., Brown, Rebekah R. 2008

[18] Peterson, S.A., Miller, W.E., Greene, J.C., and Callahan, C.A., 1985, "Use of Bioassays to Determine Potential Toxicity Effects of Environmental Pollutants," Perspectives on Nonpoint Source Pollution, pp. 38-45

[19] Yousef, Y. A. (1985). Consequential Species of Heavy Metals. BMR- 85-286 (FL-ER-29-85), Florida Department of Transportation, Tallahassee, FL.

[20] Wu, J. S., Allen, C. J., Saunders, W. L. and Evett, J. B. 1998 Stephenson et al., 1999). Characterization and pollutant loading estimation for highway runoff. Journal of environmental Engineering, 124(7), 584 592

[21] Young, G. K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. (1996). Evaluation and management of highway runoff water quality. FHWA-PD- 96-032. GKY and Associates Inc., Springfield, VA

[22] Burch, C. W., Johnson, F., and Maestri, B., 1985a, Management Practices for Mitigation of Highway Runoff Pollution: VOlume I, Guidelines, FHWA/RD-85-001, Versar Inc., Springfield, VA.

  