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Data acquisition within a regional scale. The experience of the remote satellite transmission in West Africa

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Abstract Onchocerciasis, or river blindness, is an endemic disease which causes great damage in West Africa. Within the WHO programme to control this disease (OCP), it has been found that, by using remote satellite transmission, reliable data on the discharge of the water courses can be obtained. These data are necessary to calculate exactly how much insecticide should be introduced into the rivers. A description of the equipment and its use is followed by an initial report which covers the functioning of the equipment, its efficiency and the economies realized. We discuss the improvement in the returns to the treatment and the reduction in the running costs of the programme. Software for forecasting the discharge at different times was developed by ORSTOM at the request of the OCP. The different functions of the software (PERLES) are described. The addition of the software has further improved the remote transmission system. In conclusion, we discuss the advantages of remote transmission techniques for operational hydrology (flood warning systems, hydrological networks, etc.).

Acquisition de données à l'échelle d'une région. L'expérience de la télétransmission par satellite en Afrique de l'Ouest

Résumé L'onchocercose, ou cécité des rivières, est une maladie endémique qui cause d'importants ravages en Afrique de l'Ouest. Dans le cadre du programme de l'OMS de lutte contre ce fléau (OCP), la télétransmission par satellite est apparue comme un moyen sûr d'obtenir des données fiables concernant les débits des cours d'eau traités. Ces données sont indispensables pour permettre un calcul précis des doses d'insecticides injectées dans les rivières. Une description du matériel et de son protocole d'utilisation précèdent un premier bilan dressé tant en terme de fonctionnement du matériel proprement dit, qu'en terme d'efficacité et d'économies réalisées. On peut ainsi mettre en avant l'amélioration du rendement des traitements et la réduction des coûts de fonctionnement du programme. Un logiciel de prévision des débits à différentes échéances a été mis au point par l'ORSTOM à la demande de l'OCP. Ce logiciel (PERLES) est décrit au niveau de ses différentes unités fonctionnelles. Son couplage avec le système de télétransmission a permis d'accroître les performances du système. En conclusion, on met en avant l'intérêt des techniques de télétransmission dans le cadre d'une hydrologie opérationnelle (réseaux d'annonces de crues, réseaux hydrométriques).

INTRODUCTION

Onchocerciasis, or river blindness, is a disease transmitted to man by small flies, simulium (*Simulium damnosum*), which inject filaria into the body when they bite – these filaria eventually cause blindness.

This disease is endemic in West Africa, and particularly in the Sudanese savanna region. The infested areas are usually abandoned when often these are the most fertile areas because they are adjacent to the rivers. The larvae of the onchocerciasis vector develop in water in areas of rapids or where the flow is fast, allowing good oxygenation.

In 1974 the World Health Organization (WHO) launched the OCP (Onchocerciasis Control Program), a large programme to control onchocerciasis in West Africa. This programme currently covers all or parts of several African countries (Benin, Togo, Ghana, Ivory Coast, Burkina Faso, Mali and Guinea) and is due to be extended towards the west (Sierra Leone and West Senegal) (Fig. 1).

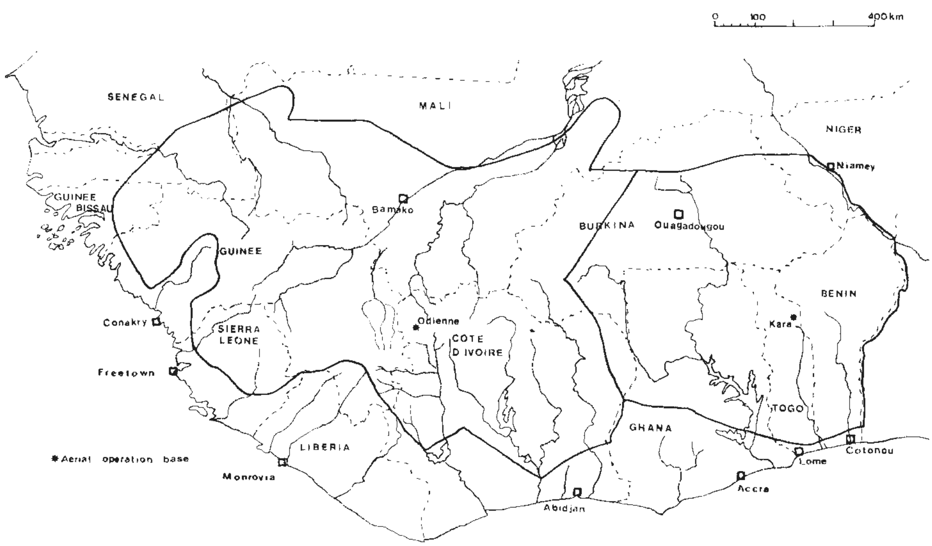

Fig. 1 Map of the area covered by the OMS/OCP programme.

Due to the lack of any suitable medicine for mass treatment, the aim of the OCP is to destroy the simulium larvae by treating the rivers with insecticides. First, WHO used Abat, an insecticide whose properties do not require exact hydrological data. During their weekly inspection, the WHO/OCP teams recorded the water levels at the hydrometric stations. At the end of the week these levels were given to the treatment base who calculated the quantity of insecticide to be used and gave cards with the weekly treatments to the aeroplane and helicopter pilots responsible for the spraying. The quantities given were not precise, especially in the rainy season, but the margin of error tolerated by the insecticide was such that an exact hydrological study was not considered necessary. However, certain disadvantages in the procedure considerably reduced the effectiveness of the treatment:

(a) Access to the data was impossible because the access roads to the hydrometric stations were impassable in the rainy season or because the treatment areas were too far from the WHO/OCP bases.
(b) When the discharge in the reaches varied too much from that taken as the basis for the calculation of insecticide doses, treatment of the larvae was ineffective. It was often the case during the rainy season.
(c) The reliability of the water level data was very limited for several reasons: approximate readings, numerous stages in the transmission of the information, doubts about the accuracy of the gauges.

Since 1985, because of cases of resistance to the insecticide. WHO/OCP had to use new products, which are less tolerant (high cost, limited spread, risks of intoxication, significant differences in effectiveness when diluted). Given the problem of effectiveness and cost, it was necessary to have accurate information about the discharge of each reach at the time of treatment and therefore to have exact and reliable hydrological data. It was therefore decided to install a remote satellite transmission network, to transmit the water levels recorded at different points in the OCP treatment area.

THE REMOTE TRANSMISSION SYSTEM USED IN OCP

The advantages of remote transmission

The use of new insecticides with very strict conditions of use means that the effectiveness of the treatment is dependent on a good fitness between the discharge and the dose of insecticide. To achieve this maximum effectiveness therefore means that those responsible for the aerial treatment of the reaches must work in real time.

Given the size of the area covered by WHO/OCP, the satellite transmission of the data collected by automatic recorders seems to be one of the best ways of achieving this objective (Pouyaud & Le Barbe, 1987). Indeed the technique offers several advantages:

(a) guaranteed access to data in all seasons;
(b) transmission of the water levels almost in real time because of the number of times the satellite relays pass every day;
(c) more reliable data than that from the river gauges, which has to be

transcribed a number of times – each one a source of errors;

(d) quick and easy centralization of the data through the reception centres at the aerial operation bases (currently two, in Odienne, Cote d'Ivoire, and Lama Kara in Togo) whose function is to collect the information relayed by the satellites.

Equipment and methodology

Description of the equipment In close collaboration with the ORSTOM Hydrology Laboratory, the company Elsyde France, has developed a hydrological platform called CHLOE. This platform consists of a system for calculating the water levels of an area of water using a pressure sensor and an electronic box containing a clock and a system for coding and recording data on a removable disk. The system is powered by a solar panel and a battery. In collaboration with ORSTOM and ELSYDE France, the company CEIS-Espace has added an ARGOS card which transmits the data in a signal picked up by a relay satellite and sent to the reception centres at the aerial treatment bases.

Methodology The remote transmission beacon is installed near a water course and is of course operational only if the calibration curve of the section it controls has already been determined. The electronic box is placed above the highest water level and at any distance from the pressure sensor (SPI). These two items (electronic box and pressure sensor) are linked by a flexible cable (Fig. 2).

At regular timed intervals, the pressure is measured and corrected by temperature which allows the level of the water to be calculated. Furthermore, the SPI can be questioned at any time outside the programmed measuring times. The interval between the measurements is half an hour. The measurements are recorded on disks together with the time and date if the variation is more than +/- 1 cm from the last measurement. These disks last for approximately one year.

Every 220 s, the ARGOS card sends values of the 15 previous half hours by wireless beam. If one of the satellites in the ARGOS system passes over the beacon and the reception station at that moment, it relays the message sent by the beacon.

The reception station (SRDA) collects and handles the messages as they arrive. Developed by CEIS-Espace, the station has an IBM-AT computer. Such a station can manage a fleet of one hundred remote transmission beacons. The SRDA software creates and uses different files, powered in real time every time the satellite passes. The station checks the messages received, correcting transmission errors if necessary, using an error correction code. These files when sorted can be printed out, either automatically for some parameters or controlled by the computer operator for others. The station puts out a certain number of "alerts" concerned with the internal functioning of the platforms or with the minimum or maximum water level thresholds fixed by the operator (Pouyaud, 1987).

Fig. 2 The hydrological platform, with its solar panel, linked to the pressure sensor, on the Dion River, Diamaradou, Guinea (photograph by Michel Gautier, ORSTOM).

Current report

The fleet of beacons Due to the stream velocity conditions necessary for their development, simulium larvae are mainly found in water courses of medium width or in headwaters, in areas where the water movement is greatest. The network of hydrological platforms equipped with remote transmission is therefore more dense in the headwaters of the Niger, the Sassandra, the Bandama, the Comoe and the Black Volta. Currently, apart from the sixty WHO/OCP beacons the network contains a dozen beacons from the Hydro-Niger network and two others managed by the Black Volta Basin Agency.

Operation report These hydrological platforms which comprise the "pressure sensor – remote transmission system" are of recent innovation and are likely to be improved from a technological point of view. However, after two rainy seasons and despite some problems (e.g. with the electric power, disks, electronic cards) the report is generally positive. Because of the difficulties encountered modifications have been made to improve the reliability of the equipment. One example is the improvement in the way the disk is connected and the importance given to the transmission of the message over the storage on hard disk, which should limit breakdowns due to the disks.

The experience gained during the last two years will be very useful both for future planning and in the installation and operation of this technologically sophisticated equipment.

Improvement in the efficiency of the treatment and reduction of costs
Before the new method of treatment was introduced the pilots sprayed the water courses with doses of insecticide calculated from the previous week's gauge readings. In the rainy season it was then often impossible to obtain the correct fitness between the discharge measured and the insecticide injected. As exact hydrological data is now available the doses can be calculated with a precision rarely achieved before. Apart from this improvement in the efficiency of the treatment which is very important for the programme, there has also been a significant reduction in cost. This has contributed to the great economies realized in 1987. Several explanations can be given:

(a) a better calculation of the doses of insecticide, and thus a reduction in costly overdoses,
(b) more efficient treatment which allows for breaks in treatment of a week or more,
(c) suspension of treatment if flood levels are too high.

In order to further improve the efficiency of the device, WHO/OCP asked ORSTOM to develop software to predict the discharge in each of the reaches to be treated, based on the data transmitted by satellite.

HYDROLOGICAL FORECASTING AND REMOTE SATELLITE TRANSMISSION, THE PERLES SOFTWARE

Aims

The programme PERLES which is now installed in the microcomputers at the OCP aerial operation base in Odienne was developed to further improve the efficiency of the remote satellite transmission network.

Several factors influenced its development:

(a) The programme had to be completely user-friendly as it would be used by the OCP operators who are trained in neither computers nor hydrology.
(b) PERLES had to be able to predict discharges for all the reaches under treatment at different times. To achieve this, different forecasting models are used which estimate the discharge every 3, 6 and 12 h in the rainy season, when variations in discharge can occur very rapidly. In

the dry seasons the water courses recede and the predictions are made at 1, 3, 5 and 8 days.

(c) Such a programme, which uses not only the data transmitted by the remote transmission beacons, but also the OCP teams' readings from the staff gauges, should also include data base management. PERLES manages and stores the readings as well as the calibration curves from all the stations (staff gauges and beacons) covered in the programme.

Structure

PERLES has two parts: the first is installed in the reception station, the second is installed in a microcomputer linked to the station which is used for all the forecasting calculation and the management operations.

Reception station The software installation at the reception station collects, organizes and manages the transfer of the water levels received via the satellite to the microcomputer.

This transfer is facilitated by the possibility offered by PERLES of managing the "transfer tables" which contain the numbers of the ARGOS beacons to be dealt with. When the data are transferred, the date is recorded for each beacon before the calculation stage. This means that only the water levels recorded since the date of the last transfer are entered, and that allows to satisfy one of the main criteria, namely that the whole operation – transfer of data, calculation and publication of predictions – must not take more than 15 minutes.

The microcomputer The second part of the PERLES software is installed in the microcomputer used for calculations (Fig. 3). It has several functions which can be divided into two groups.

Access to the first group of functions is open to any PERLES operator. It consists of: data reception, management of the calibrations of the reference stations and of the hydrometric data base, calculation and publication of the discharges and the corresponding doses of insecticide for each reach treated. All these operations are carried out by selecting options from the different menus.

The second group of functions is only accessible to the hydrologist who builds the models used to make the predictions. Parameters are defined for each reach concerned. These parameters include not only the coefficients of the models used but also the priority coefficients attributed to them.

In fact this is one of the particular qualities of PERLES, the software ranks the methods of forecasting for each reach by priority. There are five methods: a propagation model based on the Hayami method (Ven Te Chow, 1959; Quivey & Keefer, 1974), an autoregression models, a correlation model between the remote transmission beacon and the staff gauge, OCP's own empirical method and the recession model. Each of these methods requires specific information to enable its use. For each reach we have therefore defined a preferential order of use of these forecasting techniques. If the

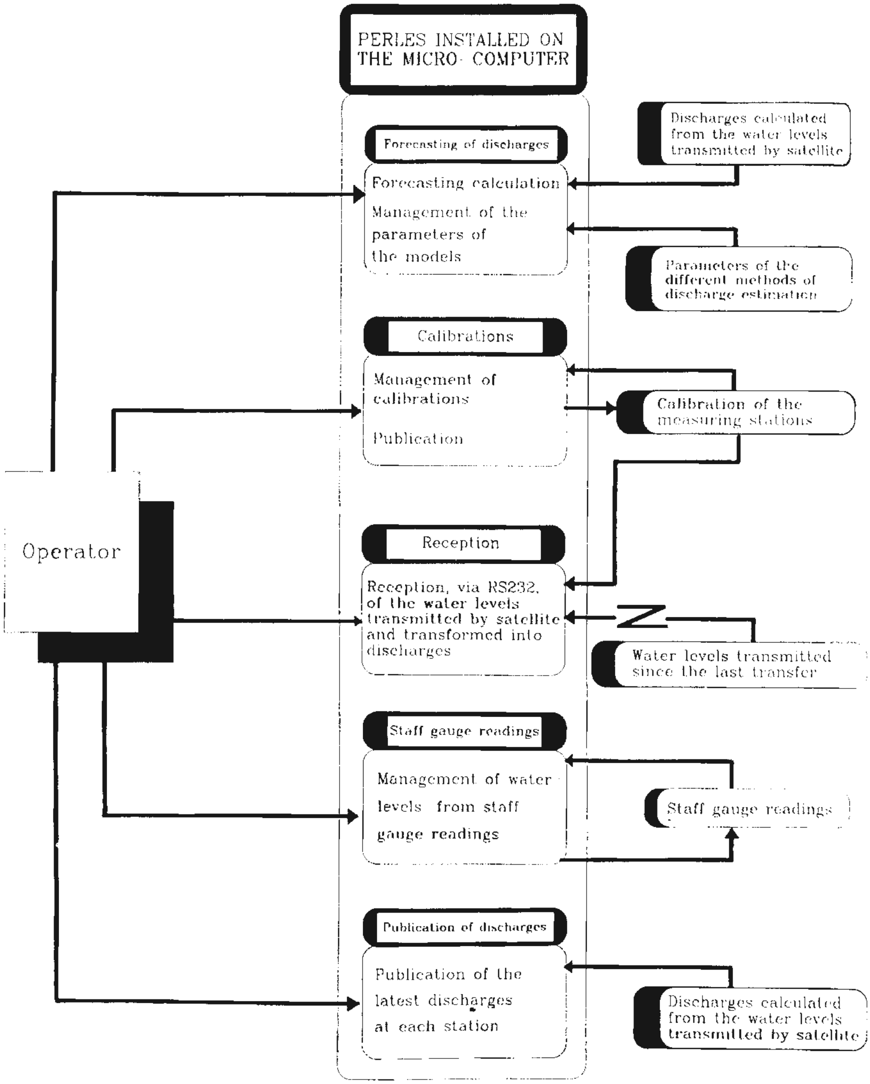

Fig. 3 Organizing scheme of the PERLES software installed on the microcomputer in charge of the forecasting calculations.

method which is the best adapted and the most precise cannot be used (e.g. for lack of necessary data), the next one is used and so on.

The methods used The forecasting methods used in this software are well known to hydrologists. As a matter of fact, and as mentioned above, the most important software characteristic refers to the use of these methods in series, and according to priorities previously defined if necessary.

(a) The diffused flood wave model is used first whenever possible. It consists of ignoring the terms of inertia in the Barre de Saint Venant equations (Bader *et al.*, 1988, Le Barbe & Bader, 1988).

(b) The autoregression models are used for the reaches equipped with transmission beacons. The autoregression equations are determined with the help of a progressive regression method, "stepwise" (Draper & Smith, 1981).

(c) The correlations between the beacons and the gauges, allow improvement in the estimates of the discharges for the reaches where the staff gauge is only read weekly.

(d) The empirical correlation model sometimes used as a last resort correlates the discharge of different water courses in the determination of the discharge of a given reach. This correlation results from years of observation and the local OCP staff's excellent knowledge of the area.

(e) The recession model used in the dry season, a period during which the rainfall in the area treated is non-existent or light, is a classic decreasing exponential function.

The values of the discharge calculated at the different times can be taken as inputs in a software developed elsewhere. This one aims to improve the organisation of flying hours and filling points for fuel and insecticide.

CONCLUSION

The PERLES software is a complete entity. Not only is it a user-friendly tool for the forecasting of discharges and the calculation of insecticide doses, but also a staff gauge data base manager.

Its modular organization (see Fig. 3) allows many modifications notably the introduction of different forecasting models if necessary.

The timing of the software fits in well with the time taken for the necessary daily briefing of the pilots and the start of the treatment.

Furthermore, the hydrographic network equipment in the OCP area, i.e. the satellite transmission beacons, has enabled us to progress from a system whose reaction time was weekly to one where the calculations can be made in real time.

The linking of PERLES with the ARGOS system has allowed further improvement of the device by enabling predictions to be made at different times. A good fitness is therefore obtained between the doses of insecticide introduced and the discharge. It has led to significant improvements in the OCP programme:

(a) it avoids underdosage – which causes failures and risks eventually isolating strains of simulium resistant to the insecticides used,

(b) it avoids overdosage – which is unnecessarily costly and which can have a damaging effect on the environment,

(c) it increases the success rate and allows occasional suspension of treatment in some reaches, which in itself reduces the cost.

OCP is satisfied with these initial results and intends to complete its fleet of beacons as it extends the programme towards the west. Eventually there should be 100 remote transmission beacons in the network.

Outside of the OCP, satellite transmission offers numerous prospects and is a technique of the future in hydrology. It should be extremely useful in flood warning systems in large catchments. However, its advantage for the rationalization of the management of a national hydrological network is obvious. Hydrological platforms can transmit certain parameters relating to their own operation. They can therefore check on themselves to a certain extent which can reduce the network running costs considerably by reducing the number of maintenance visits and targetting them better (Pouyaud, 1988).

These advantages make satellite transmission even more attractive for developing countries in the tropics where sometimes the access roads to the stations are impassable or where the local follow-up is often inadequate.

REFERENCES

Bader, J. C., Le Barbe, L. & Servat, E. (1988) Télétransmission des données hydrologiques dans le cadre du programme de lutte contre l'onchocercose. In: *Proc. Sahel Forum on the State of the Art of Hydrology and Hydrogeology in the Arid and Semi-Arid Areas of Africa* (Ouagadougou, Burkina Faso) (ed. by M. Demissie & G. E. Stout). IWRA, Urbana, Illinois.

Le Barbe, L. & Bader, J. C. (1988) Utilisation du système ARGOS par le programme de lutte contre l'onchocercose. Le réseau expérimental du Nord-Togo. *Hydrologie Continentale* 3 (1), 25-40.

Draper, N. R. & Smith, H. (1981) *Applied Regression Analysis.* John Wiley, New York.

Pouyaud, B. (1987) Présentation de la station de réception directe ARGOS et de son logiciel. *Troisièmes Journées Hydrologiques de l'ORSTOM* (Montpellier, 23-24 septembre 1987). Colloques et Séminaires, Editions de l'ORSTOM, Paris.

Pouyaud, B. (1988) Réseaux hydrologiques, banques de données informatisées et télé-transmission. In: *Proc. Sahel Forum on the State of the Art of Hydrology and Hydrogeology in the Arid and Semi-Arid Areas of Africa* (Ouagadougou, Burkina Faso) (ed. by M. Demissie & G. E. Stout). IWRA, Urbana, Illinois.

Pouyaud, B. & Le Barbe, L. (1987) Onchocercose, hydrologie et télétransmission. In: *Water for the Future: Hydrology in Perspective.* (Proc. Rome Symp., April 1987), 239-244. Publ. no. 164.

Quivey, M. C. & Keefer, J. (1974) Simple method for predicting dispersion in streams. *J. Environ. Engng Div. ASCE.*

Ven Te Chow (1959) *Open Channel Hydraulics.* McGraw-Hill, New York.

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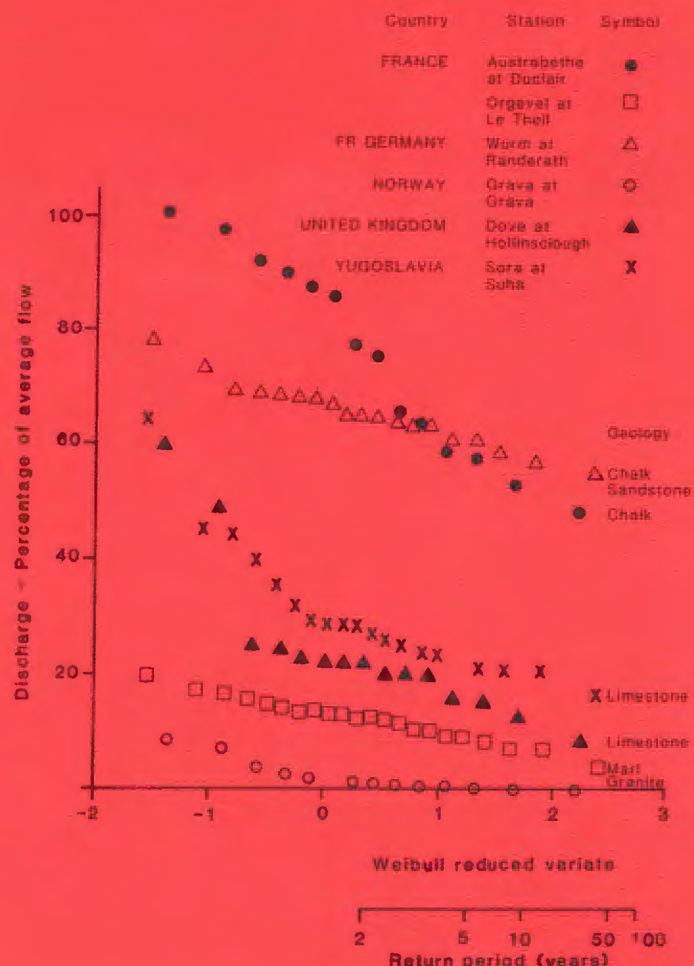

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