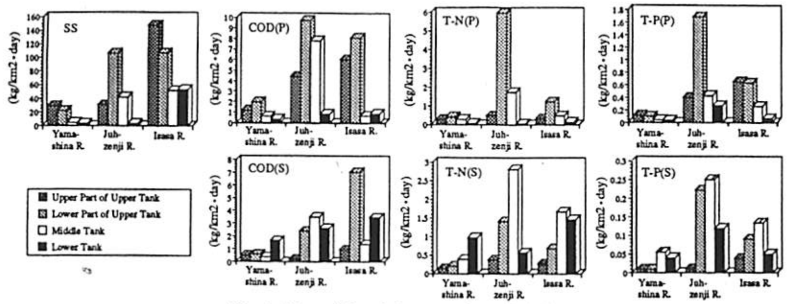

Fig.6 Runoff load from each tank-hole

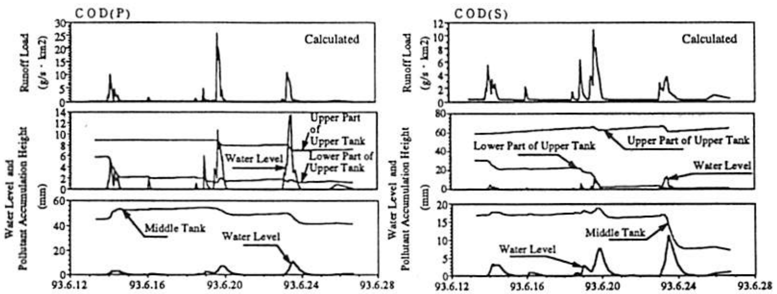

Fig.7 Water level and pollutant accumulation height in the tanks (Event No. Ic2)

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URBAN RUNOFF POLLUTION: DETERMINATION OF DESIGN POLLUTOGRAPHS

Roberto Jiménez, Ángela Ríos, Javier Temprano, Joaquín Suárez, Iñaki Tejero.
Departamento de Ciencias y Técnicas del Agua y del Medio Ambiente. Universidad de Cantabria.
Avenida de los Castros s/n, 39005 Santander-Spain.

KEYWORDS: Storm, rainfall (intensity and duration), urban runoff, water quality, receiving water body, hydrographs, pollutographs.

INTRODUCTION

The runoff produced by rain and snow in urban areas is a problem which is not outside the field of environmental management; an examination of the water displaced to the collection areas after a storm reveals that it is not clean water. The variety of contaminants in urban runoff may include: heavy metals (chromium, cadmium, copper, lead, nickel, zinc), pesticides, herbicides, and organic compounds such as fuels, oils, solvents, lubricants and fats *(ASCE, 1993; Novotny, 1991; Valiron, 1992).*

The aim of this research is to establish design pollutographs, based on the rainfalls that produce them and their contaminant impact by using different evaluation criteria.

METHODOLOGY

Initial Data

A ficticious urban basin was chosen as representative of towns such as Santander (Spain) with a population density of 100 persons/ha and a flowrate of 250 L/capita.day. One hectare was taken as the base surface area, defined by a cell of 100m by 100m. This basin was given a gradient of 4 in 1000 and an impermeable surface area of 60%. The Manning roughness coefficient for impermeable areas was taken such that the maximum flow of the hydrograph (in the absence of evaporation, filtration and accumulation in depressions) approximately coincides with that obtained using the rational method. The model used in the mathematical simulation was the US EPA's *Stormwater Management Model (SWMM).*

A set of rainfalls characterized by rectangular hyetographs of intensity **I** and duration **D** were adopted. The presence of snow or its melting were not simulated. The simulation was made for August, an average monthly evaporation value of 3.78 mm/day was introduced. Horton's model for clay soils (predominant in Santander) was used for infiltration. Erosion was not considered.

The accumulation of dust and dirt was represented by an exponential type curve which depended on the length of the curbs in the basin for commercial-residencial land use and 7 days of dry weather before the onset of rain, for which the asymptotic dirt accumulation value and, therefore, the most unfavourable situation is obtained. Neither the removal of dirt by street cleaning nor the rain pollution were simulated. In the studied basin three contaminants were analysed: BOD_5, total solids and total nitrogen.

Estimation of Pollutographs

For the basin described above an ample set of rainfalls were simulated to obtain the corresponding pollutographs. The analysis of these tries to obtain the most unfavourable rainfall, as far as pollution is concerned, for design purposes. The set of rainfalls (rectangular hyetograph) is fixed into a matrix (intensity - duration) with ranges of intensity values (0, 1, 10, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 220, 240, 260, 280, 300 and 600 mm/h) and duration (0, 2, 4, 6, 8, 10, 15, 20, 25, 30, 35, 50, 80, 120, 180, 240 and 300 min.). Each of the rainfalls in this matrix is simulated for 10 hours, obtaining its hydrograph (flow variation throughout the duration of the runoff), its pollutographs (contaminant concentration variation throughout the duration of the runoff) and its flowgraphs (contaminant mass flow variation throughout the duration of the runoff).

Evaluation criteria of the least favourable pollutograph

The great variety of forms and characteristics found in the hydrographs and pollutographs requires their classification and evaluation according to their contamination and discharge. Defining the least favourable pollutograph, and therefore rainfall, depends on the desired objective. Differences could occur if the discharge of said pollutograph into a receiving water body is being considered (river, estuary, bay, ocean, etc.), or its direct transfer to a waste water treatment plant (WWTP) or if the objective is to design an overflow control and treatment system.

From a qualitative point of view, the least favourable pollutograph will be the one which brings the most contamination, as defined by concentration, instantaneous flow or unloaded mass. In turn these variables should be characterised (average values, peaks, etc.). Moreover, other conditions exist which make a given contamination (the variable) more or less unfavourable, such as: duration time of the variable, volume of associated water and event probability. Generally, the most unfavourable sense of these conditions is: longer time, lower volume, and greater probability.

The following evaluation criteria have been defined:

- Fp evaluation criterion: a rainfall event is more unfavourable the greater the peak mass flow (Fp) of its flowgraph. Between two events which have the same Fp, the most unfavourable will be the one with the greater contamination and therefore lower flow.

- Fm evaluation criterion: A pollution event is most unfavourable the greater its average mass flow Fm, and at the same average flow the greater the weighted average concentration (criterion Fm-C) or greater mass of contaminant (Criterion Fm-M) which is the same as a longer runoff time.

- Evaluation criterion D-T: The criterion dose D (or contaminant concentration) - exposure time T can be used to protect, with an adequate degree of security, a community of organisms or a determined water use. This new criterion permits the union of the criteria Fm-C and Fm-M into one. The value $D^a x T^b$ has been used as a comparative variable, where a and b can adopt different values according to the quality criterion for each contaminant. In effect, a=b=1 has been taken to represent the conservation of mass of a flowgraph, and in the case of amoniacal nitrogen a=1, b=0.37, deduced from the dynamic quality criterion reported by *Likjlema (1993)*, for a return period of 0.25 years. The dose-time criterion is not applicable under a minimum concentration (minimum dose). The exposure time has been approximated using the runoff time.

-Evaluation criterion P: a pollution event with the same characteristics as another would be more unfavourable if its probability of occurring (P) is greater. The return period of the rainfalls which produce said pollution events have been used.

Application to the case of river discharge

Besides the intrinsic characteristics of the pollution events, the receiving water characteristics can influence the unfavourability of such events. Therefore, the case of a river definable by its characteristics (flow and contaminant concentration) has been considered. Instantaneous complete mixing is considered in order to estimate the concentration downstream of the discharge point.

RESULTS

By applying criterion Fp it is possible to define in graphic form rainfall intensity - duration (rainfall matrix) the geometric location which with the same peak mass flow has a greater value for the maximum concentration, corresponding to the line A-12 (Fig.1).

Similarly, applying criterion Fm-C obtains lines C-1-2-3-4-5-6-7 and 3-8-9-10-13-15-19 (Fig.1), while the criterion Fm-M gives place to the line C-1-2-3-4-5-6-7 (Fig.1). Applying criterion D-T produces the lines C-1-2-3-4-5-6-7 for a=b=1 and C-1-2-3-8-9-10-11-12 and the 10-13 (Fig. 1) for a=1 and b=0.37.

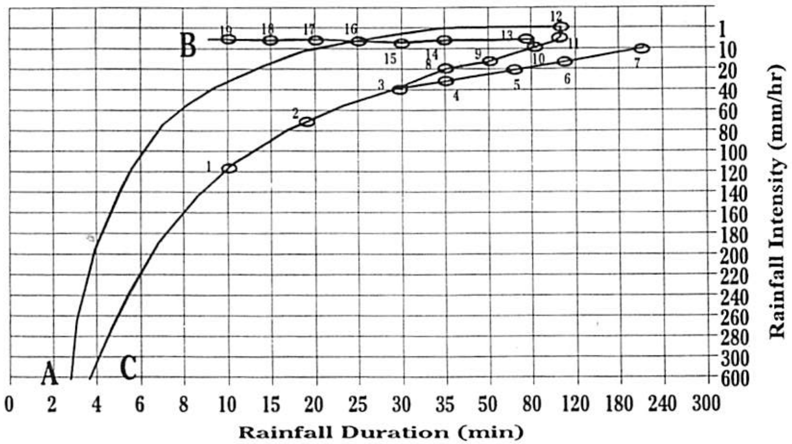

Fig. 1.- Rainfalls which produce the most unfavourable pollution events, according to different criteria.

Studying the average concentration of pollution (BOD and TS) in the river as a consequence of the discharge of surface runoff for differing initial river flow and pollution values it turns out that the most unfavourable events are found in the line 1-10-19 (Fig.1) in such a way that diminishing the initial pollution concentration in the river or increasing its flow moves the solution in the direction 19-10-1 (towards high intensity and short duration rainfalls). For amoniacal nitrogen, applying criterion D-T for the river waters results in the most unfavourable events being those of the line C-1-7 (Fig.1).

Proposed calculation method

From the lines of unfavourable rainfalls, and considering a negligible initial river contamination, the most unfavourable rainfall event has been calculated for each river flow. This has been made relative to the impermeable nature of the basin's surface, expressed as L/s.ha imp.. Characterizing each unfavourable rainfall by its intensity and duration, these can be obtained from the river flow (Fig.2). Therefore for a given basin and independantly of its pluviometry the most unfavourable rainfall can be determined. For a specific geographic location, as is the case of Santander (Spain), the return period of the least favourable rainfall can be determined, which gives an idea about the probability of pollution events occurring.

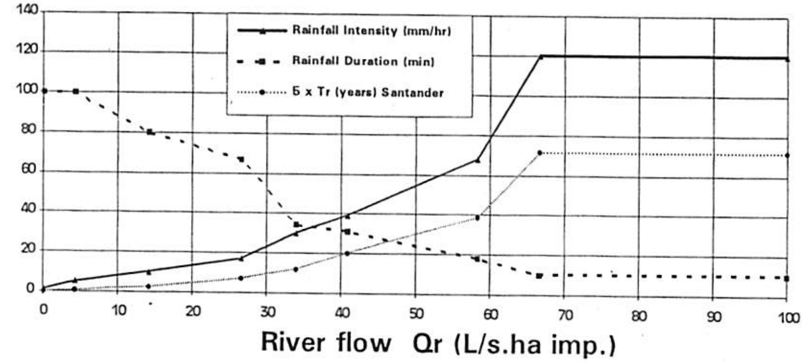

Fig.2.- Rainfall characteristics (intensity - duration) which produce the worst pollution situations in a river (as a consequence of the discharge of surface runoff from the studied basin) as a function of river flow. As an example, the return period (Tr) of said rainfall is given for Santander (Spain).

For Santander: $I\ (\mathrm{mm/hr}) = 130 \times Tr\ (\mathrm{years})^{0.42} \times D\ (\mathrm{min})^{-0.52}$

As the basin's characteristics vary, the final design lines (Fig.1) will shift in the rain matrix. Given their similarity between the variable "time in which the peak mass flow occurs" and the concentration time, the design line A-12 of the criterion Fp will move leftwards when analysing smaller basins or those with greater gradients and the opposite will occur for larger basins. This seems to be also applicable for the design line of the criterion Fm.

CONCLUSIONS

The largest instantaneous concentrations in a river are produced by the rainfalls which provoke the maximum peak flows. For a given intensity all the rainfalls longer than a certain duration produce the same maximum instantaneous concentration. In this case the maximum instantaneous concentration of an event increases with the intensity of the rainfall which provokes it, therefore its probability decreases. This is an extreme frequency variable.

The worst pollution events assessable by the dose-time criterion are those produced by rainfalls whose frequency is not extreme, definable by a segment of line in the rainfall intensity-duration diagram.

Both the flow and the initial concentration of the river affect the definition of the most unfavourable surface runoff contamination event. In general, the long lasting low intensity rainfalls are more unfavourable when they enter rivers with a low flow and/or high initial contamination.

The most unfavourable rainfall, definable by its intensity and duration, is independent of the local climatology, and therefore is the same for similar basins in different geographical locations.

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ROOF RUNOFF STORM WATER QUALITY

Takashi Sakakibara
Public Works Research Institute, Ministry of Construction,
Asahi 1, Tsukuba City, 305, Ibaraki, Japan

KEYWORDS: Water quality, Storm water utilization

INTRODUCTION

On-site storm water storage has the function to store the runoff water from roofs and roads. Among them roof runoff storm water is considered to be an important and effective alternative for supplied water.

Over one hundred buildings have adopted the storm water utilization system with on-site storage (Sakakibara, unpublished). Most of them are located in the district of Tokyo and belong to public building and building of private firms. Individual houses are rare cases so far.

This utilization, i.e. spraying garden greenery or toilet flushing, might be attractive for each houses as the motivation of installation, compared to the objective as the countermeasure against flood control.

To encourage the installation in individual houses, there needs the quantitative and qualitative investigation on stored storm water. However there exists very few results with regard to water quality.

This paper aims to make clear the feasibility of the use of stored water from the viewpoint of water quality.

METHODS

To achieve the objective mentioned above, we carried out the investigation of roof runoff storm water quality. The investigation started in April 1993 and ended in March 1994.

The site of investigation was selected in Kasumigaura Kohoku Regional Wastewater Treatment Plant in Ibaraki prefecture, where the office house of pilot plant by Public Works Research Institute is located.

Roof runoff from the office house was gathered to the storage tank. The contributed roof